Global Market Insight for Information Technology Companies



1995
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Program: Semiconductor Application Markets Asia/Pacific
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	DQ Predicts	Fall Asia/Pacific EPF	September 1995
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	Market Forecast	1995 Regional Outlook	April 1995
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Asia/Pacific Electronic Equipment Production Forecasts: Five-year forecasts for data processing, communications, consumer, industrial, automotive, and military segments.

Available in the Second and Fourth Quarters

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Available in the Third Quarter

Semiconductor Consumption by Application Market: These documents contain detailed information on Dataquest's view of semiconductor consumption in electronic equipment. Semiconductor consumption for the six major application markets is provided.

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- **Singapore Semiconductor Consumption by Application Market**
- **South Korea Semiconductor Consumption by Application Market**
- **Taiwan Semiconductor Consumption by Application Market**

Published in the Second, Third, and Fourth Quarters

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SEMICONDUCTORS APPLICATION MARKETS
ASIA/PACIFIC 1995

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Power Glitch Strikes Penang, Again...

Overloaded currents ignited a fire on Sunday, June 25, that wrecked nine overland power cables underneath the Penang Bridge, which links Malaysia's "Silicon Valley" with the mainland. A power failure hit all financial and residential areas, and the 203 factories on the island of Penang. The island now is feeding mostly from the underwater cables that supply 52 percent of Penang's total 330MW daily requirement.

Penang Development Corporation (PDC), the island's state authority, is working closely with the Tenaga Nasional Berhad (TNB), the country's privatized power body, to overcome the problem. TNB hopes to restore the power supply through the first cable within 10 days of the fire, which it claims will provide sufficient capacity to support the initial needs of the manufacturing industry. Dataquest understands that factories in Zone A will receive electricity for the first three days of the week, while those in Zone B will get its three-day ration beginning on Thursday.

Those Affected...

Among those semiconductor assembly and test facilities hit by the power failure are:

- Intel. Everyone is murmuring words of concern over the world's largest Pentium assembly and test facility. The Penang operation assembles and tests 80 percent of Intel's global Pentium capacity, with the remainder in Chandler, Arizona. Sixty percent of Intel Penang's assembly/test unit output is non-Pentium chips, which means that the facility is able to continue its "priority" lines using its internal generators. We understand that Intel also is leveraging several assembly subcontractors (mostly located outside of Penang) to handle excess capacities. Dataquest estimates that Intel Penang incurred minimal capacity loss of less than 0.3 percent for this week, or downtime of three days. This affected only the non-Pentium lines (microcontrollers). Intel's third Pentium assembly and test facility in Manila, the Philippines, will be operational this year. Intel also has announced construction of its fourth facility in Shanghai, China, which will assemble and test flash memories and embedded microcontrollers.

- National Semiconductor. National Semiconductor assembles and tests logic and ICs for PCs and multimedia in its Penang operation. It has received its three-day ration and will not be in operation for the rest of the week. Its other facilities are in Singapore

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(high-end ICs; largest assembly/test facility), in the Malaysian state of Malacca (analogs), and in Cebu, the Philippines (discretes).

- Siemens. The Penang facility is one of the main assembly/test facilities for optoelectronics. The factory lost three days' capacity until it received electricity on Thursday. Its other facilities are in Singapore (design/assembly/test of DRAM, discretes, optoelectronics, and ASICs) and in the Malaysian state of Malacca (DRAM, power ICs, transistors, and optoelectronics).

- AMD. AMD Penang assembles 50 percent of its global capacity of PLDs, flash memories, and EPROM. The power failure happened several days after AMD's shipment and resulted only in minimal loss. The Singapore facility tests all chips from Penang. AMD's Bangkok, Thailand, facility assembles and tests low-end version products.

- Hewlett-Packard. HP's optoelectronics assembly/test facility is partially covered by its own backup power. Some jobs are subcontracted out to Unisem, a local assembly subcontractor.

- Hitachi Semiconductor. Hitachi Semiconductor in Penang assembles and tests memories, logic, discretes, and optoelectronics. Hitachi shut down the Penang facility for three days. Its alternate plant in the neighboring state of Kedah assembles and tests small volumes of transistors and other digital ICs. Hitachi Taiwan handles only discretes.

- Other companies affected include Integrated Device Technology and Taiwan-based ASE Electronics.

And Those Unaffected...

Some semiconductor assembly and test facilities were not affected by the power disruption. These other facilities can be found mostly in southern the states of Selangor and Malacca.

- Motorola. Motorola's largest assembly and test facility outside the United States is in Selangor. It has a discrete wafer fabrication plant in the state of Negri Sembilan and a joint-venture company with Philips to assemble and test discretes in the same state. Only the walkie-talkie facility in Penang was affected.

- SGS-Thomson. SGS-Thomson established its two Asian assembly and test facilities for power ICs, analogs, and nonvolatile memories in the state of Johor and in Singapore. It has a wafer fab in Singapore.

- NEC. NEC assembles and tests transistors and LEDs in Selangor.

- Texas Instruments. TI in Selangor assembles and tests logic. The other "centers of excellence" are dedicated to assembly and test of DRAM and EEPROM (Singapore), linear ICs (Taiwan), and ASICs (the Philippines).

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- Harris. Harris recently relocated its entire assembly/test operation from Singapore to Selangor, making the Malaysian facility one of the largest in Malaysia. Harris assembles and tests power ICs.

- Toshiba. Toshiba in Selangor assembles and tests audio/video ICs, while its Thai operation deals with bipolar ICs and transistors.

- Other facilities outside of Penang are Rectron (diodes), Rohm-Wako (LEDs and diodes), and Quality Technology (optocouplers). Two IC assembly subcontractors, Carsem and Unisem, are in the neighboring state of Perak.

Dataquest Perspective

Is there a major cause for concern aside from the production loss (as high as 20 percent for most of the manufacturers on the island) and short-term delay in shipment? The damage is not really critical and life-threatening, although the issue now is whether local authorities can prevent another problem. A similar incident that happened seven years ago disrupted power supply for two weeks. Penang must quickly restore the confidence of its back-end IC facilities and of newcomers such as Dell (PCs), and Quantum and HP (rigid disk drives).

In view of the minimal loss and slowdown in the PC market, Dataquest believes that the Penang power loss will not adversely affect the price of Pentium chips.

Our research confirms that TNB will be able to resuscitate the first line by this Saturday, and the second by the middle of next week. Both cables would satisfy 65 percent of Penang's daily energy consumption. Priority certainly is given to the manufacturing plants. A lesson to learn for all Penang facilities--get those generators for backup!
By Eddy Tan

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Formosa Plastics-Komatsu Alliance in Taiwan—Update

This *Dataquest Alert* is an update to one on this subject initially issued May 18, 1995. Dataquest has obtained additional information on Taisil's production and ramp plans for 200mm silicon wafers, and this new information is now reflected in Table 1. Taisil is MEMC's joint venture with China Steel formed during 1994 to produce silicon wafers in Taiwan. All other aspects of the *Dataquest Alert* remain the same as in the initial release.

Komatsu Electronics Corporation and the Asia-Pacific Investment Co., which is owned by the Formosa Plastics Group (FPG), this week signed a memorandum to build a silicon wafer manufacturing factory in Taiwan. The name of the new company will be Taiwan Komatsu Electronic Materials Corporation, which will have capital investment of U.S.$250 million. Ownership will be divided 51:49 in favor of Komatsu. Construction is planned to begin by the fourth quarter of 1995, and mass production is forecast to begin by 1997.

Table 1

Comparison between Taiwan Komatsu Electronic Materials Corporation and Taisil Electronic Materials Corporation

Companies	Taiwan-Komatsu	Taisil
Investors	FPG, Komatsu	CSC (Taiwan), MEMC
Technology Source	Komatsu (Japan)	MEMC (United States)
Capital ($M)	250	191
Capacity (8-Inch Wafers/Month)	200,000	215,000
Initial Capacity (8-Inch/Month)	80,000	80,000
Pilot Time	Third quarter of 1996	January 1996
Initial Production Time	Fourth quarter of 1996	March 1996
Final Capacity Realized	To be announced	Mid to late 1997
Shareholders	Komatsu (51 percent), FPG (49 percent)	MEMC (45 percent), CSC (35 percent), others (20 percent)
Location	Not available	Hsin-Chu Science Park

Source: Dataquest (May 1995)

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This is a technology transfer arrangement from Komatsu. The specified final capacity of 8-inch slices is about 200,000 wafers per month, but the first phase to be completed in 1997 will be for 80,000 slices. Both companies agree that a formal contract completing the joint venture will be signed by each party no later than July. FPG Director Y.C. Wang and Komatsu Director Mr. Nakanishi joined the meeting to sign the memorandum. Each director expressed his optimistic view for the future of this company and said details regarding the agreement were still being worked out.

Following the recent successes of Taiwan's semiconductor device manufacturing companies, local investors have been eyeing long-term profits and trying to move upstream into the silicon wafer manufacturing business. This is the second recent silicon wafer announcement--following Taisil Electronic Materials Corporation's entry into the field.

Dataquest Perspective

The Taiwanese semiconductor industry has been expanding rapidly in the past three years but has outpaced supportive semiconductor industries such as silicon wafers. These recent announcements are positive signs for the local industry, which is completely dependent on imported wafers. As for long-term success, both venture companies highlighted in Table 1 will have strong technical and financial resources: FPG is the biggest privately held group in Taiwan, and the China Steel Corporation (CSC) is a government-supported company with capital of more than $2.7 billion; MEMC Electronic Materials Corporation and Komatsu are global technology leaders in wafer production. The cooperation of these companies ensures their ventures will have the capital to expand and the technology to compete. Neither will have to worry about demand.

These two plants, taken together, could appreciably supply Taiwan's production needs for 200mm wafers. However, we believe that a portion of these plants output will be exported, resulting in a continued net deficit of 200mm wafers for Taiwan. Dataquest believes Taiwan's semiconductor industry's appetite for silicon wafers will far exceed local production unless further investments are made. By 1997, when both companies' production becomes fully ramped, as planned, these facilities will be able to supply less than 60 percent of Taiwan's total wafer demand. Nevertheless, this increasing high level of interest in the semiconductor industry among Taiwan's largest conglomerates will mean Taiwan has the financial wherewithal to sustain or, quite possibly, accelerate its expansion run rate.

By Ben F.P. Lee (Taiwan), Daniel Heyler (Hong Kong), and Clark Fuhs (San Jose)

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Philips' Next Asian Foundry (Shanghai, China): ASMC

The Venture

Philips Semiconductor, Northern Telecom, and their Chinese partners on March 30 announced the official start of their joint venture's foundry operations, Advanced Semiconductor Manufacturing Corporation (ASMC) of Shanghai. Approval of the contract for the joint venture, signed November 1994, completes the financial arrangements and marks the official start of the joint venture's foundry operation.

The semiconductor manufacturing facility, operated by Philips since 1991 in Shanghai, has been converted into a wafer foundry serving primarily Philips and Northern Telecom, which have 38 percent and 34 percent ownership stake, respectively. The other 28 percent is controlled by unspecified Chinese parties. This Shanghai Philips had started as a bipolar line and later used CMOS primarily for Philips' own internal audio and video applications.

With a name as similar to TSMC as ASMC is, one cannot help but ask whether this will be the next mainland edition of "The TSMC Success Story"? Philips insists there are no specific plans to create a Shanghainese -SMC (SSMC), but does believe the long-term direction could become similar. We agree that the current level of technology (a capacity of 10,000 5-inch wafers per month, 2 to 4 microns) and operation uncertainties in China make such conjectures premature.

Dataquest Perspective

At last, a recent fab announcement in China that is real! Although the press seems to enjoy announcing new fabs in China (about seven in the past year), Dataquest continues to see more interest and discussion than actual investments or alliances. We see a lot of posturing by semiconductor suppliers to convince the Chinese government there are plans for investments in China. We have not seen and do not expect to see substantial production growth or technology advances in China in the next three to five years, as stated in our 1994 *Focus Report*.

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The important issue here is that Philips has significant *existing* end-equipment production in China. Philips operates 15 joint ventures and employs more than 9,000 people in China. Northern Telecom similarly has experienced substantial growth in demand for its telecommunications equipment in China. Both companies expect continued production growth such that large investment in a semiconductor foundry is a hedge on high growth. Both companies have signed long-term licensing contracts with ASMC, which paves the way for more process technologies, such as BiCMOS. The immediate plan is to install a 6-inch wafer line using 0.8- to 1.0-micron process technologies. Although existing output has been consumer-based, expansion plans will be for telecommunications.

What's in it for Northern Telecom? Northern Telecom has sat by and watched the phenomenal success of Alcatel attributed in part to an early China strategy of building as much equipment as feasible within China. Alcatel sources semiconductors from its fab, Shanghai Belling. Remarkably, Dataquest has observed that the communications market is set to surpass the consumer electronics market in China, largely because of infrastructure spending. Large communications companies, including Motorola, that build their equipment in China have proved to be more successful than those that do not. However, with production growing by more than 30 percent a year, there is a perceived need to build local semiconductor plants. One line of thinking is that, should a trade war break out, losses would be too huge to recover. We see a similar concern at Motorola, which sells more pagers in China than anywhere and is positioned to sell a lot more, as well as phones. If there is to be any major investment in China, it would make the most sense to come from companies such as Philips and Motorola. But if foundry can indeed become a viable source of components, then again, hugely risky investments become less attractive and less necessary.

Dataquest forecasts China to become Asia/Pacific's largest semiconductor market (outside Japan) by the end of this decade, surpassing Taiwan. Although initial output at ASMC will serve the needs of Philips and Northern Telecom, the pure-foundry venture plans to expand services to other companies.

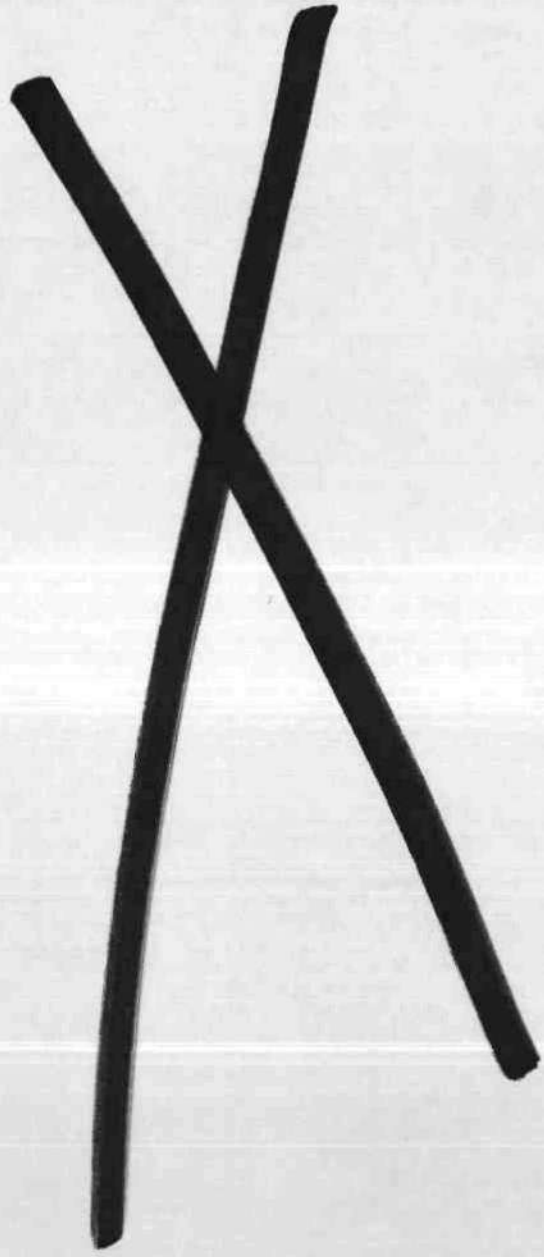
Who might these companies be? An increasing number of equipment companies will need a secure, long-term source of low-cost, locally produced semiconductors. There will be others, such as those that have built fabs in Europe and the United States, that cannot afford to risk market exclusion resulting from protective tariffs or trade wars. As we have said, foreign companies have been wary of building their own fabs in China. However, turning to local foundry such as ASMC will be the preferred alternative, with far less financial risk. The question has been, who wants to be the first? Thus far, no one. These two companies' large long-term captive needs have spurred this move, but, as with TSMC, the *unintended consequences* may be dazzling.

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The strategy appears sound. So we'll have to watch capital spending, ramp time, yields, and the Chinese government's treatment of ASMC before we can say it is on its way to becoming Philips' next TSMC.

By Daniel Heyler

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Perspective



Semiconductor Application Markets Asia/Pacific

Dataquest Predicts

Data Processing and Consumer Segments Dominate Production Revenue, but Communications Leads Growth

Abstract: *The Asia/Pacific electronics industry grew at a robust 20.8 percent in 1994 to $142.6 billion. In our fall forecast of electronic equipment production, Dataquest predicts that the electronics industry will continue a healthy growth rate of 16 percent in 1995 to reach $165.4 billion. This region outperforms the rest of the world, and Dataquest predicts that production will reach $297.4 billion by 1999. This article predicts Asia/Pacific electronic equipment production by six applications: data processing, communications, consumer, industrial, military/civil aerospace, and transportation.*
The information presented highlights important country and market trends and identifies significant economic factors influencing these trends.
By Ben F.P. Lee

Electronics Production Leads Asia/Pacific's Economic Growth

The Asia/Pacific electronics industry led the regional economic recovery in many countries and grew 20.8 percent in 1994 to $142.6 billion. This growth is predicted to moderate to 16 percent in 1995 and is expected to continue at a strong 15.8 percent compound annual growth rate (CAGR) from 1994 to 1999.

The electronics industry saw a mix of growth rates across all sectors and countries. The data processing industry, the largest category, grew by 29.2 percent to $63.2 billion. The annual growth rate for the data processing industry will be 18.4 percent in 1995, not as strong as 1994. Figure 1 shows the electronic equipment production forecast from 1995 to 1999 by six categories. As illustrated, data processing is the largest in terms of sales

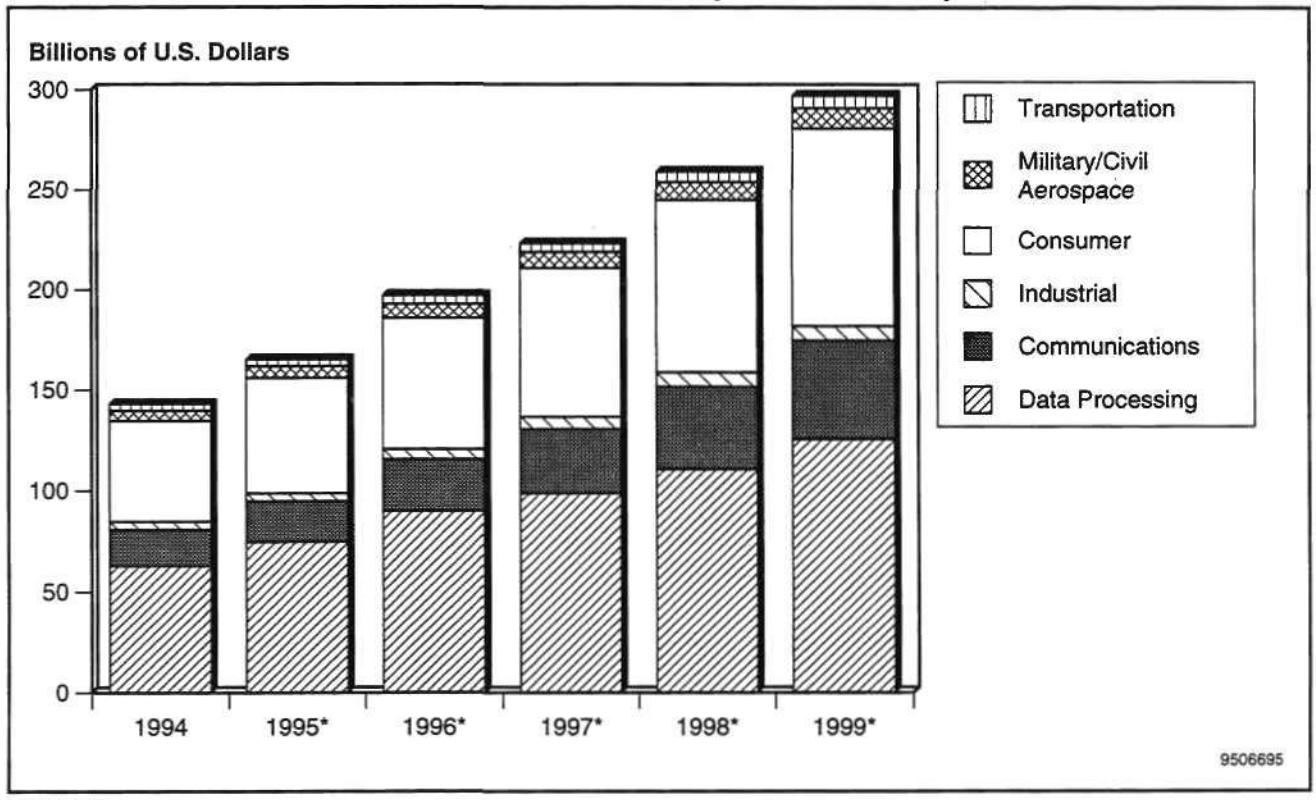
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revenue, followed by consumer electronics and communications. These three categories will account for almost 92 percent of production revenue in 1995 and will lead all electronic equipment production in Asia/Pacific. Figure 2 illustrates the forecast by major electronic sectors. Figure 3 shows electronic equipment production trends by major countries in Asia/Pacific.

Figure 1
Asia/Pacific Electronic Equipment Production by Sector (Factory Revenue)



*Forecast
Source: Dataquest (December 1995)

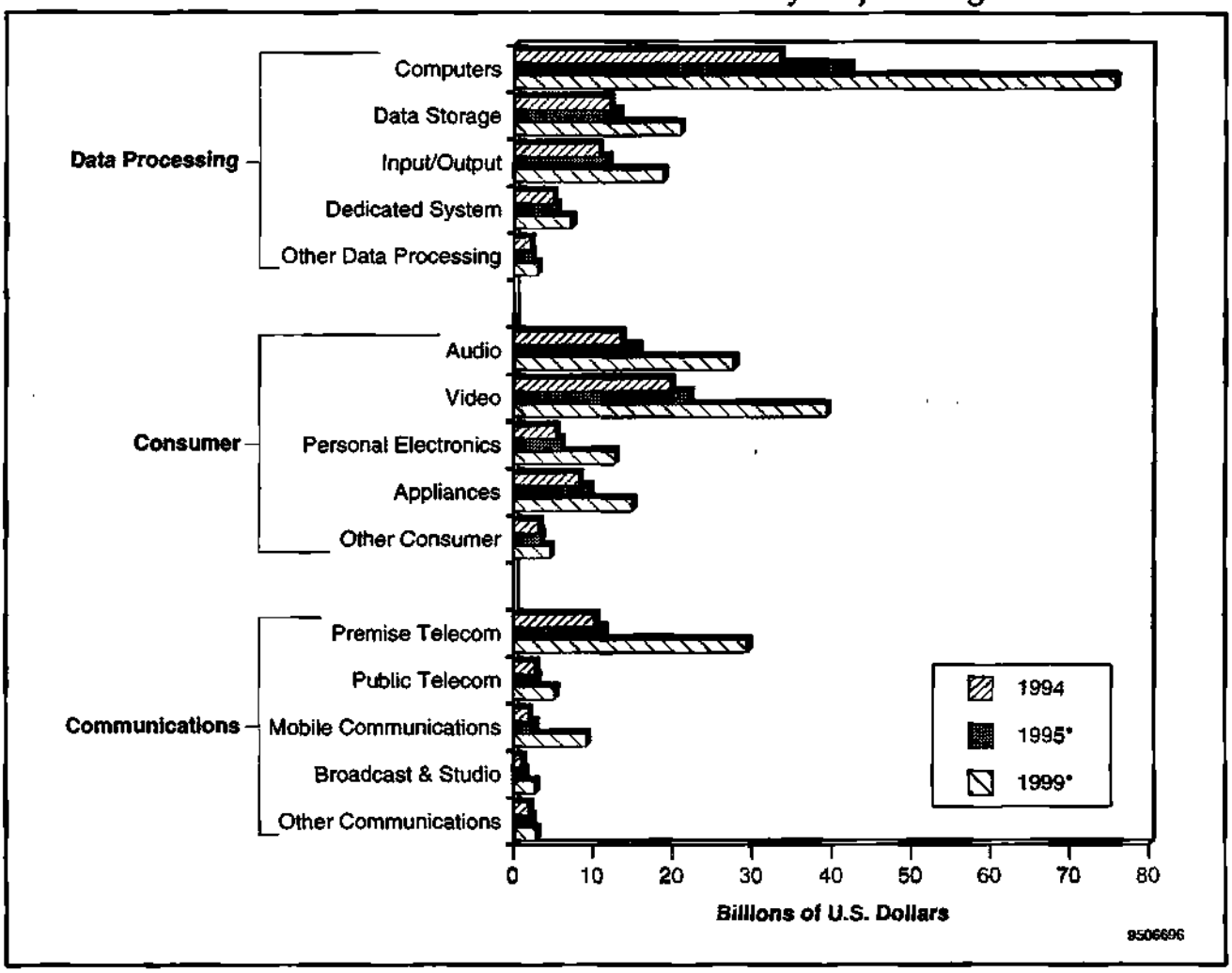
Data Processing Leads Electronic Equipment

Data processing is the largest sector of electronic equipment production in Asia/Pacific—44.3 percent in 1994, projected to expand to 45.2 percent in 1995. We predict that data processing will maintain a 40 percent-to-45 percent share of worldwide electronics equipment production for the coming years.

Production revenue for data processing jumped by almost 30 percent to $63.2 billion in 1994 (see Table 1). This healthy growth was fueled mainly by the expansion of the computer and data storage sector, which generated revenue of $33.4 billion and $12.1 billion in 1994, respectively, with about a 37 percent annual growth rate. This expansion was driven by huge demand for personal computers and an increasing level of OEM/ODM activity, particularly in Taiwan and Singapore. Strong demand for data processing equipment has lasted almost throughout the year. The computer sector is expected to maintain its high growth of 26 percent, reaching $42.1 billion in 1995. Data processing, however, has been constrained by sharp price cuts this year, and is expected to produce annual growth of only 9 percent to $13.3 billion in 1995.

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Figure 2
Asia/Pacific Growth of Electronic Production Revenue by Major Categories



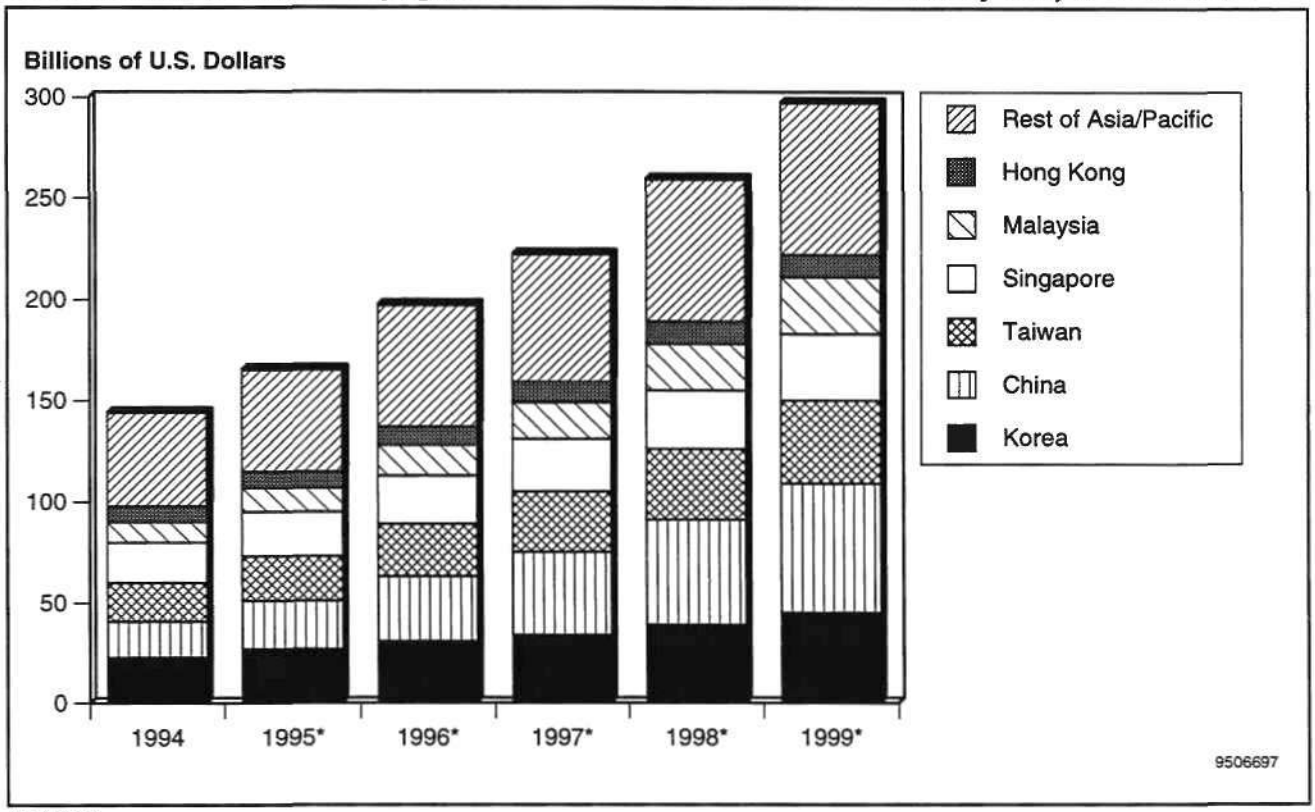
*Forecast
Source: Dataquest (December 1995)

Data storage will continue to maintain its No. 2 ranking after computers, given the planned expansion of large rigid disk drive (RDD) facilities in Singapore, Malaysia, and Thailand. The Japanese are also aggressively setting up RDD assembly facilities in the Philippines in a bid to escape the high value of the yen. Other Asia/Pacific countries are expected to show signs of RDD activities.

Input/output is ranked third in the data processing sector. Monitors are the main products, with Asia/Pacific contributing over 60 percent of worldwide shipments. Taiwanese companies are the key players for this product. However, the monitor market seems to have reached its mature stage. The evolution of display technology will be moderate and sluggish compared with the evolution of personal computers, and monitors will grow between 12 percent and 15 percent.

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Figure 3
Asia/Pacific Electronic Equipment Production Revenue Forecast by Major Countries



*Forecast
Source: Dataquest (December 1995)

Table 1 shows the data processing equipment forecast by five categories. Computers, data storage, and input/output are the three major products in this sector. Singapore, Taiwan, South Korea, and Hong Kong are the major manufacturing bases in Asia/Pacific for data processing equipment. China potentially will be a very significant supplier, expected to produce revenue of over $11 billion in 1999.

Table 1
Asia/Pacific Data Processing Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995*	1996*	1995 Growth (%)	1996 Growth (%)	CAGR (%) 1994-1999
Total Data Processing	63,177	74,809	90,221	18.4	20.6	14.7
Computers	33,428	42,113	53,004	26.0	25.9	17.8
Data Storage	12,135	13,275	15,449	9.4	16.4	11.5
Input/Output	10,647	11,911	13,683	11.9	14.9	12.1
Dedicated Systems	4,889	5,280	5,708	8.0	8.1	7.9
Other Data Processing	2,078	2,229	2,378	7.3	6.7	7.2

*Forecast
Source: Dataquest (December 1995)

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Consumer—Volume Is Shifting from Japan to Asia/Pacific

Consumer electronics is the second-largest electronics equipment sector in Asia/Pacific in terms of production revenue. Asia/Pacific produced $49.9 billion worth of consumer equipment in 1994, or 35 percent of Asia/Pacific's total electronic equipment production (see Table 2). Consumer electronics is expected to gain 13.7 percent growth to $56.8 billion in 1995 (a 34.3 percent share of the region's electronic equipment production). Growth in 1995 is lower than the 16.5 percent growth of 1994. Dataquest predicts that consumer electronic equipment will grow at a CAGR of 14.8 percent to $99.4 billion in 1999.

Video equipment is the major product in this sector. Asia/Pacific is expected to produce $22.2 billion worth of video equipment in 1995, followed by audio equipment ($15.6 billion), and appliances ($9.6 billion). These three sectors represent 85.3 percent of total consumer electronic equipment and will continue to dominate throughout 1999.

South Korea, China, and Malaysia are the three major manufacturing bases in Asia/Pacific, followed by Taiwan, Singapore, and Hong Kong. China and Malaysia show the highest growth potential. China is expected to expand by 1.3 times between 1995 and 1999 to surpass South Korea as the No. 1 manufacturing country in Asia/Pacific. However, Malaysia is expected to grow 1.5 times during the same period, becoming the fastest-growing region in Asia/Pacific.

A huge volume of consumer electronics assembly lines has shifted from Japan to countries with low labor and land costs, such as China and Southeast Asia (specifically Malaysia). This production shift has stimulated the booming consumer industry in these regions.

Table 2
Asia/Pacific Consumer Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995*	1996*	1995 Growth (%)	1996 Growth (%)	CAGR (%) 1994-1999
Total Consumer	49,897	56,753	65,033	13.7	14.6	14.8
Audio	13,535	15,652	18,162	15.6	16.0	15.4
Video	19,677	22,154	25,339	12.6	14.4	14.9
Personal Electronics	5,292	5,965	7,052	12.7	18.2	19.3
Appliances	8,266	9,589	10,813	16.0	12.8	12.6
Other Consumer	3,127	3,393	3,668	8.6	8.1	8.2

*Forecast
Source: Dataquest (December 1995)

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Communications—Internal Demand Will Drive the Market

Although it is the third-largest electronic equipment segment, communications electronics is expected to be the fastest-growing sector in Asia/Pacific from 1994 to 1999. Fueled by strong growth in mobile communications equipment, the communications industry grew by 15.6 percent to $20.3 billion in 1995, or a 12.3 percent share of total electronics equipment production (see Table 3).

The internal markets of China and Southeast Asia have created a huge volume of demand for premises telecommunications equipment and are expected to increase production revenue of premises telecom over 32.6 percent to $11.4 billion in 1995. The high growth fueled by mobile communications and premises telecom is expected to cause communications to expand 15.6 percent in 1995, better than 1994's growth of 13.1 percent.

Table 3
Asia/Pacific Communications Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995*	1996*	1995 Growth (%)	1996 Growth (%)	CAGR (%) 1994-1999
Total Communications	17,604	20,344	26,111	15.6	28.3	22.8
Premises Telecommunications	10,282	11,399	15,117	10.9	32.6	23.4
Public Telecommunications	2,655	2,847	3,401	7.2	19.5	14.4
Mobile Communications	1,844	2,630	3,852	42.6	46.5	37.8
Broadcast and Studio	974	1,270	1,335	30.3	5.2	22.3
Other Communications	1,848	2,198	2,405	18.9	9.5	8.1

*Forecast
Source: Dataquest (December 1995)

Economically, Asia/Pacific will be the most active region in the world over the next few years. The booming economy requires a huge volume of communications equipment. Internal demand in Asia/Pacific will stimulate the growth of the region's communications industry, with highest demand for premises telecom. China, Taiwan, and South Korea are three major manufacturing sites. However, most of the assembly lines for the domestic market have shifted to China from Taiwan, the United States, and Europe. China is expected to produce premises telecom production revenue of $11.8 billion by 1999 and would then be ranked as the largest manufacturing site in Asia/Pacific.

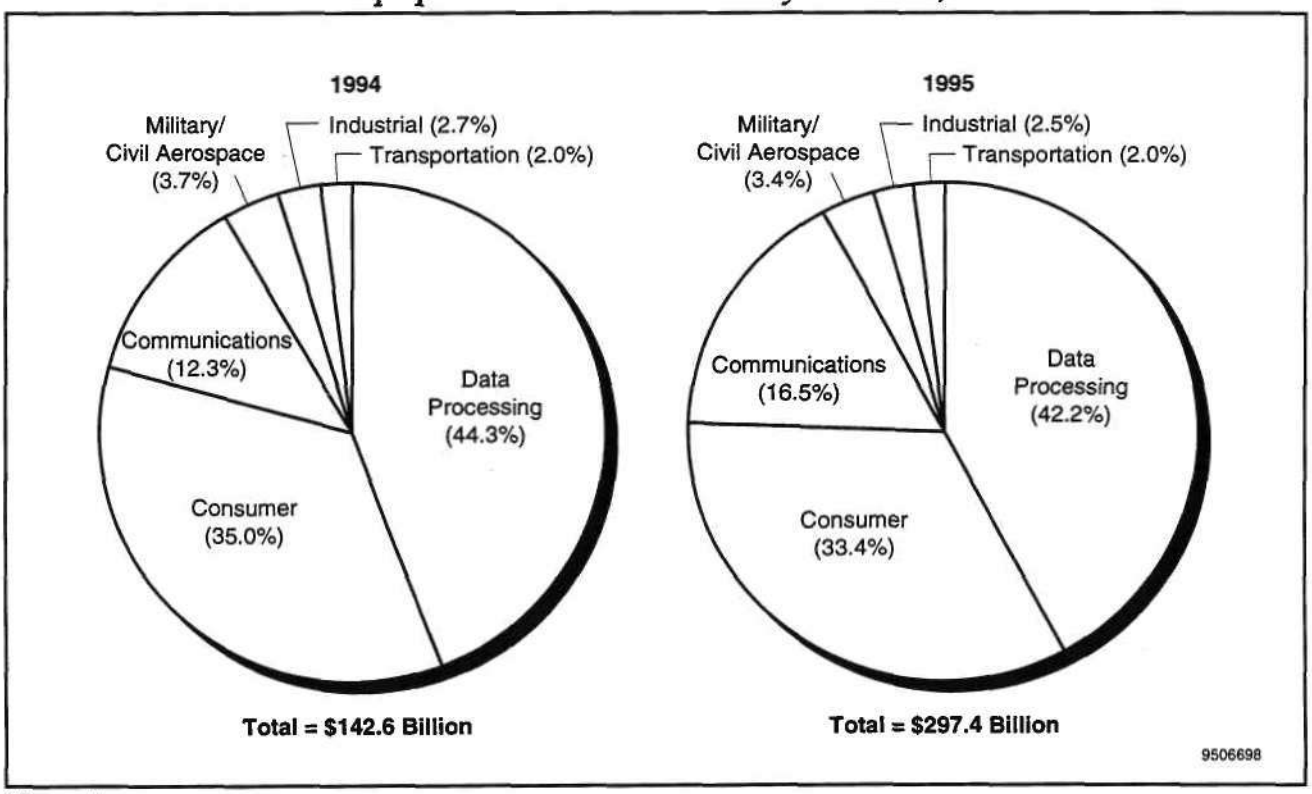
Mobile communications is still experiencing an initial stage of high growth. Pagers, walkie-talkies, and mobile phones are the major products of this sector, produced mainly in Korea, China, Taiwan, and Singapore. This is Asia/Pacific's fastest-growing communications sector at a 37.8 percent growth rate compounded from 1994 and 1999.

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Regional Trends—Asia/Pacific in the Year 1999

Figure 4 shows Asia/Pacific electronic equipment factory revenue by six categories. We compare 1994 and 1999 to illustrate the long-term trends for the six categories. The data processing and consumer sectors are expected to drop by 2.1 percent and 1.6 percent, respectively. However, the communications sector will rise by 4.2 percent.

Figure 4
Asia/Pacific Electronic Equipment Production Factory Revenue, 1994-1999



*Forecast
Source: Dataquest (December 1995)

Semiconductor Demand Market in Asia/Pacific

Asia/Pacific's strong growth in electronic equipment production is creating vast semiconductor opportunities in Asia/Pacific. Asia/Pacific's 1994 market of $22.8 billion is expected to grow by 36.5 percent to $31.1 billion in 1995 (see Table 4). Obviously, semiconductor consumption growth in 1995 is expanding at a rate greater than the 16 percent growth of electronic equipment production. The data processing sector has created huge demand for MOS memory, MOS microcomponents, and MOS logic. The promotion of advanced hardware and software has stimulated consumption of MOS digital devices. The MOS digital segment is expected to grow 42.2 percent in 1995 and 31.5 percent in 1996. The market expansion of MOS digital devices will continue, at a CAGR of 26.4 percent from 1994 to 1999. Dataquest expects that the total semiconductor consumption market in Asia/Pacific will expand at a CAGR of 23.6 from 1994 to 1999, greater than electronics equipment production growth of 15.8 percent within the same period.

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Table 4
Asia/Pacific Semiconductor Consumption, 1994-1995 (Millions of U.S. Dollars)

	1994	1995*	1996*	1995 Growth (%)	1996 Growth (%)	CAGR (%) 1994-1999
Total Semiconductor	22,812	31,144	39,446	36.5	26.7	23.6
Total Integrated Circuit	19,767	27,021	34,601	36.7	28.1	24.3
Bipolar Digital	370	362	299	-2.1	-17.3	-13.2
MOS Digital	15,085	21,454	28,202	42.2	31.5	26.4
MOS Memory	7,210	11,189	15,439	55.2	38.0	29.2
MOS Microcomponent	5,463	7,117	9,030	30.3	26.9	24.3
MOS Logic	2,412	3,148	3,733	30.5	18.6	21.9
Analog ICs	4,312	5,205	6,100	20.7	17.2	18.0
Total Discrete	2,524	3,343	3,915	32.4	17.1	17.8
Total Optoelectronic	521	780	930	49.9	19.2	21.2

*Forecast
Source: Dataquest (December 1995)

Dataquest Perspective

Asia/Pacific is increasing in importance as the world's largest electronics equipment manufacturing base. Data processing, consumer electronics, and communications are the three sectors that will dominate the electronic equipment industry in Asia/Pacific through 1999. This region could become a dedicated manufacturing base and key electronic equipment supplier. Of the countries of Asia/Pacific, South Korea, Taiwan, Singapore, and Hong Kong are the current major manufacturing sites. China, in particular, and Malaysia are the new superstars for electronics equipment production in the Asia/Pacific region. A potentially large market and a highly cost-competitive electronic equipment manufacturing base are the key factors that will take China to the forefront of electronic equipment production.

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Perspective

Semiconductor Application Markets Asia/Pacific

Industry Perspective

Asia/Pacific Electronic Equipment Forecast

Abstract: *Dataquest semiconductor application analysts in Asia/Pacific, Europe, Japan, and North America have completed the spring worldwide electronic equipment production forecast. This newsletter presents analysis on our key 1994 Asia/Pacific statistics and short-term 1995 equipment production, and provides our 1995-to-1999 long-term forecast. This worldwide, by-region database has been released to Semiconductor Application Markets Asia/Pacific clients.*
By Daniel Heyler (Hong Kong)

Overview

The Asia/Pacific electronic equipment industries have undergone remarkable growth during the past decade, outpacing all other regions of the world. We see no signs of this growth waning in either the short or long term. Our recent 1994-to-1999 forecast shows Asia/Pacific electronic equipment production experiencing a compound annual growth rate (CAGR) of 14.7 percent, compared to 7.0 percent for worldwide growth. Asia/Pacific's computer and consumer industries will be the key drivers for the next five years, while communications will become the fastest-growing sector by 1997.

Market Review

Asia/Pacific electronic equipment production expanded by about 18 percent in 1994, which translated into semiconductor consumption growth of 32 percent, as published in our final market share statistics (see Table 1). Although both equipment production and semiconductor consumption decelerated in 1994, the latter's slide was more pronounced. Semiconductor consumption slowed from 45 percent in 1993 to 32 percent in 1994, while equipment slowed from about 20 percent to 18 percent. This discrepancy was attributed to supply constraints on key components, which in turn

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Table 1
Asia/Pacific Semiconductor Consumption, 1993-1994
(Millions of U.S. Dollars)

	1993	1994	Percentage Growth (1993-1994)
Total Semiconductor	17,121	22,583	31.9
Total Integrated Circuit	14,709	19,589	33.2
Bipolar Function	386	362	-6.2
Bipolar Memory	7	6	-14.3
Bipolar Logic	379	356	-6.1
MOS Digital	11,049	15,011	35.9
MOS Memory	4,833	7,181	48.6
MOS Microcomponent	4,225	5,438	28.7
MOS Logic	1,991	2,392	20.1
Analog IC	3,100	3,966	27.9
Hybrid IC	174	250	43.7
Total Discrete	2,019	2,478	22.7
Total Optoelectronic	393	516	31.3

Source: Dataquest (April 1995)

constrained device revenue growth. Unable to procure parts, motherboard and subsystem makers shipped large volumes of parts without memories or microprocessors. Although supply will remain short during the first half of 1995, Dataquest expects bottlenecks to improve in the latter half of 1995. But DRAM supply is not expected to catch demand until late 1996, according to our latest estimates. As shown in Figure 1, we expect continuous strength in data processing, namely computers, during the next two years.

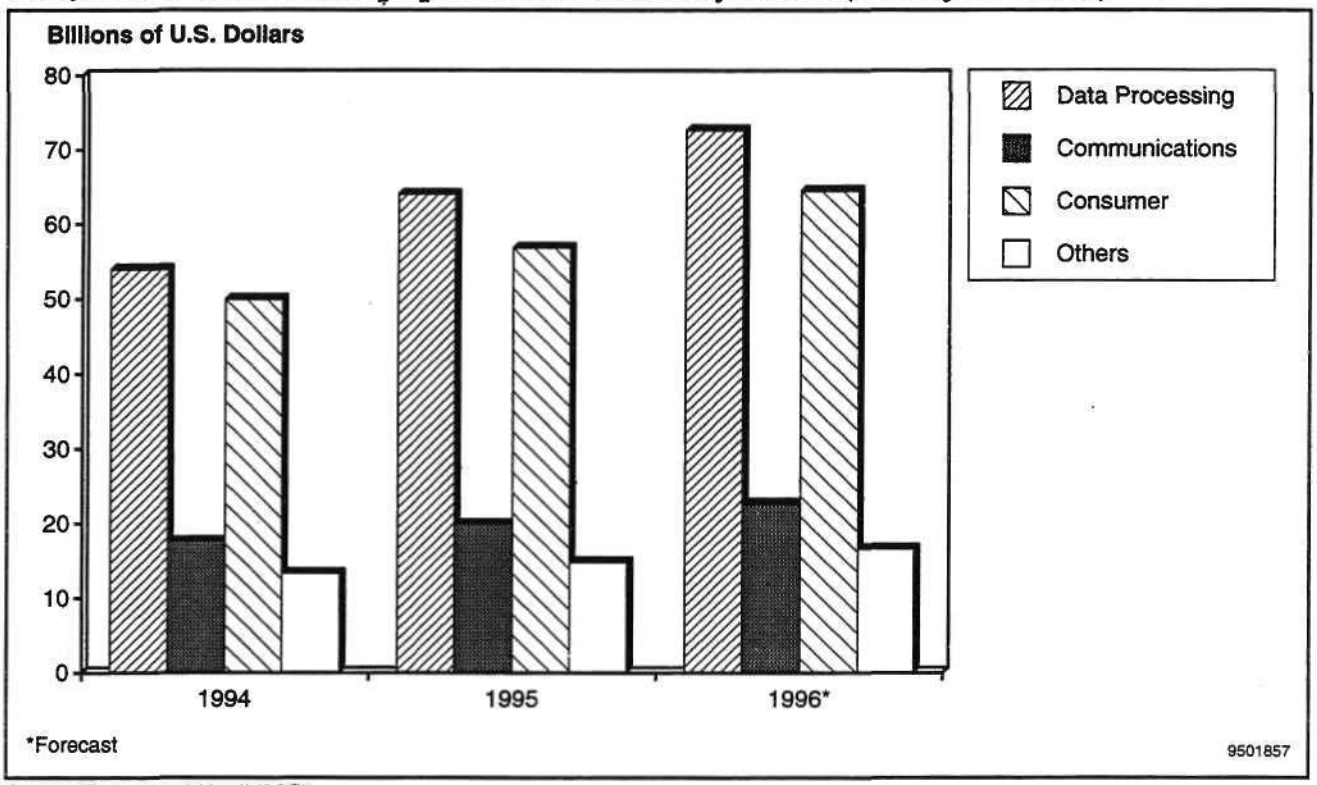
Asia/Pacific in the Year 1999

We do not see any major change in the data processing, consumer, and communications share of Asia/Pacific's total production over the long run (see Figure 2). However, within each category we expect a plethora of factors to come into play at different periods in our forecast. For example, we expect data processing to reign as the largest segment. Although this segments's growth from 1993 to 1995 was driven by OEM business, 1996 to 1999 will focus on Asia/Pacific markets, which in turn will impact design, manufacturing, and procurement. The key trends in 1994 are summarized as follows:

- Driven by strong worldwide demand for personal computers and peripherals, data processing remained Asia/Pacific's largest electronic equipment sector in factory revenue terms, reaching 25 percent of worldwide production, or U.S.$53.9 billion, in 1994.
- Spurred by the still-necessary production shift of Japanese consumer electronics giants to Asia/Pacific, consumer electronics was not far behind data processing, reaching $49.9 billion, which accounted for 37 percent of worldwide production.

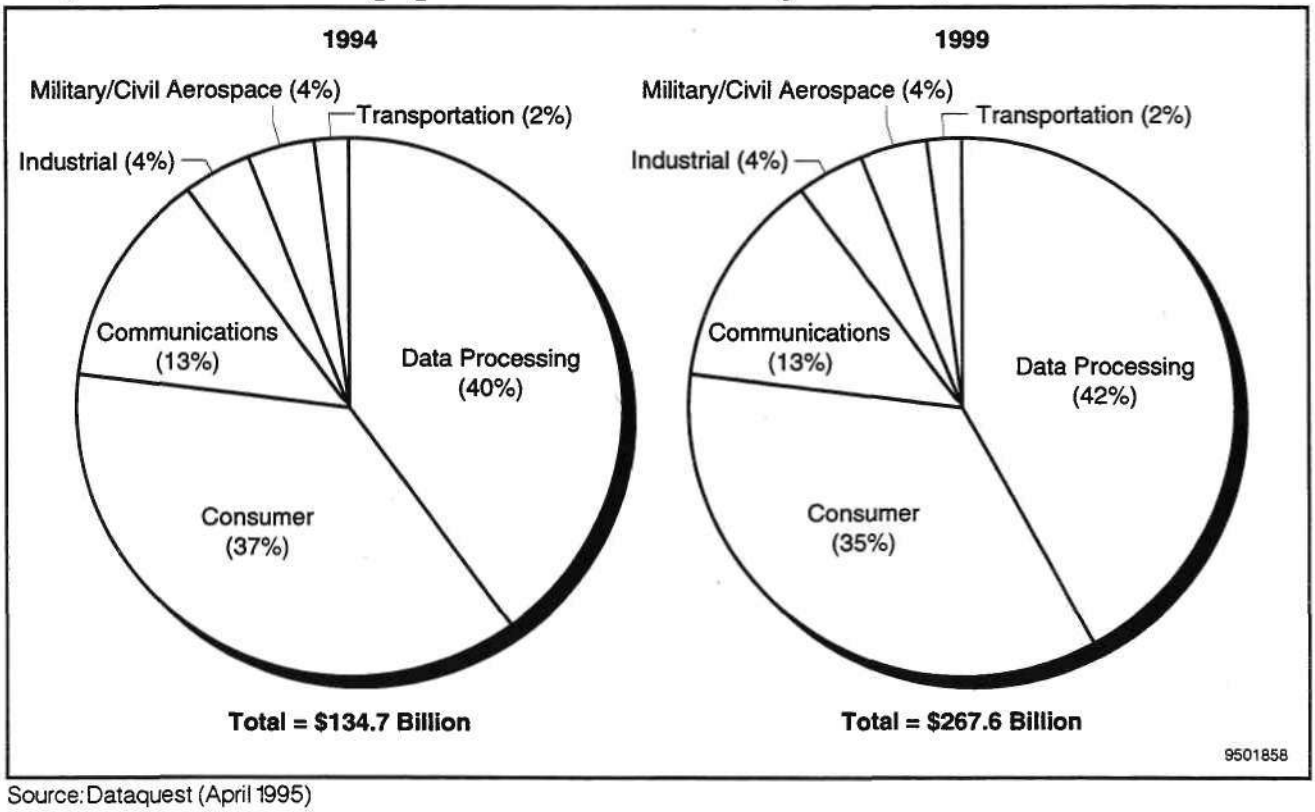
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Figure 1
Asia/Pacific Electronic Equipment Production by Sector (Factory Revenue)



Source: Dataquest (April 1995)

Figure 2
Asia/Pacific Electronic Equipment Production Factory Revenue, 1994 and 1999



Source: Dataquest (April 1995)

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- Both export and local demand for communications equipment propelled production to $17.6 billion in 1994, which accounted for only about 13.6 percent of worldwide production.
- Other electronic equipment segments, including industrial, transportation, and civil/military aerospace, reached a combined valued of $13.3 billion.

Dataquest generates electronic equipment data twice a year. We provide short-term analysis and updates as well as long-term-trend assessments.

Data Processing: The PC Boom—Will Asia Be Any Different, or Better?

Computer production, composed mostly of PCs/motherboards, accounts for about half of data processing revenue, followed by storage, which represents about one-fourth (see Table 2). We expect accelerating PC market growth for the next five years in Asia to warrant additional investments in manufacturing, hence local procurement of DRAMs and MPUs will increase. Explosive growth in populous countries such as China is likely to occur during the 1997 to 2000 period—Dataquest expects Australia, China, Korea, and India each to be million-unit markets. As for product life-cycle issues, the need for low-cost, high-performance computing will increase as home "edu-tainment" becomes a major market driver. More and more PC companies are developing Asian consumer market strategies. Recent statements by Apple Computer concur and note that more units likely will be sold in Asia than in the United States within two to three years. Product market life cycles may still lag those of the United States, Japan, and Europe by 1998 and 1999, but by only one or two quarters on average. Globalization of procurement and semiconductor manufacturing will have a price equalization effect during this period. In short, the PC boom will be no less significant in Asia than it has been anywhere else, and quite likely will be more earthshaking.

Table 2
Asia/Pacific Data Processing Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Total Data Processing	53,881	63,967	18.7	16.1
Computers	24,784	30,287	22.2	21.3
Data Storage	12,135	15,059	24.1	12.5
Input/Output	10,647	11,711	10.0	11.4
Dedicated System	4,889	5,280	8.0	7.9
Other Data Processing	1,426	1,629	14.3	-3.5

Source: Dataquest (April 1995)

Worldwide PC Market Outlook: Even Better

Dataquest's computer group has just revised its worldwide PC unit shipment forecast upward, which has been reflected in our data processing estimates. Dataquest's PC shipment forecast calls for 57 million units to ship in 1995, and in excess of 65 million units in 1996. This means a strong 19 percent growth in worldwide PC unit shipments this year and equally impressive 18 percent growth for 1996.

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Pricing pressure related primarily to PCs in 1994 caused revenue growth to be slightly weaker than forecast. Figures in 1995 are lowered because of expected price wars on 486s, led by Intel's push to drive the Pentium market. Greater-than-expected growth in the Asian PC markets will help counterbalance average-selling-price hits and Intel's entry into the board business. Accelerated demand for Pentiums in 1996 will contribute to positive revenue growth in 1995, but aggressive pricing, especially at the low end of the 486- and 586-based levels, will moderate revenue growth.

Dataquest's analysis of the supply side of the DRAM market concludes that the current undersupply will persist until the end of 1996. Rising or stable memory prices coupled with increased memory-per-system requirements translates into higher component costs for PC manufacturers. Although microprocessor price wars have begun to heat up, memory constraints will reduce the speed at which system prices can fall.

OEM business from Japan and continued demand from the United States and Europe have kept factories humming in Taiwan. PC manufacturers in Taiwan after 1995 will have the necessary infrastructure to supply most key components and are hinting at re-entering the brand-name business, at least in Asia. We expect PC production to remain strong in Asia's two major producing regions, Taiwan and Singapore. The growth in local markets will enhance these existing manufacturers in two ways:

- It will create opportunities for companies such as Acer to gain market share in these familiar, emerging markets.
- It will increase OEM/original design manufacturing demand from multinationals (existing customers or new) seeking to improve local market presence through the localization of design, manufacturing, and distribution.

Consumer: Japan's Worldwide Production and Export Base

Dataquest has raised its long-term consumer electronics production forecast for Asia/Pacific upon completion of its production shift report (see Table 3). We see investment decelerating in 1995 and in 1996 after peaking in 1993 and 1994. As for long-term growth, our surveys conducted in Japan of major consumer electronic manufacturers reveal that current shifts in production likely will continue through 1999. So, one wonders whether anything will be left to shift. What we see is a continuous involvement and link among the design, production, and distribution teams in Japan and Asia/Pacific. Production is being *shifted* and *upgraded* for long-term use in Asia, while high-end equipment continues to be built in Japan. China is one of the few countries that has a trade surplus with Japan. Why? Imports of Japanese electronics from China have become significant enough to shift the balance of trade in China's favor. Although Asian plants continue to export up-to-date appliances, stereos (audio), televisions (video), and VCRs (video) to the world, shipments within Asia/Pacific will make it the largest consuming region by the year 1999.

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Table 3
Asia/Pacific Consumer Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Total Consumer	49,897	56,753	13.7	13.7
Audio	13,535	15,652	15.6	15.4
Video	19,677	22,154	12.6	11.9
Personal Electronics	8,192	9,365	14.3	16.1
Appliances	5,366	6,189	15.3	14.3
Other Consumer	3,127	3,393	8.5	8.2

Source: Dataquest (April 1995)

Communications: Strong Growth to Follow Large Infrastructure Spending

Although communications equipment consumption in Asia/Pacific is booming, the region continues to rely heavily on imports necessary to build the region's telephony infrastructure. The high-volume products are telephone handsets, answering machines, modems, pagers, and fax machines. The lion's share of these products are exports. Existing infrastructure limitations are inhibiting short-term production growth but fueling large investment from leading telecommunications companies. We expect an increasing amount of premise and public equipment to be built in Asia/Pacific. In China, for instance, companies that build from within China receive favorable investment terms. Mobile is the fastest-growing sector, but it is less than one-third the size of premise. The service sectors are in the formative stage of development across the region and are undergoing exponential growth. We believe that investment in production will occur incrementally, not exponentially, which is shown in our CAGR of 14.5 percent (see Table 4). Starting from 1997, however, the five-year CAGR is likely to exceed 20 percent.

Table 4
Asia/Pacific Communications Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Total Communication	17,604	19,914	13.1	14.5
Premise Telecom	5,989	6,899	15.2	15.3
Public Telecom	4,655	5,307	14.0	14.6
Mobile Communications	1,844	2,130	15.5	21.4
Broadcast and Studio	974	1,180	21.1	17.4
Other Communications	4,141	4,398	6.2	8.2

Source: Dataquest (April 1995)

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Dataquest Perspective

Because of the combined growth of two large sectors, data processing and consumer, plus the surge in communication, Asia/Pacific is forecast to become the second-largest equipment-producing region by 1997, albeit based on constant Japanese-to-U.S.-dollar exchange rates. However, because of yen appreciation expected to continue for the next five years, Japan's production will show positive dollar growth. Conversely, such appreciation is the main reason for relocating production to Asia/Pacific in the first place.

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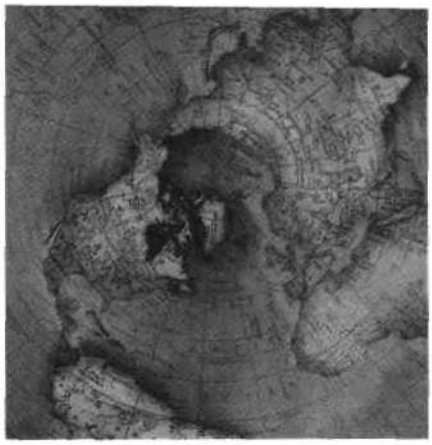
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Market Analysis

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Asia/Pacific Races Ahead in Unit Production of Electronic Equipment



Market Trends

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Publication Date: December 18, 1995
Filing: Market Analysis

Asia/Pacific Races Ahead in Unit Production of Electronic Equipment



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Chapter 1
Introduction

Asia/Pacific is clocking the fastest growth rates in most major equipment categories and is set to become the No. 1 manufacturing base for data processing and consumer electronic equipment after this year. Because it is one of the most populous regions in the world, Asia/Pacific offers not only excellent manufacturing cost advantages but also a vast potential market growing in tandem with the affluence of its inhabitants. Given the twin engines of data processing and consumer equipment, Asia/Pacific is expected to rival North America in terms of total electronic equipment production revenue by the end of the century.

For the first time, we are providing a sum-up forecast of production volume by unit of selected electronic equipment. Figure 1-1 compares the volume production of the equipment that Dataquest estimated for 1994. Stereos, both personal and portable, took up the largest share in terms of unit produced in Asia/Pacific, followed by corded telephones, color televisions, rigid disk drives, videocassette recorders, and personal computers. Figure 1-2 shows that the corresponding semiconductor opportunities (or total application market, TAM) belong to predominantly PCs. Rigid disk drives, color televisions, videocassette recorders, and stereo systems account for the other sizable semiconductor market by virtue of the units produced in the region.

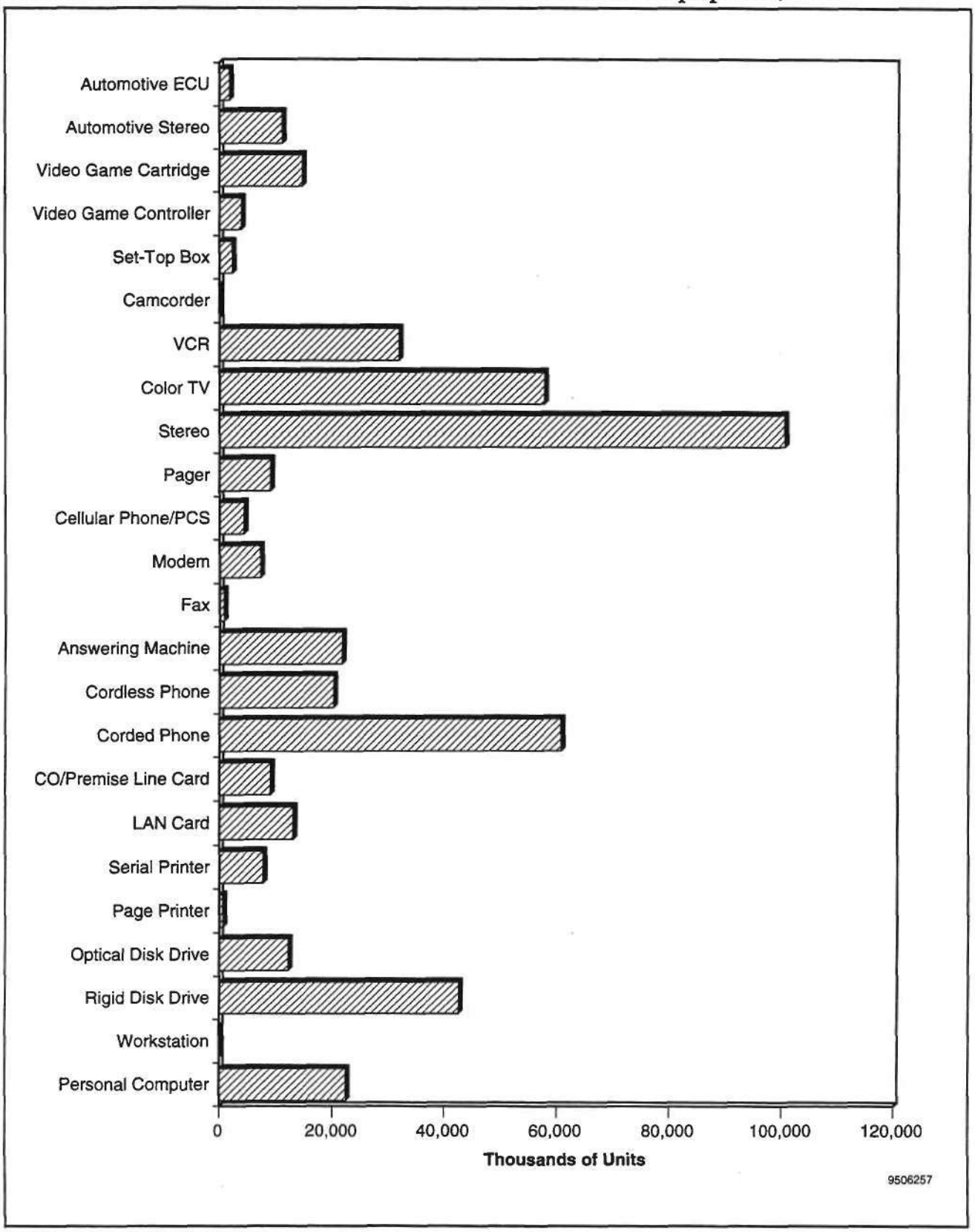
This report presents our estimates of units produced in the region from 1993 through 1999, plus the corresponding factory revenue for the 24 types of electronic equipment under four categories:

- Data processing (PC, workstation, rigid disk drive, optical disk drive, page printer, and serial printer)
- Communications (LAN card, central office (CO)/premise line card, corded telephone, cordless telephone, answering machine, facsimile machine, modem, cellular telephone, and pager)
- Consumer equipment (personal and portable stereo, color television, videocassette recorder, camcorder, set-top box, video game controller, and video game cartridge)
- Transportation (automotive stereo and automotive electronic control unit)

Each table in this report also will contain the estimated semiconductor content, which together with the unit production yield TAM for the semiconductor market for each type of electronic equipment. Each table will be accompanied by another showing the corresponding annual growth rates, followed by a figure summarizing the unit production and factory revenue.

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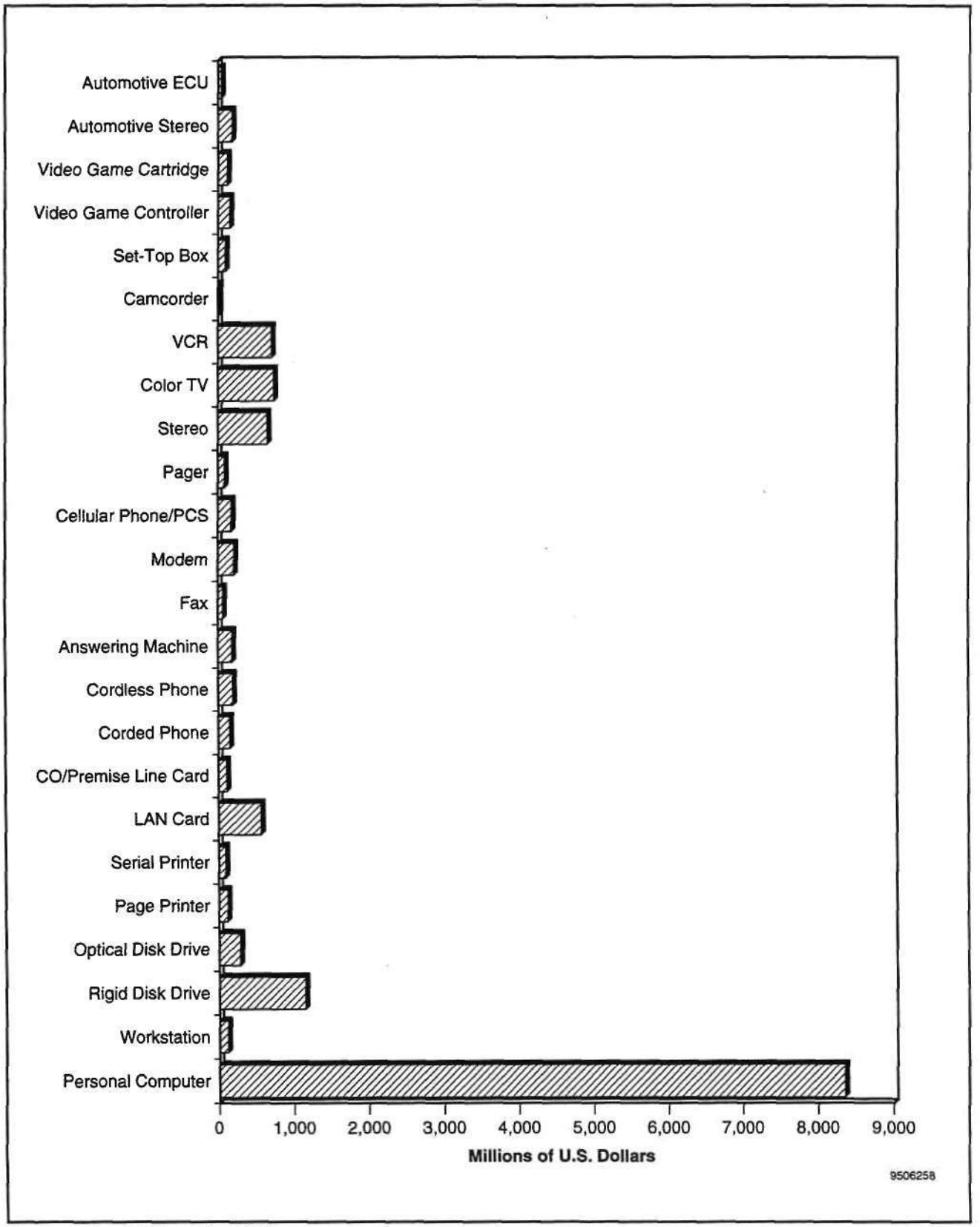
Figure 1-1
Asia/Pacific-Rest of World (ROW) Production of Electronic Equipment, 1994



Source: Dataquest (November 1995)

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Figure 1-2
Asia/Pacific-ROW Semiconductor Consumption, 1994



Source: Dataquest (November 1995)

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Chapter 2
Data Processing

This chapter will cover only PCs, workstations, rigid disk drives, optical disk drives, page printers, and serial printers.

Personal Computer

Asia/Pacific accounted for 42 percent of the worldwide manufacturing volume of PCs in 1994. We expect the share to grow throughout the decade because Dell, Packard Bell, and Gateway 2000 announced their plans to manufacture in Malaysia, while Compaq and IBM are increasing capacity through joint ventures in Shenzhen. Taiwan clearly dominates with its global facilities in producing desktops, notebooks, and motherboards. Its OEM/ODM relationship with U.S.-based manufacturers, coupled with its design skills, ensure future manufacturing growth. FIC and GVC are following in the footsteps of Acer and Mitac in creating their own brands and marketing channels. Singapore ranks second because of large Compaq, Hewlett-Packard, and Apple facilities. We forecast a 1994 to 1999 compound annual growth rate (CAGR) of 22.6 percent from 22.5 million units to 62.2 million units of PCs, with a majority loaded with Pentium-class microprocessors (see Table 2-1, Table 2-2, and Figure 2-1). Semiconductor suppliers will see the market opportunity triple to $37 billion by 1999, mostly in the form of memory and microprocessors.

Table 2-1
Asia/Pacific-ROW Personal Computer Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	17,194	22,481	26,779	34,235	40,668	50,080	62,183	22.6
Factory ASP ($)	1,374	1,439	1,520	1,499	1,398	1,293	1,191	-3.7
Factory Revenue ($M)	23,623	32,340	40,712	51,328	56,837	64,757	74,046	18.0
Semiconductor Content ($)	296	372	480	557	610	607	594	9.8
Semiconductor TAM ($M)	5,086	8,357	12,843	19,080	24,813	30,416	36,938	34.6

Source: Dataquest (November 1995)

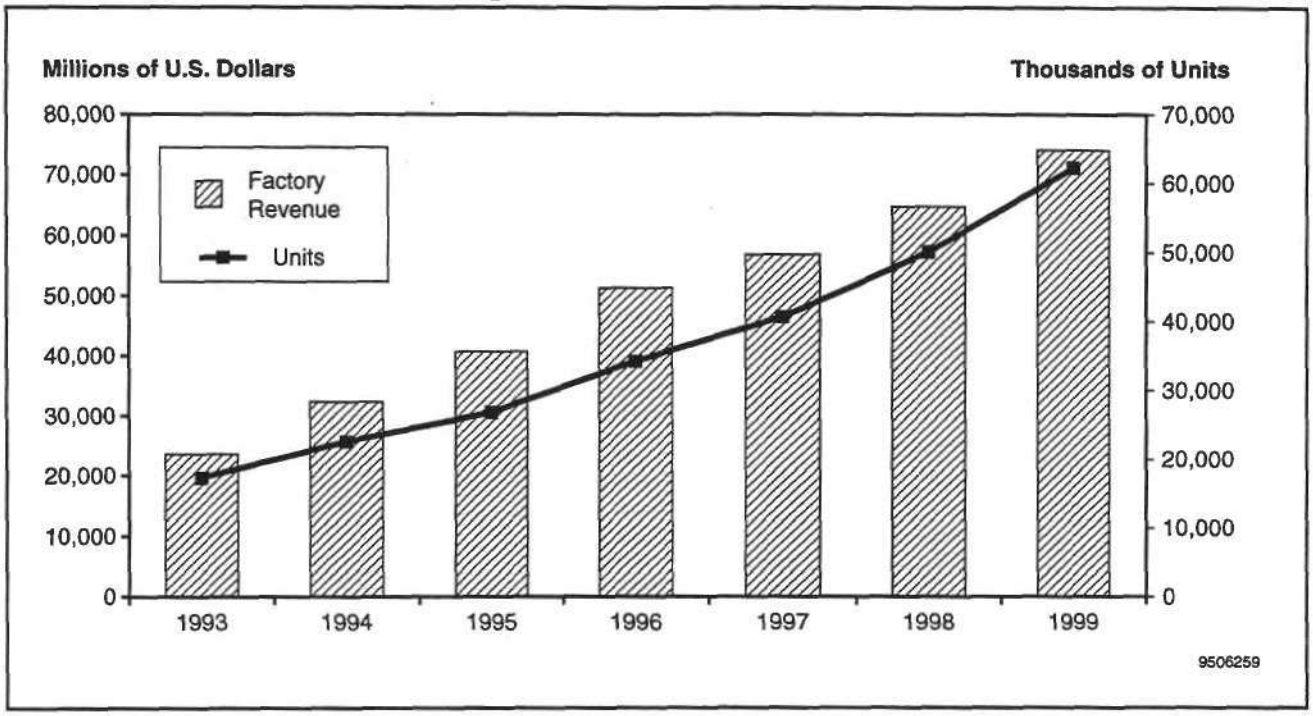
Table 2-2
Asia/Pacific-ROW Personal Computer Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	30.8	19.1	27.8	18.8	23.1	24.2
Factory ASP	4.7	5.7	-1.4	-6.8	-7.5	-7.9
Factory Revenue	36.9	25.9	26.1	10.7	13.9	14.3
Semiconductor Content	25.7	29.0	16.2	9.5	-0.5	-2.2
Semiconductor TAM	64.3	53.7	48.6	30.0	22.6	21.4

Source: Dataquest (November 1995)

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Figure 2-1
Asia/Pacific-ROW Personal Computer Production Forecast



Source: Dataquest (November 1995)

Workstation

Workstations are similar to desktops. The differences lie in CPU performance, graphics interface quality, memory and hard disk size, and their application of UNIX. Workstations, manufactured mainly in North America, are low-volume items in Asia/Pacific but fetch fairly stable average selling prices (ASPs). Sun Microsystems among the major global manufacturers subcontracts production to local assemblers in the region. We forecast the unit volume produced to rise modestly from 74,000 units in 1994 to 111,000 units in 1999 (see Table 2-3, Table 2-4, and Figure 2-2).

Table 2-3
Asia/Pacific-ROW Workstation Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	49	74	92	108	90	114	111	8.4
Factory ASP ($)	15,243	14,699	15,227	15,516	15,557	14,867	14,719	0
Factory Revenue ($M)	747	1,088	1,401	1,676	1,400	1,695	1,634	8.5
Semiconductor Content ($)	1,070	1,535	1,590	1,730	1,445	1,300	1,270	-3.7
Semiconductor TAM ($M)	52	114	146	187	130	148	141	4.4

Source: Dataquest (November 1995)

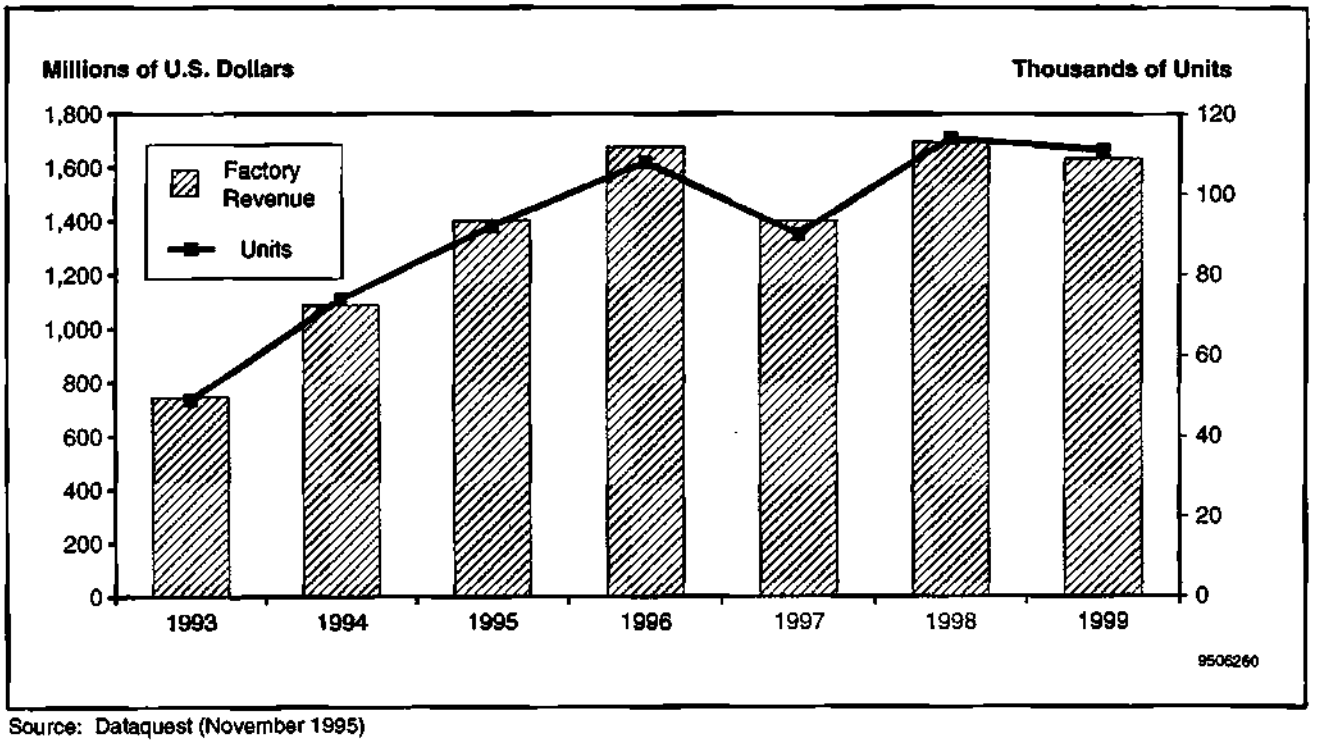
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Table 2-4
Asia/Pacific-ROW Workstation Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	51.0	24.3	17.4	-16.7	26.7	-2.6
Factory ASP	-3.6	3.6	1.9	0.3	-4.4	-1.0
Factory Revenue	45.6	28.8	19.6	-16.4	21.0	-3.6
Semiconductor Content	43.5	3.6	8.8	-16.5	-10.0	-2.3
Semiconductor TAM	116.7	28.8	27.7	-30.4	14.0	-4.9

Source: Dataquest (November 1995)

Figure 2-2
Asia/Pacific-ROW Workstation Production Forecast



Source: Dataquest (November 1995)

Rigid Disk Drive

Rigid disk drives are the second largest by unit volume produced in Asia/Pacific-ROW. The year 1994 saw a historic annual growth of 44.3 percent growth in units, which will steadily grow 20 to 30 percent each year throughout the decade. Dataquest projects this year's 53.8 million units assembled in the region to double to 127.7 million units in 1999 (see Table 2-5, Table 2-6, and Figure 2-3). The capacity point is quickly migrating to gigabyte proportions but will remain within the popular 3.5- and 2.5-inch form factor. Singapore is the largest production base because of huge investments from U.S. companies. Seagate, the major player that now is even bigger with the acquisition of Conner, is expanding; other manufacturers are also increasing production volume not only in Singapore but also in other countries. The United States-Singapore axis is encouraging other followers such as Malaysia, also backed by U.S. investors, and the Philippines, a brand-new manufacturing base dominated by the Japanese (Hitachi, Fujitsu, Toshiba, and NEC). Other hot spots include

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China (Seagate/Conner and Hyundai to announce) and South Korea (Hyundai and Samsung). Rigid disk drives offer the second-largest group of semiconductor opportunities, other than PCs, and will remain so throughout the decade.

Table 2-5
Asia/Pacific-ROW Rigid Disk Drive Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	29,547	42,628	53,773	64,932	84,145	106,454	127,681	24.5
Factory ASP ($)	265	230	180	182	165	160	150	-8.2
Factory Revenue ($M)	7,830	9,804	9,679	11,818	13,884	17,033	19,152	14.3
Semiconductor Content ($)	25	27	28	30	30	28	26	-0.8
Semiconductor TAM ($M)	725	1,149	1,525	1,949	2,507	2,959	3,301	23.5

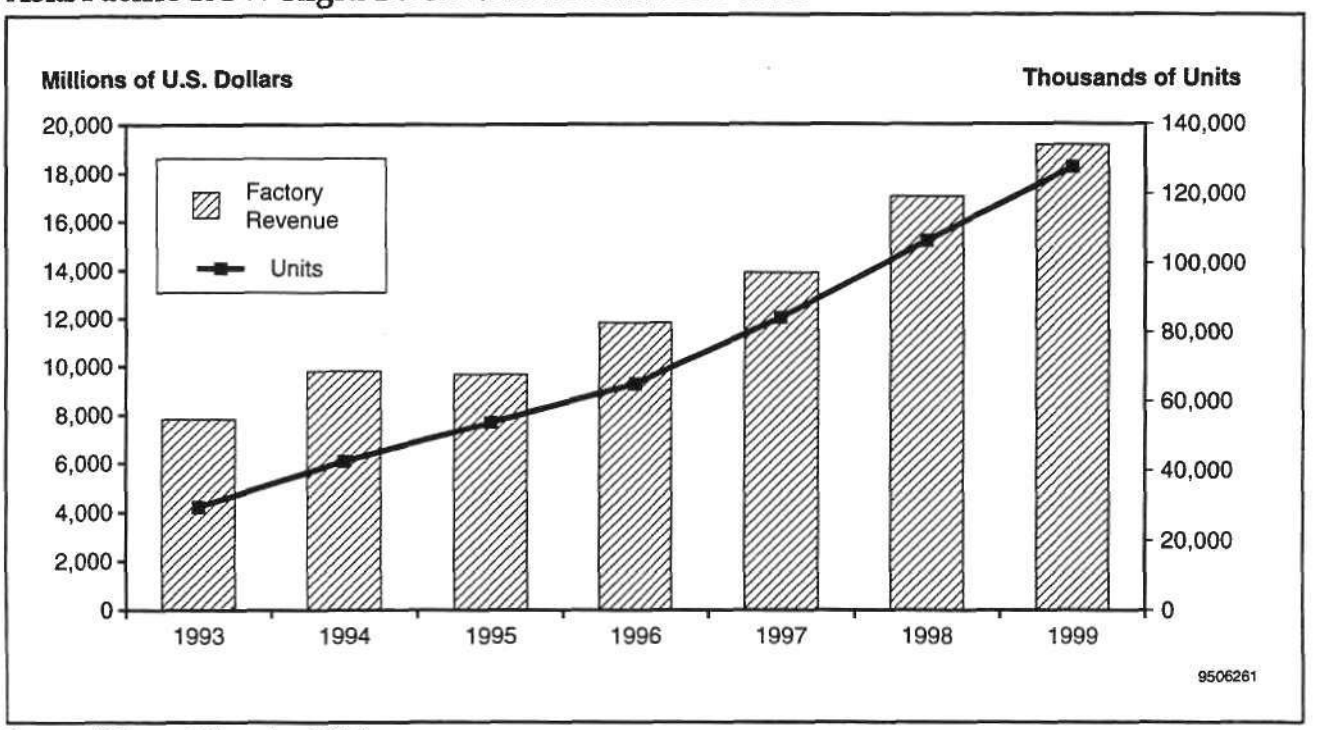
Source: Dataquest (November 1995)

Table 2-6
Asia/Pacific-ROW Rigid Disk Drive Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	44.3	26.1	20.8	29.6	26.5	19.9
Factory ASP	-13.2	-21.7	1.1	-9.3	-3.0	-6.3
Factory Revenue	25.2	-1.3	22.1	17.5	22.7	12.4
Semiconductor Content	9.8	5.2	5.8	-0.7	-6.7	-7.0
Semiconductor TAM	58.4	32.7	27.8	28.6	18.0	11.5

Source: Dataquest (November 1995)

Figure 2-3
Asia/Pacific-ROW Rigid Disk Drive Production Forecast



Source: Dataquest (November 1995)

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Optical Disk Drive

Optical storage devices, mostly CD-ROM drives, made their debut in Asia/Pacific with a 476 percent annual growth rate in 1994 (see Table 2-7, Table 2-8, and Figure 2-4). Demand is driven by the home multimedia market. Quad-speed drives are popular, but six-speed shipment is ramping up. Japanese manufacturers will continue to move production of so-called low-end CD-ROM drives to Southeast Asia and China and will maintain high-end development and production in Japan. Indigenous companies in Taiwan and Singapore are also growing their own brands and promise to corner a portion of the market. Acer Peripherals, Elite, and BTC are the major players set to lead Taiwan to be key suppliers of optical disk drives in the next few years. Aztech and Creative, both from Singapore, require this segment of the business to complete their multimedia business, while Wearnes and Optic Storage are contributing in terms of volume and technology (on six- and eight-speed, respectively). Among the Japanese manufacturers, Singaporean, and Taiwanese companies, NEC is increasing manufacturing capacities in Malaysia.

Table 2-7
Asia/Pacific-ROW Optical Disk Drive Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	2,110	12,154	19,409	22,803	25,113	26,651	27,950	18.1
Factory ASP ($)	178	135	99	83	67	61	60	-15.0
Factory Revenue ($M)	376	1,641	1,921	1,893	1,683	1,626	1,677	0.4
Semiconductor Content ($)	23	23	20	19	18	17	16	-7.0
Semiconductor TAM ($M)	49	280	388	433	452	453	447	9.9

Source: Dataquest (November 1995)

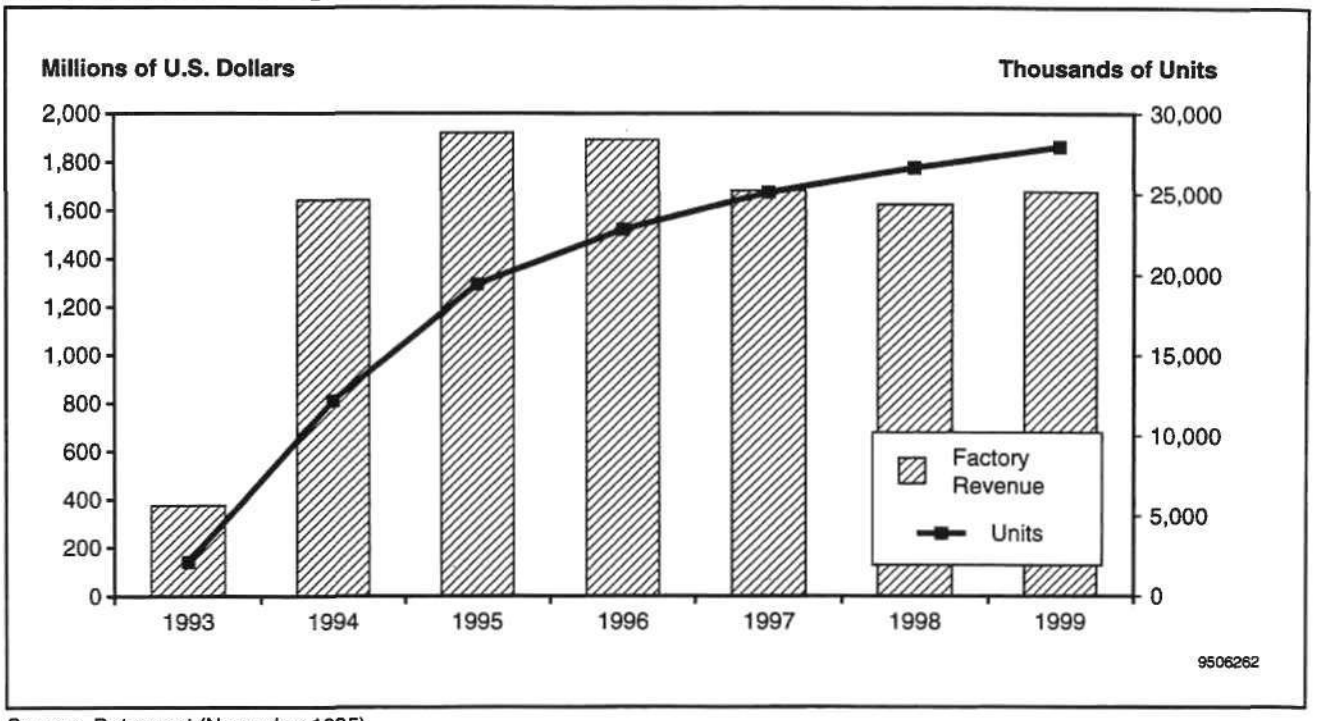
Table 2-8
Asia/Pacific-ROW Optical Disk Drive Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	476.0	59.7	17.5	10.1	6.1	4.9
Factory ASP	-24.2	-26.7	-16.2	-19.3	-9.0	-1.6
Factory Revenue	336.9	17.1	-1.5	-11.1	-3.4	3.2
Semiconductor Content	0	-13.0	-5.0	-5.3	-5.6	-5.9
Semiconductor TAM	476.0	38.9	11.6	4.3	0.2	-1.3

Source: Dataquest (November 1995)

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Figure 2-4
Asia/Pacific-ROW Optical Disk Drive Production Forecast



Source: Dataquest (November 1995)

Page Printer

We define page printers as electronic equipment that prints the whole page all at once. Compared to the rest of the regions, Asia/Pacific is the smallest manufacturing base for page printers. Trigem, Samsung, and Lucky-Goldstar dominate the manufacturing and end-user Korean market. Most of the semiconductor opportunities (60 percent) are offered to volatile and nonvolatile suppliers, but expect rising growth in demand for microcomponents and ASICs. Table 2-9, Table 2-10, and Figure 2-5 show our forecast of Asia/Pacific's production of page printers.

Table 2-9
Asia/Pacific-ROW Page Printer Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	675	657	461	538	579	797	869	5.8
Factory ASP ($)	751	619	567	501	441	386	332	-11.7
Factory Revenue ($M)	507	406	261	270	255	308	288	-6.6
Semiconductor Content ($)	142	180	161	126	120	117	113	-8.8
Semiconductor TAM ($M)	96	118	74	68	69	93	98	-3.6

Source: Dataquest (November 1995)

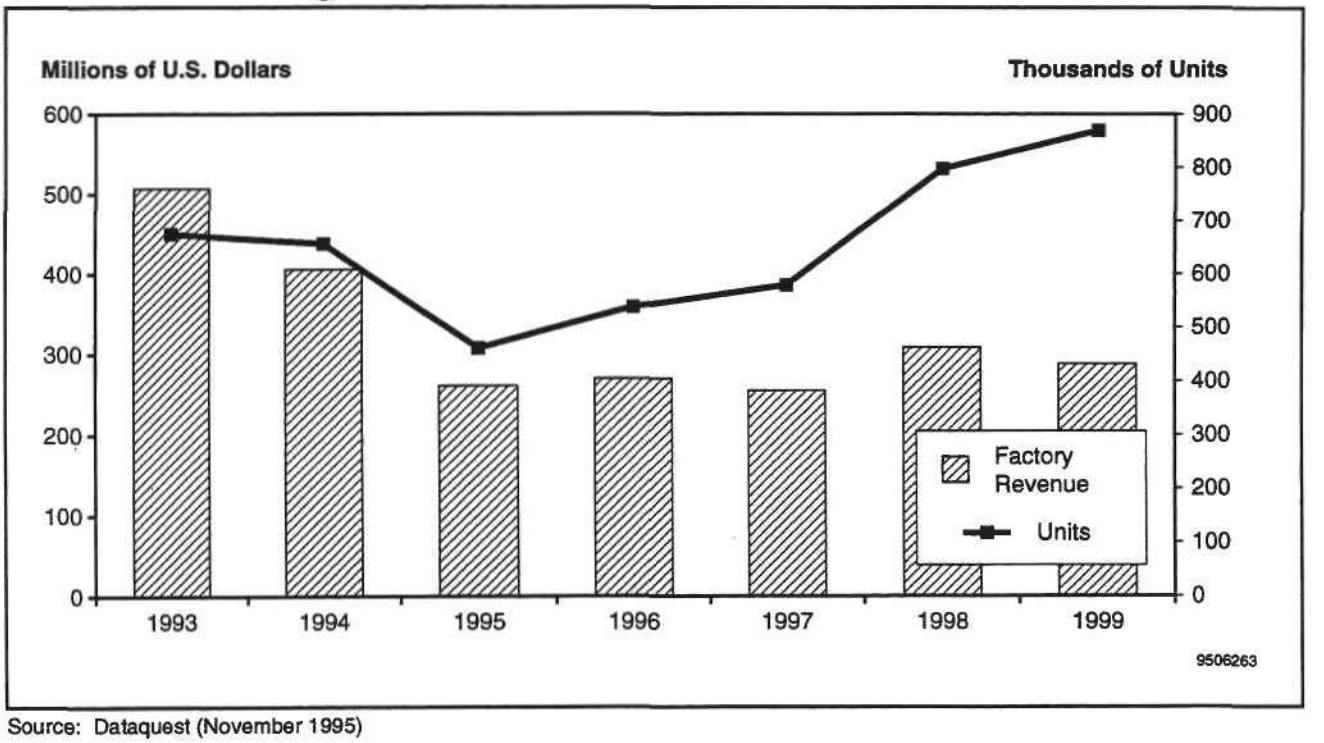
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Table 2-10
Asia/Pacific-ROW Page Printer Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	-2.7	-29.8	16.7	7.6	37.7	9.0
Factory ASP	-17.6	-8.4	-11.6	-12.0	-12.5	-14.0
Factory Revenue	-19.8	-35.7	3.2	-5.3	20.5	-6.2
Semiconductor Content	26.6	-10.6	-21.5	-4.8	-2.5	-3.4
Semiconductor TAM	23.3	-37.2	-8.4	2.5	34.2	5.3

Source: Dataquest (November 1995)

Figure 2-5
Asia/Pacific-ROW Page Printer Production Forecast



Source: Dataquest (November 1995)

Serial Printer

Serial printers print one character at a time. These printers are manufactured in greater quantities, compared to the page printers. Dataquest projects unit production to double to 14.6 million units in 1999 (see Table 2-11, Table 2-12, and Figure 2-6). Serial printers are manufactured mainly in China by Japanese companies (Epson and Panasonic) and in Korea by the indigenous companies (Samsung, Lucky-Goldstar, and Qnix). The high volumes offer greater opportunities to suppliers of analog/logic devices.

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Table 2-11
Asia/Pacific-ROW Serial Printer Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	4,202	7,717	10,032	11,537	12,922	13,568	14,613	13.6
Factory ASP ($)	183	167	154	138	132	127	122	-6.2
Factory Revenue ($M)	770	1,290	1,542	1,595	1,705	1,720	1,778	6.6
Semiconductor Content ($)	7	12	15	15	15	16	16	7.3
Semiconductor TAM ($M)	31	90	147	172	193	213	241	21.9

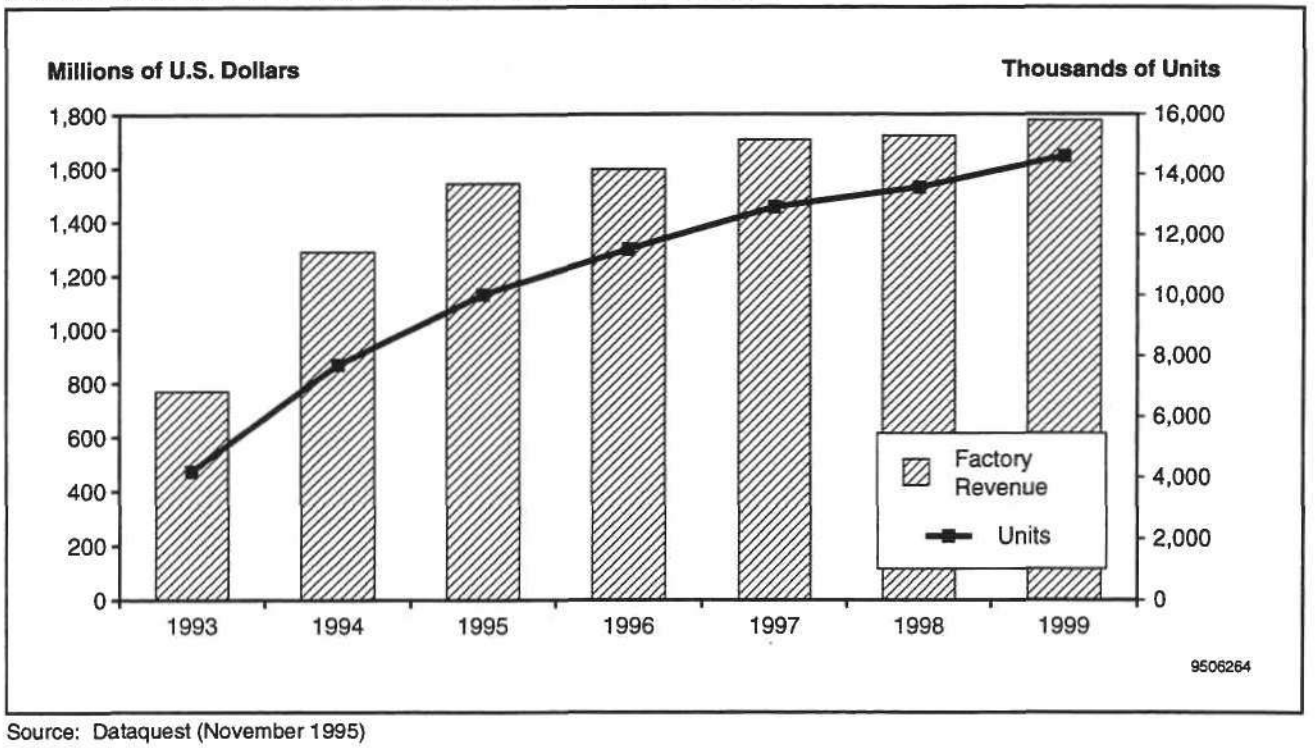
Source: Dataquest (November 1995)

Table 2-12
Asia/Pacific-ROW Serial Printer Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	83.7	30.0	15.0	12.0	5.0	7.7
Factory ASP	-8.8	-8.0	-10.1	-4.6	-3.9	-4.0
Factory Revenue	67.6	19.6	3.4	6.9	0.9	3.4
Semiconductor Content	56.8	26.7	1.4	0	5.4	5.0
Semiconductor TAM	187.9	64.7	16.6	12.0	10.6	13.1

Source: Dataquest (November 1995)

Figure 2-6
Asia/Pacific-ROW Serial Printer Production Forecast



Source: Dataquest (November 1995)

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Chapter 3
Communications

Communications spans the following products: LAN cards, CO/premise line cards, corded telephones, cordless telephones, answering machines, facsimile machines, modems, cellular telephone/personal communications systems (PCS), and pagers. The more mature markets of Singapore and Taiwan are showing declines in manufacturing premise equipment. However, Taiwan is focusing on data communication and networking (modems and LAN cards), while Singapore (Motorola, also in Tianjin, China) is still churning out substantial volumes of pagers.

LAN Card

Office desktop connectivity is rapidly gaining importance in Asia/Pacific (and Japan). Dataquest therefore forecasts a healthy CAGR of 20.6 percent to 33 million units over the next five years (see Table 3-1, Table 3-2, and Figure 3-1). Taiwan's decade-long manufacturing of LAN cards explains its over 50 percent contribution to unit production share in Asia/Pacific. Taiwanese LAN chipset design houses, as seen in the PC OEM/ODM partnership, are able to turn around their products at competitive pricing.

Table 3-1
Asia/Pacific-ROW LAN Card Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	8,466	12,970	17,889	23,213	27,937	30,402	33,072	20.6
Factory ASP ($)	193	161	140	121	100	84	70	-15.3
Factory Revenue ($M)	1,637	2,088	2,496	2,802	2,780	2,548	2,328	2.2
Semiconductor Content ($)	48	43	38	34	28	24	20	-14.1
Semiconductor TAM ($M)	409	564	684	779	784	729	674	3.6

Source: Dataquest (November 1995)

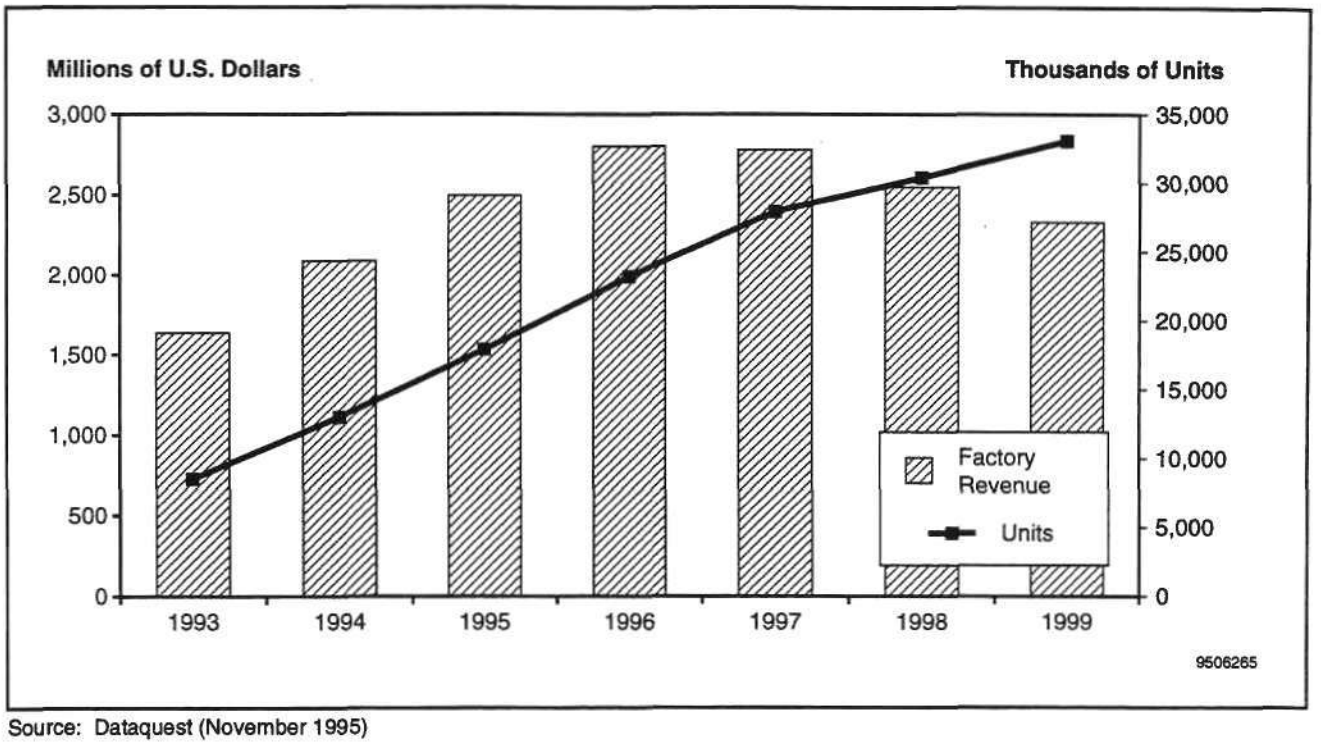
Table 3-2
Asia/Pacific-ROW LAN Card Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	53.2	37.9	29.8	20.4	8.8	8.8
Factory ASP	-16.8	-13.3	-13.5	-17.6	-15.8	-16.0
Factory Revenue	27.5	19.6	12.2	-0.8	-8.3	-8.6
Semiconductor Content	-10.1	-12.0	-12.2	-16.4	-14.6	-15.0
Semiconductor TAM	37.7	21.3	13.9	0.6	-7.0	-7.5

Source: Dataquest (November 1995)

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Figure 3-1
Asia/Pacific-ROW LAN Card Production Forecast



Source: Dataquest (November 1995)

CO/Premise Line Card

CO/premise line cards are telephone line cards. CO is the local telephone company's PBX. Premise line cards are telephone line cards used by individual corporate companies to receive telephone company signals. As with the expansion of other communications segments, Dataquest projects the production of such cards to increase at a CAGR of 21.1 percent to 23.5 million units in 1999 (see Table 3-3, Table 3-4, and Figure 3-2).

Table 3-3
Asia/Pacific-ROW CO/Premise Line Card Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	6,907	8,996	11,480	14,424	17,953	22,023	23,459	21.1
Factory ASP ($)	76	77	78	79	81	82	84	1.8
Factory Revenue ($M)	525	691	891	1,142	1,451	1,815	1,972	23.3
Semiconductor Content ($)	12	12	12	12	12	11	11	-1.8
Semiconductor TAM ($M)	83	109	132	168	213	248	258	18.9

Source: Dataquest (November 1995)

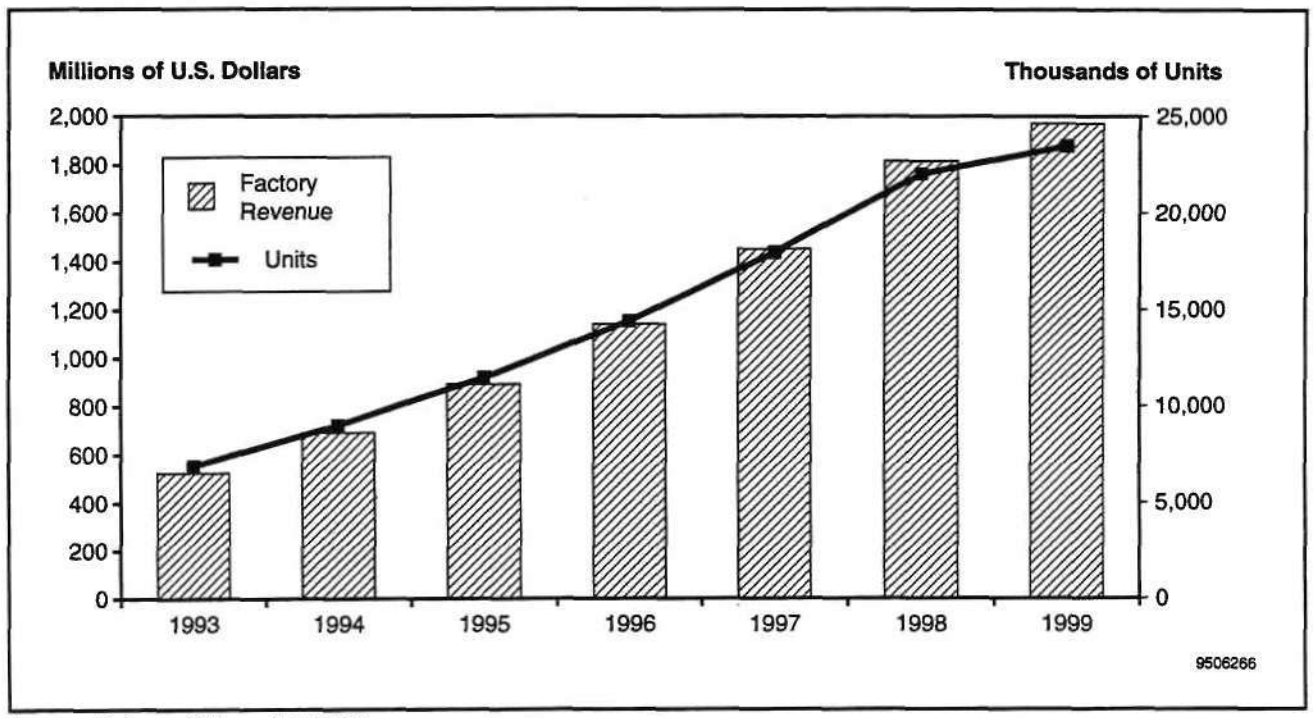
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Table 3-4
Asia/Pacific-ROW CO/Premise Line Card Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	30.3	27.6	25.6	24.5	22.7	6.5
Factory ASP	1.1	1.0	2.1	2.0	2.0	2.0
Factory Revenue	31.6	28.9	28.2	27.0	25.1	8.7
Semiconductor Content	0.7	-4.6	1.4	1.4	-5.0	-2.2
Semiconductor TAM	31.2	21.8	27.4	26.2	16.6	4.2

Source: Dataquest (November 1995)

Figure 3-2
Asia/Pacific-ROW CO/Premise Line Card Production Forecast



Source: Dataquest (November 1995)

Corded Telephone

Corded telephones constitute the bulk of communications devices produced in the region for domestic consumption, in view of the rich penetration opportunities of even the most basic form of communications device. Table 3-5, Table 3-6, and Figure 3-3 show our forecast that corded telephone production will grow modestly to 72 million units in 1999 as users become more attracted to the cordless/mobile version. Rotary dialers have been replaced by numeric keypads. Business/corporate and now home users have driven demand for multifeature telephones, which incorporate, for example, hands-free dialing, speaker phone, store capability, and display/clock. The cost of corded telephones slid with the introduction of low-cost 4-bit and 8-bit microcontrollers. Malaysia contributes a major share of regional unit production because of its big facilities from both the Japanese (such as Sanyo and its joint-venture partner) and Taiwanese manufacturers (notably Inventech and Formula).

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Table 3-5
Asia/Pacific-ROW Corded Telephone Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	57,855	60,748	63,481	66,021	68,529	70,928	72,347	3.6
Factory ASP ($)	23	23	23	23	23	23	23	-0.1
Factory Revenue ($M)	1,313	1,392	1,466	1,532	1,594	1,651	1,651	3.5
Semiconductor Content ($)	3	3	3	3	3	3	3	3.5
Semiconductor TAM ($M)	146	153	160	166	173	180	217	7.2

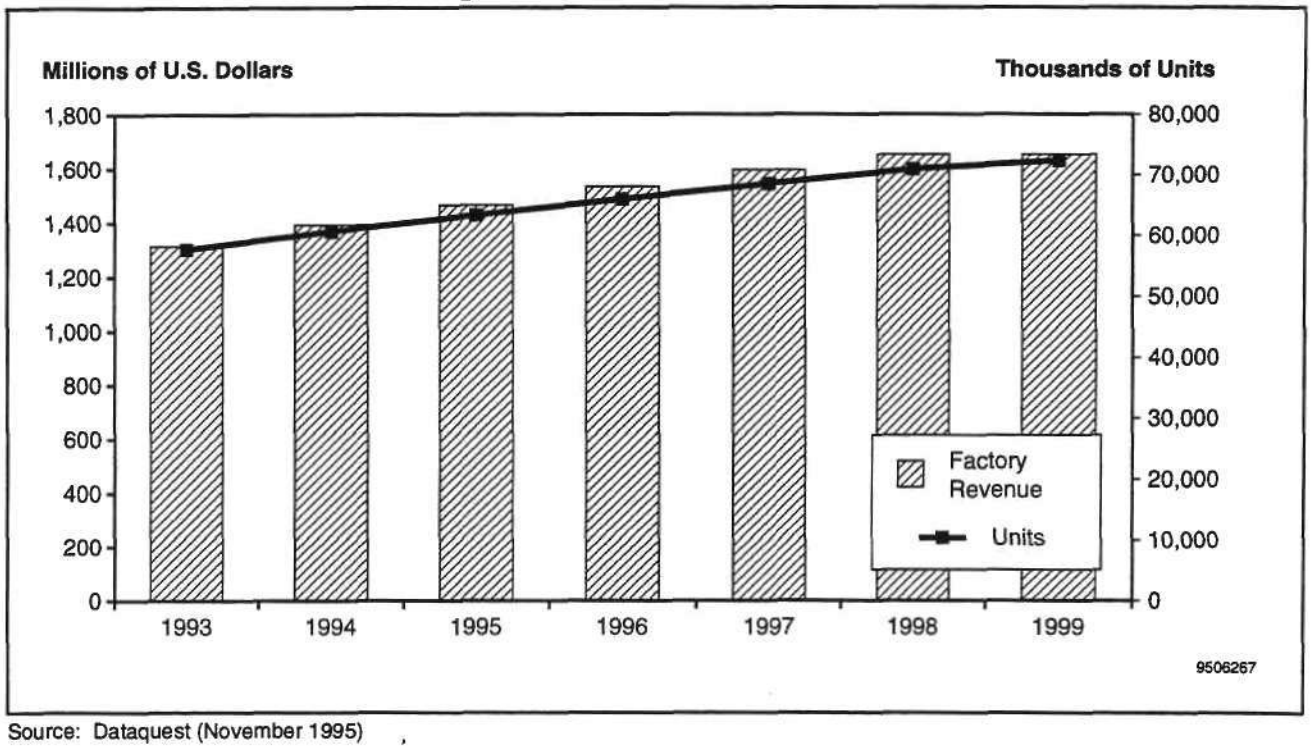
Source: Dataquest (November 1995)

Table 3-6
Asia/Pacific-ROW Corded Telephone Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	5.0	4.5	4.0	3.8	3.5	2.0
Factory ASP	1.0	0.7	0.5	0.3	0.1	-2.0
Factory Revenue	6.1	5.3	4.5	4.1	3.6	0
Semiconductor Content	0	0	0	0	0.8	18.1
Semiconductor TAM	5.0	4.5	4.0	3.8	4.3	20.5

Source: Dataquest (November 1995)

Figure 3-3
Asia/Pacific-ROW Corded Telephone Production Forecast



Source: Dataquest (November 1995)

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Cordless Telephone

Cordless telephones are getting more attractive because this form of device allows mobility and convenience, compared to its corded version. This segment of the market is driven by residential users. As with corded telephones, Asia/Pacific is the largest manufacturing base for cordless telephones. We project Asia/Pacific production to grow to 26.6 million units in 1999 (see Table 3-7, Table 3-8, and Figure 3-4).

Table 3-7
Asia/Pacific-ROW Cordless Telephone Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	19,451	20,216	21,556	22,728	23,964	25,236	26,578	5.6
Factory ASP ($)	45	43	43	44	45	47	49	2.4
Factory Revenue ($M)	866	878	927	1,000	1,078	1,186	1,302	8.2
Semiconductor Content ($)	9	10	10	11	11	12	12	4.7
Semiconductor TAM ($M)	182	193	213	240	270	297	319	10.6

Source: Dataquest (November 1995)

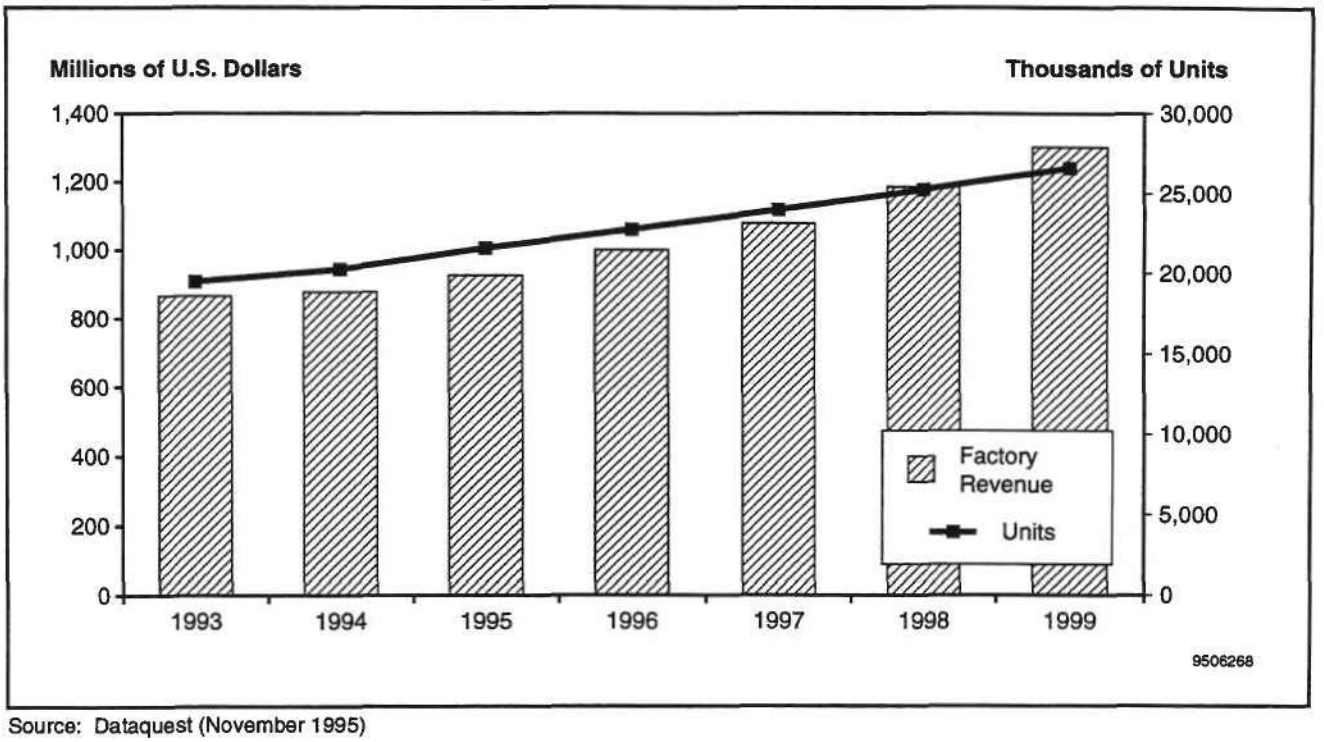
Table 3-8
Asia/Pacific-ROW Cordless Telephone Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	3.9	6.6	5.4	5.4	5.3	5.3
Factory ASP	-2.5	-1.0	2.3	2.3	4.4	4.3
Factory Revenue	1.3	5.6	7.9	7.8	10.0	9.8
Semiconductor Content	2.2	3.5	6.8	6.5	4.4	2.1
Semiconductor TAM	6.2	10.4	12.6	12.3	10.0	7.6

Source: Dataquest (November 1995)

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Figure 3-4
Asia/Pacific-ROW Cordless Telephone Production Forecast



Source: Dataquest (November 1995)

Answering Machine

Answering machines include both standalone and those built into telephonic devices. Answering machines are very popular in North America, where consumer tastes are migrating to solid-state versions rather the existing tape versions. Asia/Pacific is the largest region for producing answering machines, accounting for 83 percent unit volume worldwide. We project regional production to grow a steady CAGR of 6.6 percent from 22 million units in 1994 to 30 million units in 1999 (see Table 3-9, Table 3-10, and Figure 3-5).

Table 3-9
Asia/Pacific-ROW Answering Machine Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	18,946	21,788	23,531	25,178	26,941	28,557	29,985	6.6
Factory ASP ($)	42	39	39	37	35	33	33	-3.4
Factory Revenue ($M)	796	850	922	940	956	955	983	3.0
Semiconductor Content ($)	8	9	11	12	12	13	12	7.4
Semiconductor TAM ($M)	152	187	259	290	323	357	367	14.5

Source: Dataquest (November 1995)

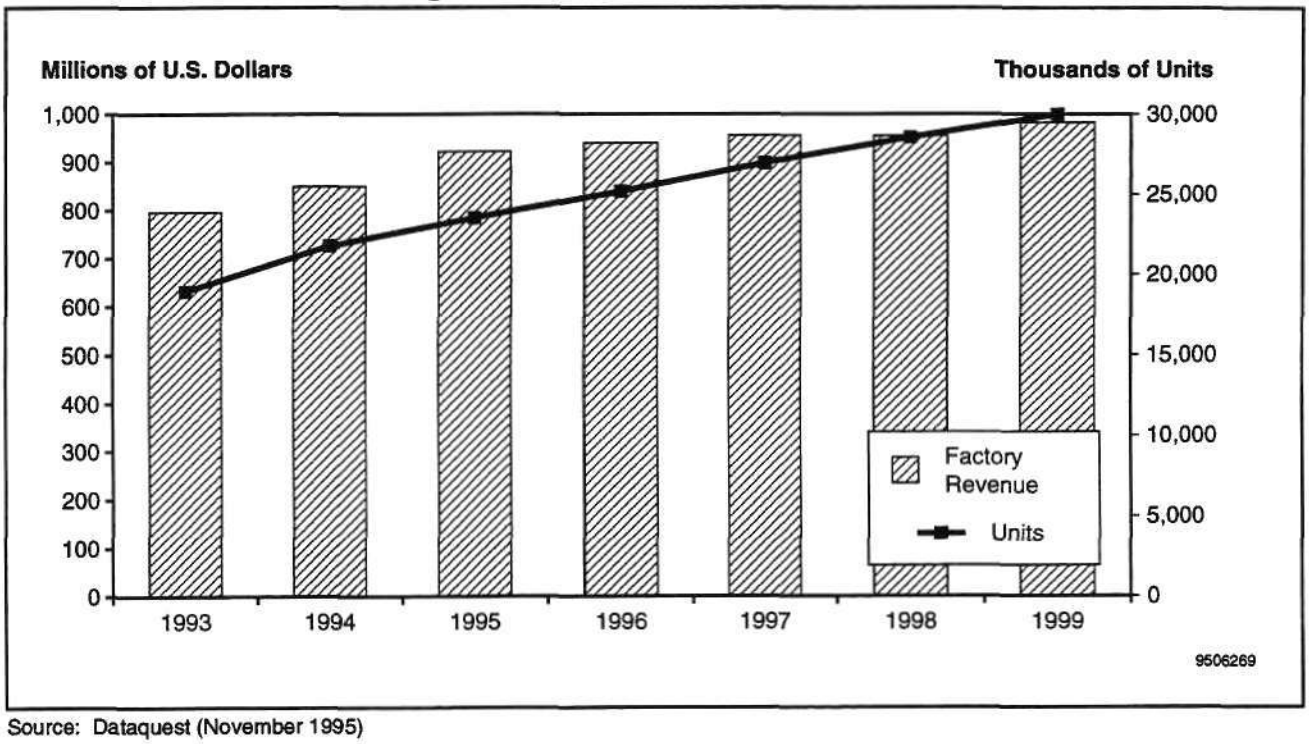
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Table 3-10
Asia/Pacific-ROW Answering Machine Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	15.0	8.0	7.0	7.0	6.0	5.0
Factory ASP	-7.2	0.4	-4.7	-4.9	-5.7	-2.0
Factory Revenue	6.8	8.4	2.0	1.7	-0.1	2.9
Semiconductor Content	7.3	28.2	4.5	4.3	4.2	-2.0
Semiconductor TAM	23.4	38.4	11.9	11.7	10.4	2.9

Source: Dataquest (November 1995)

Figure 3-5
Asia/Pacific-ROW Answering Machine Production Forecast



Source: Dataquest (November 1995)

Facsimile Machine

Although most of the developed countries show modest unit growth rates, the developing countries of Asia/Pacific are the main growth manufacturing bases for fax machines. We forecast Asia/Pacific production volume to almost triple to 2.4 million units in 1999 (see Table 3-11, Table 3-12, and Figure 3-6). The trend is to shift toward plain-paper type as the price of plain paper fax machines continues to slide. This segment of the market spells good opportunities for suppliers mainly in ASICs and logic/discrete/analog. Major manufacturers are mostly the Japanese such as Sharp, Panasonic, and Canon.

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Table 3-11
Asia/Pacific-ROW Facsimile Machine Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	602	800	1,134	1,474	1,873	2,270	2,376	24.3
Factory ASP ($)	552	514	467	430	413	424	424	-3.8
Factory Revenue ($M)	332	411	530	633	774	963	1,007	19.6
Semiconductor Content ($)	81	80	80	79	79	79	79	-0.2
Semiconductor TAM ($M)	49	64	91	116	148	179	188	24.1

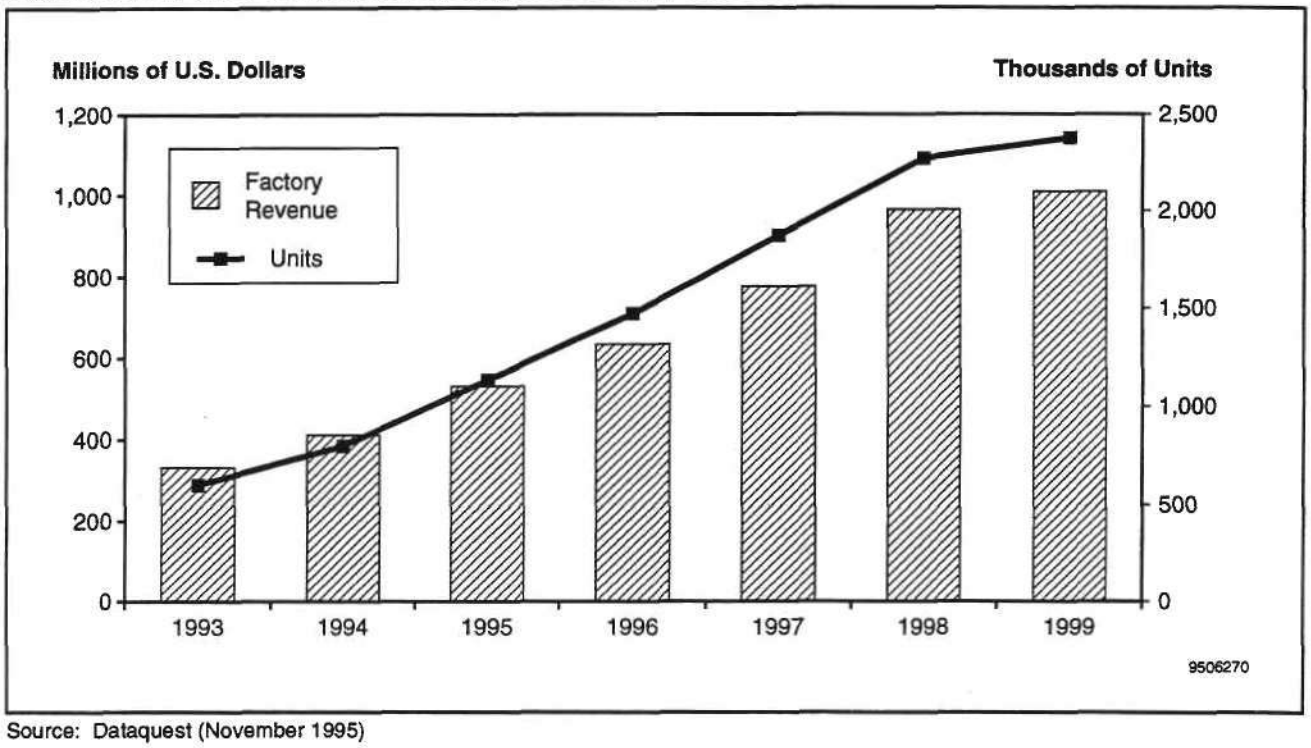
Source: Dataquest (November 1995)

Table 3-12
Asia/Pacific-ROW Facsimile Machine Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	33.0	41.8	30.0	27.1	21.2	4.6
Factory ASP	-6.9	-9.1	-8.0	-3.8	2.6	0
Factory Revenue	23.8	28.9	19.6	22.2	24.4	4.6
Semiconductor Content	-1.6	0.5	-1.3	0	0	0
Semiconductor TAM	30.9	42.5	28.3	27.1	21.2	4.6

Source: Dataquest (November 1995)

Figure 3-6
Asia/Pacific-ROW Facsimile Machine Production Forecast



Source: Dataquest (November 1995)

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Modem

Modems are another area where manufacturers in Taiwan will definitely continue their production dominance in Asia/Pacific throughout the decade. Taiwan aims to invigorate its data communications industry, part of its strategy to enhance its data processing foothold. We expect the V.34 (28,800 bps) to become the dominant standard replacing V.32 (14,400 bps) after 1998, driven by LAN interconnectivity, video telephones, facsimile transmissions, and large file transfer. Our forecast calls for regional production volume to nearly triple to 21 million units in 1999 (see Table 3-13, Table 3-14, and Figure 3-7).

Table 3-13
Asia/Pacific-ROW Modem Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	5,258	7,200	8,711	11,935	15,879	18,682	20,829	23.7
Factory ASP ($)	121	115	112	109	106	103	100	-2.8
Factory Revenue ($M)	636	828	976	1,301	1,683	1,924	2,081	20.2
Semiconductor Content ($)	31	30	29	29	29	28	27	-1.9
Semiconductor TAM ($M)	162	214	256	346	454	529	562	21.4

Source: Dataquest (November 1995)

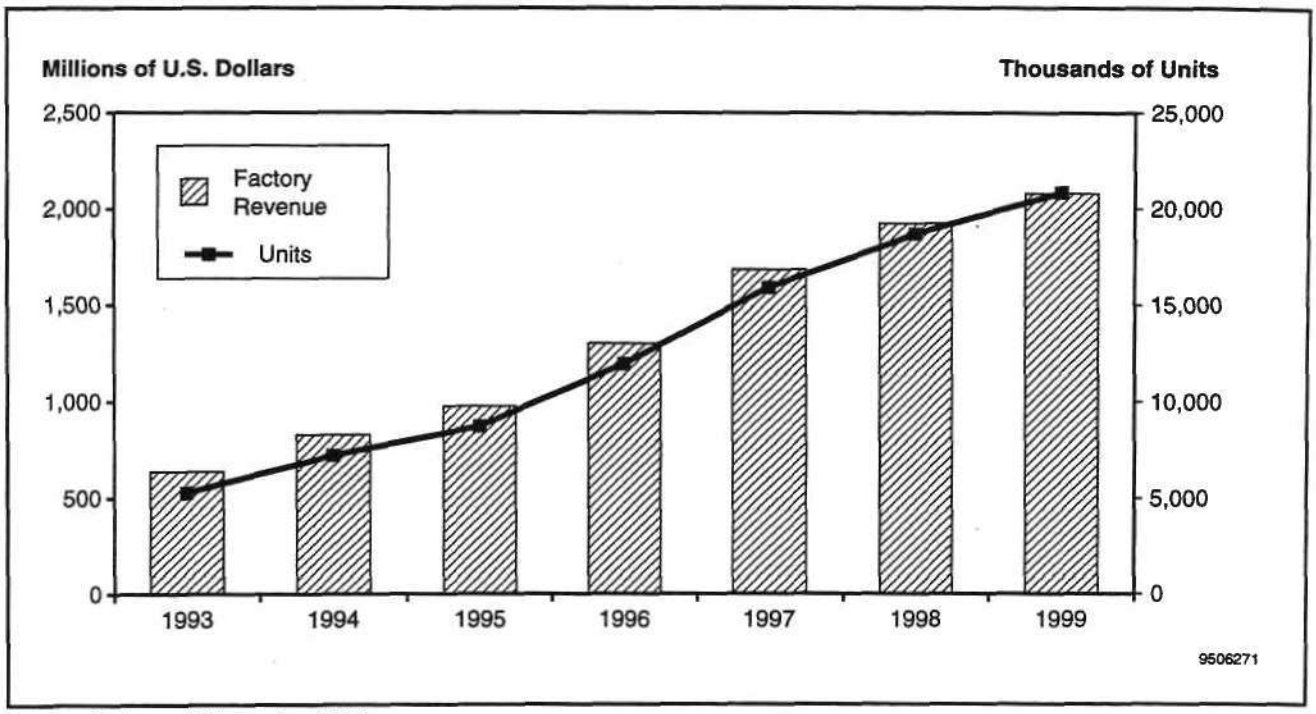
Table 3-14
Asia/Pacific-ROW Modem Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	36.9	21.0	37.0	33.0	17.6	11.5
Factory ASP	-5.0	-2.6	-2.7	-2.8	-2.8	-3.0
Factory Revenue	30.1	17.8	33.3	29.4	14.3	8.1
Semiconductor Content	-3.5	-1.1	-1.2	-1.3	-1.0	-4.7
Semiconductor TAM	32.2	19.7	35.4	31.3	16.4	6.3

Source: Dataquest (November 1995)

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Figure 3-7
Asia/Pacific-ROW Modem Production Forecast



Source: Dataquest (November 1995)

Cellular Telephone

Cellular telephones are the fastest-growing segment in our regional communications sector. The device is a logical progression from cordless telephones, allowing users an even higher degree of mobility and convenience. Dataquest anticipates the unit volume produced to catch up with that of the cordless telephones before the turn of this century. We project the unit volume production in Asia/Pacific to increase fivefold to 22 million units in 1999 (see Table 3-15, Table 3-16, and Figure 3-8). Market needs are dictating the need to design and build within the region as time-to-market increases in importance, coupled with decreasing labor content in the final product. Expect a transition from analog to digital because of enhancements in security, sound quality, and propagation capability. Semiconductor opportunities are the most promising in this whole category of communications, which include codec (coder/decoder) and interface, microcontroller (12 and 24 bits for cellular telephone), discrete, and EEPROM.

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Table 3-15
Asia/Pacific-ROW Cellular Telephone Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	2,325	4,322	5,634	7,430	9,849	14,323	21,983	38.4
Factory ASP ($)	427	367	318	281	245	220	210	-10.6
Factory Revenue ($M)	993	1,586	1,792	2,088	2,413	3,151	4,616	23.8
Semiconductor Content ($)	43	42	42	43	43	43	43	0.5
Semiconductor TAM ($M)	100	182	237	319	424	616	945	39.1

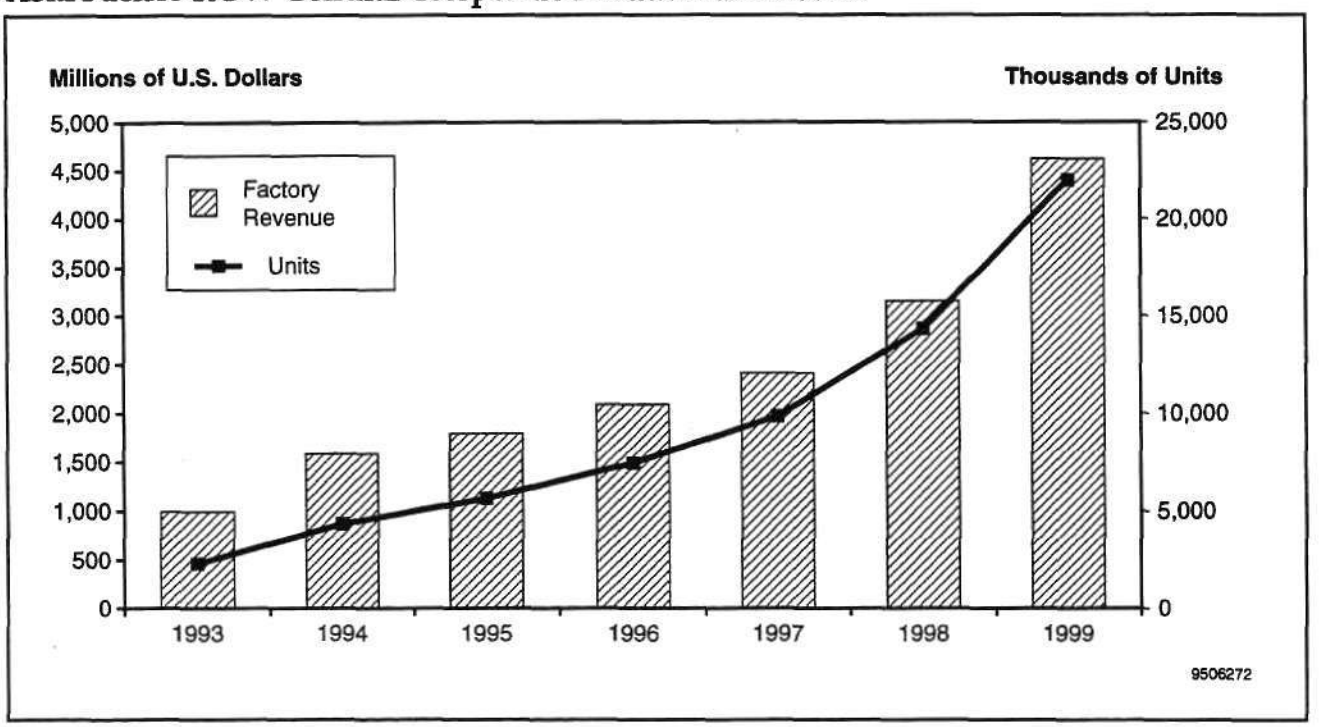
Source: Dataquest (November 1995)

Table 3-16
Asia/Pacific-ROW Cellular Telephone Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	85.9	30.4	31.9	32.6	45.4	53.5
Factory ASP	-14.1	-13.4	-11.6	-12.8	-10.2	-4.5
Factory Revenue	59.7	13.0	16.5	15.6	30.6	46.5
Semiconductor Content	-2.3	0	2.4	0	0	0
Semiconductor TAM	81.5	30.4	35.0	32.6	45.4	53.5

Source: Dataquest (November 1995)

Figure 3-8
Asia/Pacific-ROW Cellular Telephone Production Forecast



Source: Dataquest (November 1995)

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Pager

Pagers, which cried their first plain beep in the United States in the 1950s, are today more useful with their ability to transmit brief text messages. The title "King of Pagers" befits Motorola, which commands a lion's share in manufacturing these affordable mobile devices. Motorola's dedicated facility in Singapore continues to churn out large volumes, supplemented by the Chinese facility in Tianjin (which in turn will feed the Chinese market). Other manufacturers are the Japanese (NEC and Panasonic) and the Koreans (Hyundai and Lucky-Goldstar). We forecast the regional pager production to grow from 9 million units to 16 million units from 1994 to 1999 (see Table 3-17, Table 3-18, and Figure 3-9).

Table 3-17
Asia/Pacific-ROW Pager Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	4,560	9,016	10,850	12,335	13,176	14,445	16,140	12.4
Factory ASP ($)	81	77	74	74	71	71	71	-1.7
Factory Revenue ($M)	369	698	807	910	941	1,031	1,146	10.4
Semiconductor Content ($)	10	10	10	10	10	10	10	0.7
Semiconductor TAM ($M)	44	87	105	123	127	144	161	13.1

Source: Dataquest (November 1995)

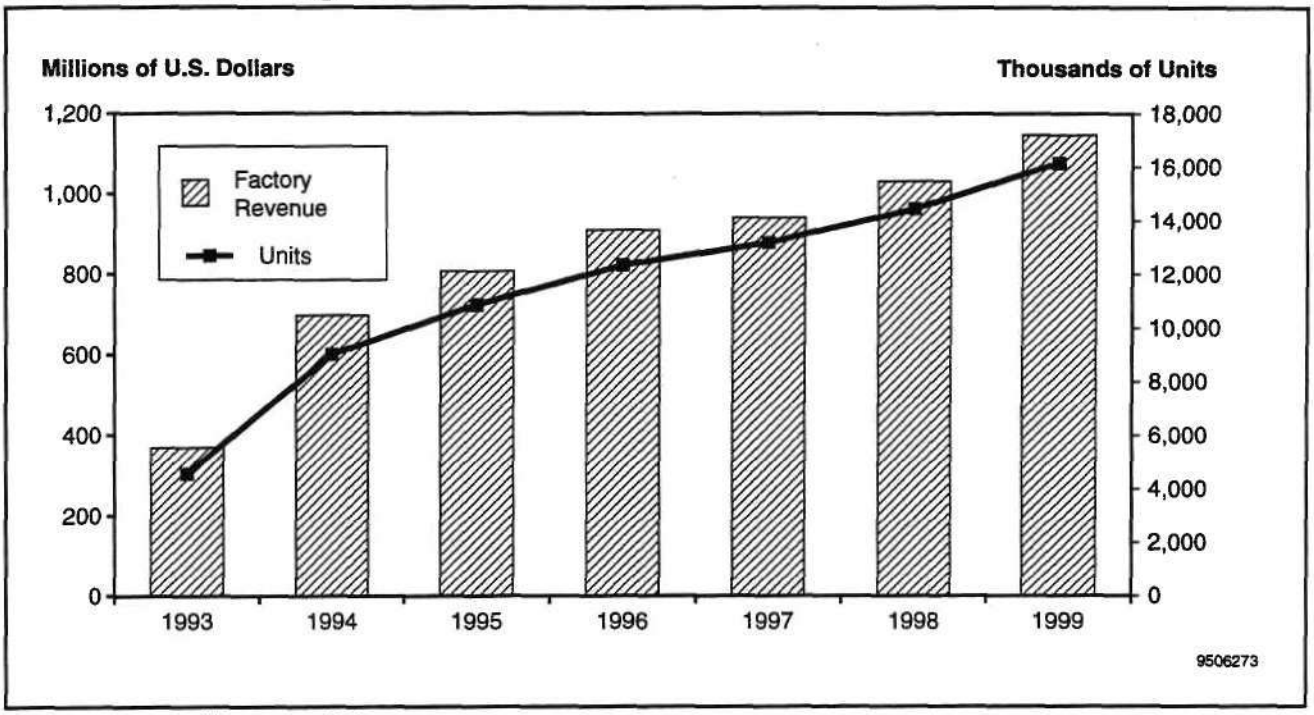
Table 3-18
Asia/Pacific-ROW Pager Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	97.7	20.3	13.7	6.8	9.6	11.7
Factory ASP	-4.4	-3.9	-0.8	-3.3	0	-0.6
Factory Revenue	88.9	15.7	12.8	3.4	9.6	11.1
Semiconductor Content	-0.5	0	3.0	-3.3	3.7	0
Semiconductor TAM	96.8	20.3	17.1	3.4	13.7	11.8

Source: Dataquest (November 1995)

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Figure 3-9
Asia/Pacific-ROW Pager Production Forecast



Source: Dataquest (November 1995)

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Chapter 4
Consumer Equipment

Consumer equipment covers the following products: personal/portable stereos, color televisions, videocassette recorders, camcorders, set-top boxes, video game controllers, and video game cartridges. Asia/Pacific has been the powerhouse in sheer unit count because of continued investments from and expansions by the pioneer Japanese and Europeans, and also by Taiwanese, Hong Kong, and Korean companies.

Personal/Portable Stereo

Personal and portable stereos constitute high-volume opportunities but low growth in revenue. Asia/Pacific represents the bulk of worldwide production share, estimated at 85 percent this year. This sector will see declines in the more mature markets of Taiwan and Singapore. The developing nations of Southeast Asia (notably the fastest-growing producer, Thailand, followed by the Philippines), however, will exhibit tremendous growth. Korea (from its indigenous companies) and Malaysia (from its Japanese and European companies) are two countries that will continue to dominate the manufacturing of stereos in Asia/Pacific. Table 4-1, Table 4-2, and Figure 4-1 represent our forecast of regional production growth of stereo systems.

Table 4-1
Asia/Pacific-ROW Personal/Portable Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	95,865	100,562	105,490	110,553	115,860	121,421	126,278	4.7
Factory ASP ($)	33	33	32	32	32	32	31	-0.7
Factory Revenue ($M)	3,116	3,268	3,376	3,538	3,708	3,885	3,960	3.9
Semiconductor Content ($)	7	7	6	6	6	6	6	-1.6
Semiconductor TAM ($M)	623	654	675	708	742	777	758	3.0

Source: Dataquest (November 1995)

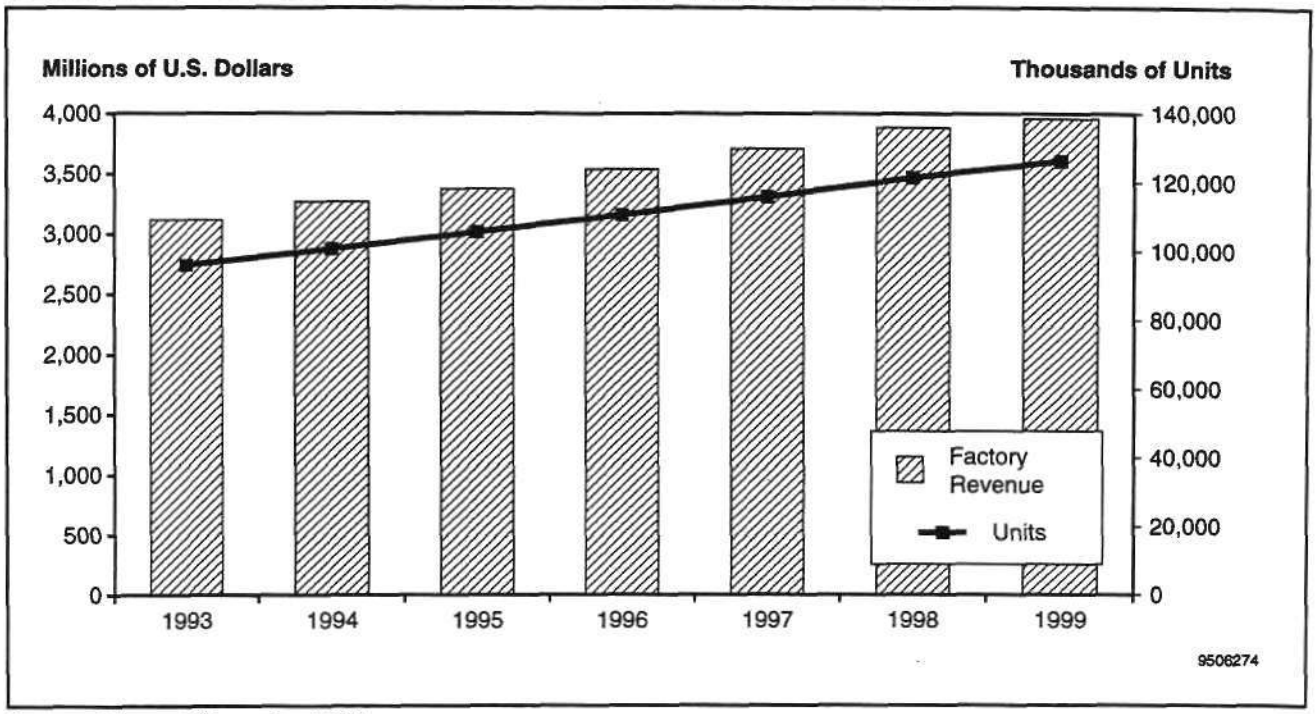
Table 4-2
Asia/Pacific-ROW Personal/Portable Stereo Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	4.9	4.9	4.8	4.8	4.8	4.0
Factory ASP	0	-1.5	0	0	0	-2.0
Factory Revenue	4.9	3.3	4.8	4.8	4.8	1.9
Semiconductor Content	0	-1.5	0	0	0	-6.3
Semiconductor TAM	4.9	3.3	4.8	4.8	4.8	-2.5

Source: Dataquest (November 1995)

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Figure 4-1
Asia/Pacific-ROW Personal/Portable Stereo Production Forecast



Source: Dataquest (November 1995)

Color Television

China will have the fastest growth rate in color televisions, given its cost-competitive labor and large potential appetite for this form of home entertainment. China's volume production is set to surpass leader Korea after 1997. Malaysia will remain the third-largest manufacturer of color televisions throughout the decade, thanks to the facilities of Japanese manufacturers (see also the following section on videocassette recorders). The trends in Asia/Pacific will still see more first-time purchases, while the more "advanced" markets will drive demand for next-generation products. Table 4-3, Table 4-4, and Figure 4-2 show our forecast of production of color televisions in Asia/Pacific.

Table 4-3
Asia/Pacific-ROW Color Television Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	51,639	57,855	64,855	72,701	80,799	89,798	96,084	10.7
Factory ASP ($)	148	149	154	156	160	164	167	2.3
Factory Revenue ($M)	7,618	8,649	9,957	11,374	12,937	14,727	16,073	13.2
Semiconductor Content ($)	13	13	13	14	14	14	15	2.6
Semiconductor TAM ($M)	653	743	857	982	1,119	1,275	1,405	13.6

Source: Dataquest (November 1995)

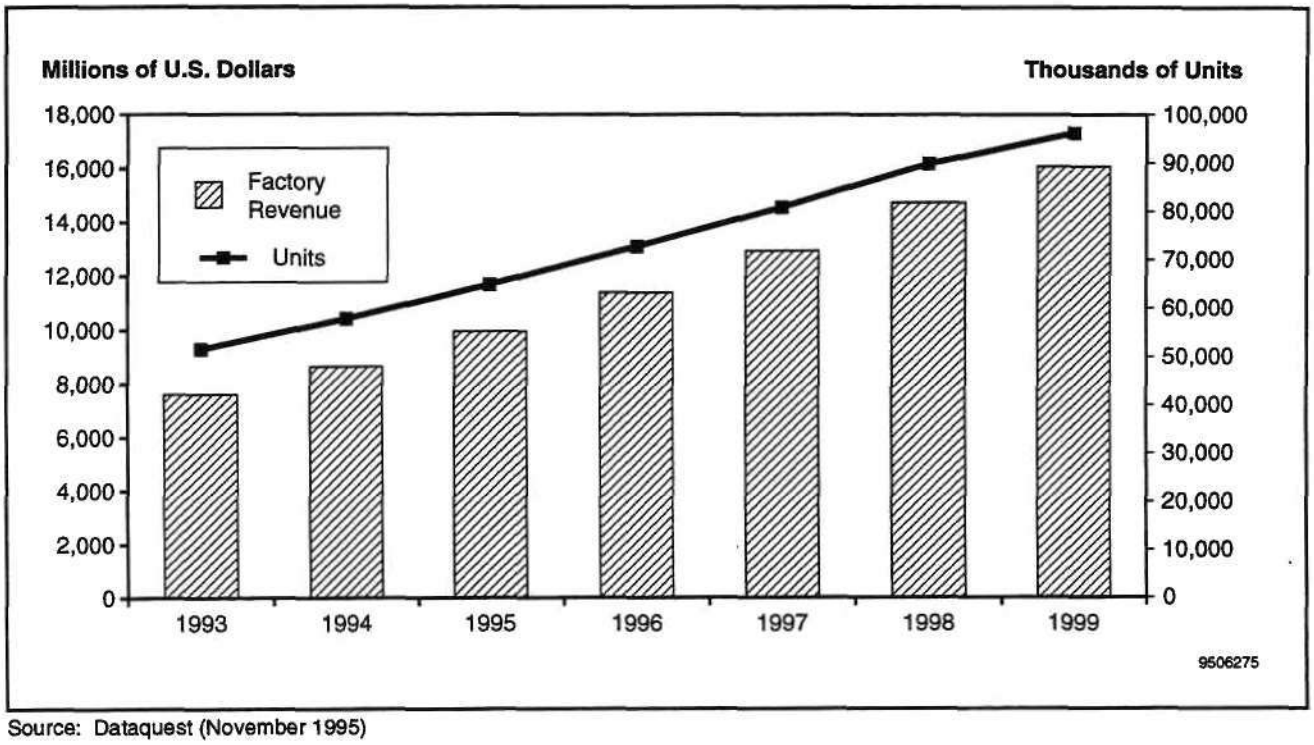
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Table 4-4
Asia/Pacific-ROW Color Television Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	12.0	12.1	12.1	11.1	11.1	7.0
Factory ASP	1.3	2.7	1.9	2.3	2.4	2.0
Factory Revenue	13.5	15.1	14.2	13.7	13.8	9.1
Semiconductor Content	1.6	2.9	2.1	2.6	2.5	3.0
Semiconductor TAM	13.8	15.4	14.5	14.0	14.0	10.2

Source: Dataquest (November 1995)

Figure 4-2
Asia/Pacific-ROW Color Television Production Forecast



Source: Dataquest (November 1995)

Videocassette Recorder

Most of the major manufacturers of color televisions also produce videocassette recorders, whose importance as an added feature of home entertainment to television owners is growing. Korea is the leader in manufacturing videocassette recorders, as in color televisions, dominated by the chaebols of Samsung, LG Electronics Group, and Daewoo, in that order of importance. Japan-based companies such as Sharp, Hitachi, and JVC continue to move production to Malaysia, making the country the No. 2 manufacturing base in Asia/Pacific. See Table 4-5, Table 4-6, and Figure 4-3 for our production projection of videocassette recorders in Asia/Pacific.

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Table 4-5
Asia/Pacific-ROW Videocassette Recorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	29,442	32,000	35,101	37,899	40,621	43,538	45,715	7.4
Factory ASP ($)	166	162	160	163	169	179	186	2.8
Factory Revenue ($M)	4,876	5,194	5,602	6,178	6,865	7,793	8,510	10.4
Semiconductor Content ($)	23	22	22	24	25	26	27	3.8
Semiconductor TAM ($M)	663	712	773	910	1,016	1,132	1,224	11.5

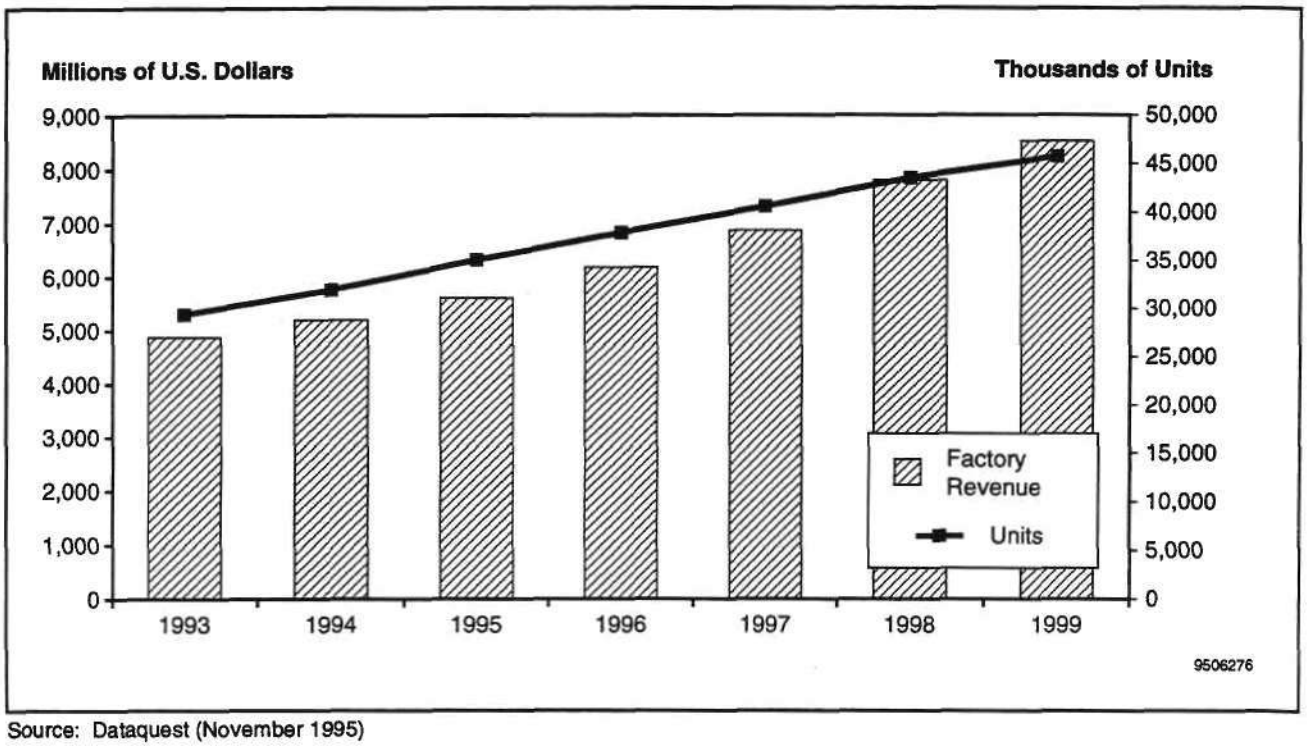
Source: Dataquest (November 1995)

Table 4-6
Asia/Pacific-ROW Videocassette Recorder Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	8.7	9.7	8.0	7.2	7.2	5.0
Factory ASP	-2.0	-1.7	2.1	3.7	5.9	4.0
Factory Revenue	6.5	7.9	10.3	11.1	13.5	9.2
Semiconductor Content	-1.3	-0.9	9.0	4.2	4.0	3.0
Semiconductor TAM	7.3	8.7	17.6	11.6	11.5	8.1

Source: Dataquest (November 1995)

Figure 4-3
Asia/Pacific-ROW Videocassette Recorder Production Forecast



Source: Dataquest (November 1995)

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Camcorder

Asia/Pacific did not begin producing camcorders until 1994. Japan is the primary production location, followed by Europe. Asia/Pacific jump-started production of camcorders as a result of the production shift from Japan. Because of Asia/Pacific's low manufacturing base, Dataquest perceives very healthy production growth rates. We forecast a CAGR of 60 percent to 1.4 million units in 1999 (see Table 4-7, Table 4-8, and Figure 4-4). This would particularly spell opportunities to suppliers of charge-coupled devices (optoelectronics).

Table 4-7
Asia/Pacific-ROW Camcorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	0	132	384	562	834	1,238	1,399	60.3
Factory ASP ($)	0	581	569	563	558	545	534	-1.7
Factory Revenue ($M)	0	77	218	317	465	675	747	57.7
Semiconductor Content ($)	0	109	107	105	103	101	99	-1.9
Semiconductor TAM ($M)	0	14	41	59	86	125	138	57.3

Source: Dataquest (November 1995)

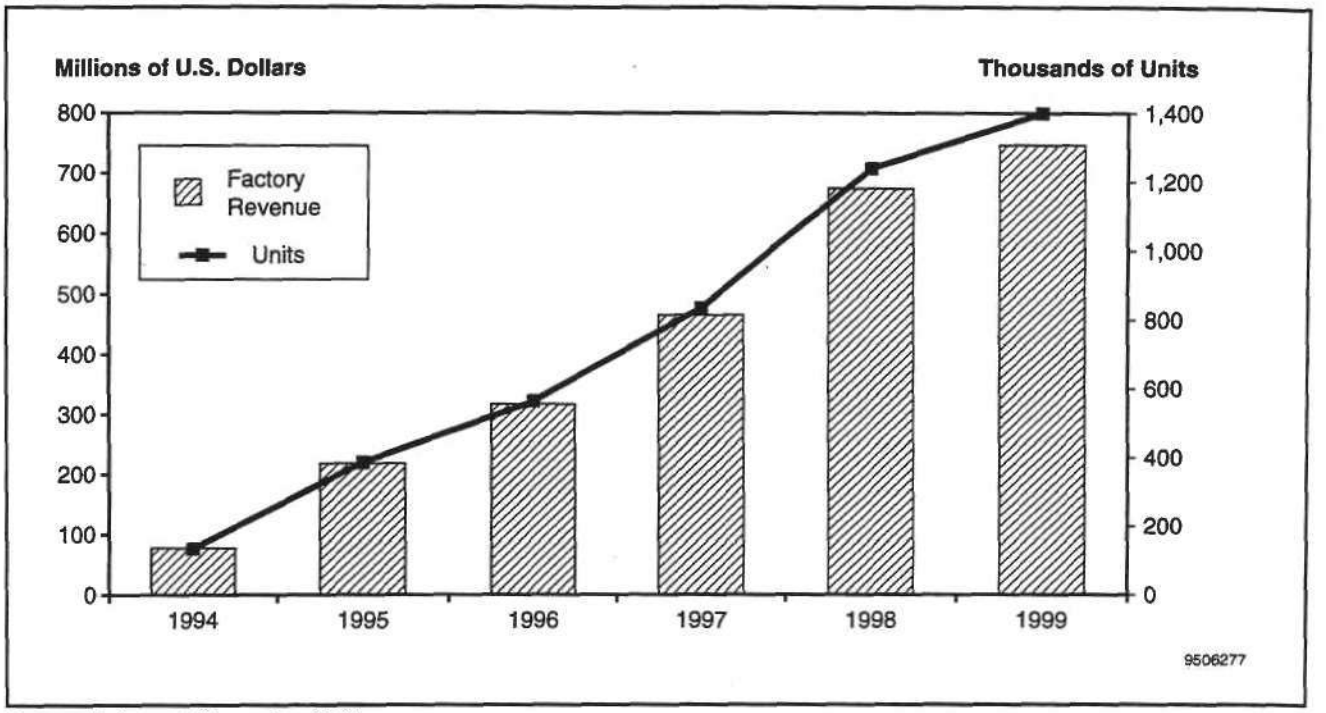
Table 4-8
Asia/Pacific-ROW Camcorder Production Forecast, Annual Growth (Percent)

	1995	1996	1997	1998	1999
Units	190.9	46.4	48.4	48.4	13.0
Factory ASP	-2.0	-1.0	-1.0	-2.3	-2.0
Factory Revenue	185.1	44.9	46.9	45.0	10.7
Semiconductor Content	-2.1	-1.1	-2.1	-2.1	-2.0
Semiconductor TAM	184.9	44.7	45.2	45.3	10.7

Source: Dataquest (November 1995)

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Figure 4-4
Asia/Pacific-ROW Camcorder Production Forecast



Source: Dataquest (November 1995)

Set-Top Box

Set-top boxes are cable television interface boxes used by consumers to receive and tune in cable TV programming. Set-top boxes represent an exciting add-on to television home owners, allowing flexible and convenient selection of programs. Asia/Pacific is joining North America and Europe in producing these devices, with General Instrument accounting for most production in Taiwan. We project Asia/Pacific's production of 16.5 percent CAGR over the next five years to 4.9 million units (see Table 4-9, Table 4-10, and Figure 4-5).

Table 4-9
Asia/Pacific-ROW Set-Top Box Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	2,001	2,278	2,778	3,300	3,833	4,380	4,896	16.5
Factory ASP ($)	125	145	175	189	196	183	164	2.6
Factory Revenue ($M)	249	329	485	622	751	803	803	19.5
Semiconductor Content ($)	34	43	63	72	80	79	76	12.0
Semiconductor TAM ($M)	68	98	175	238	307	347	372	30.5

Source: Dataquest (November 1995)

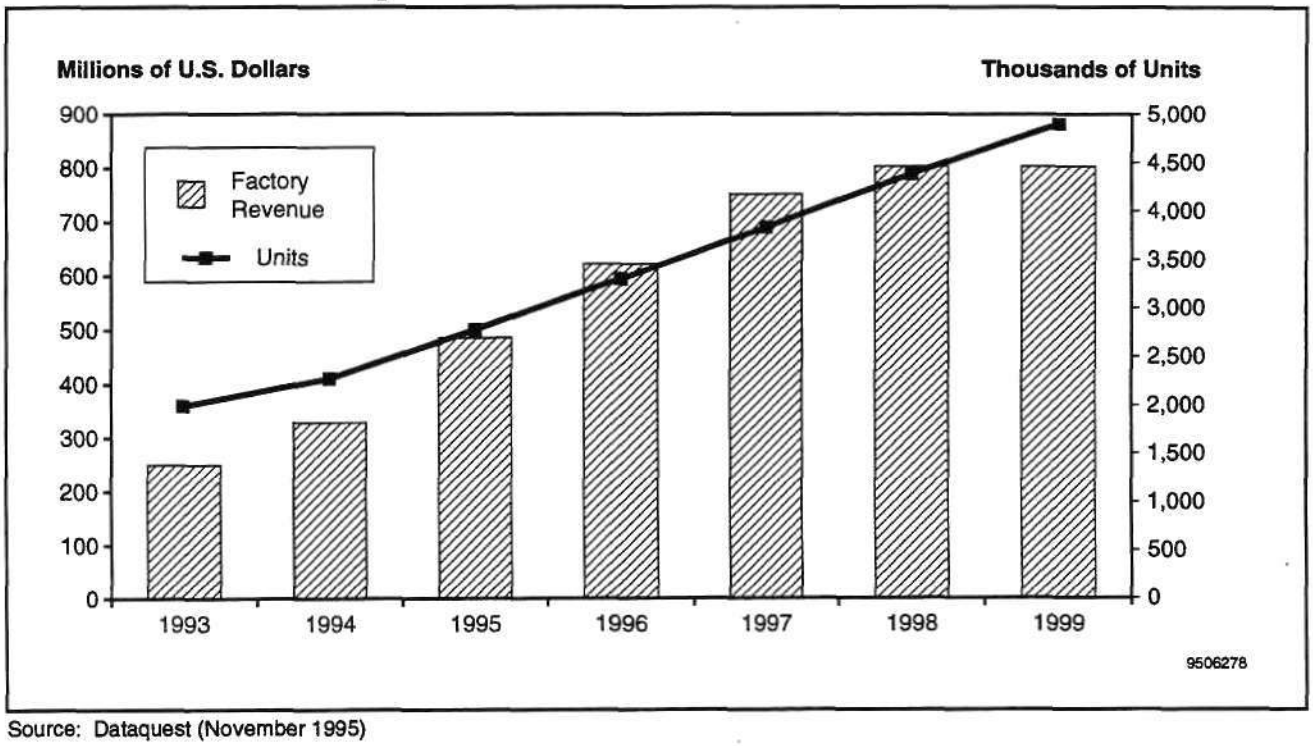
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Table 4-10
Asia/Pacific-ROW Set-Top Box Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	13.8	21.9	18.8	16.2	14.3	11.8
Factory ASP	16.1	20.8	8.0	3.9	-6.4	-10.6
Factory Revenue	32.1	47.3	28.3	20.7	6.9	0
Semiconductor Content	27.7	45.8	14.4	11.3	-1.4	-3.9
Semiconductor TAM	45.3	77.8	35.9	29.2	12.7	7.4

Source: Dataquest (November 1995)

Figure 4-5
Asia/Pacific-ROW Set-Top Box Production Forecast



Source: Dataquest (November 1995)

Video Game Controller and Video Game Cartridge

Video games are very popular in North America, and the remaining regions are catching the home entertainment fever. Sega and Nintendo are actively contracting manufacturing of these high-growth game devices to manufacturers in Asia/Pacific to escape the high yen value. Other manufacturers are found in Hong Kong and other Eastern Asia. See Table 4-11, Table 4-12, and Figure 4-6 for video game controller production projection, and Table 4-13, Table 4-14, and Figure 4-7 for video game cartridge production forecasts.

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Table 4-11
Asia/Pacific-ROW Video Game Controller Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	4,688	3,852	3,945	6,726	8,565	10,790	12,914	27.4
Factory ASP ($)	85	97	142	178	220	231	200	15.6
Factory Revenue ($M)	398	374	560	1,197	1,884	2,492	2,583	47.2
Semiconductor Content ($)	32	41	80	105	140	155	135	27.1
Semiconductor TAM ($M)	151	157	316	706	1,197	1,672	1,743	61.8

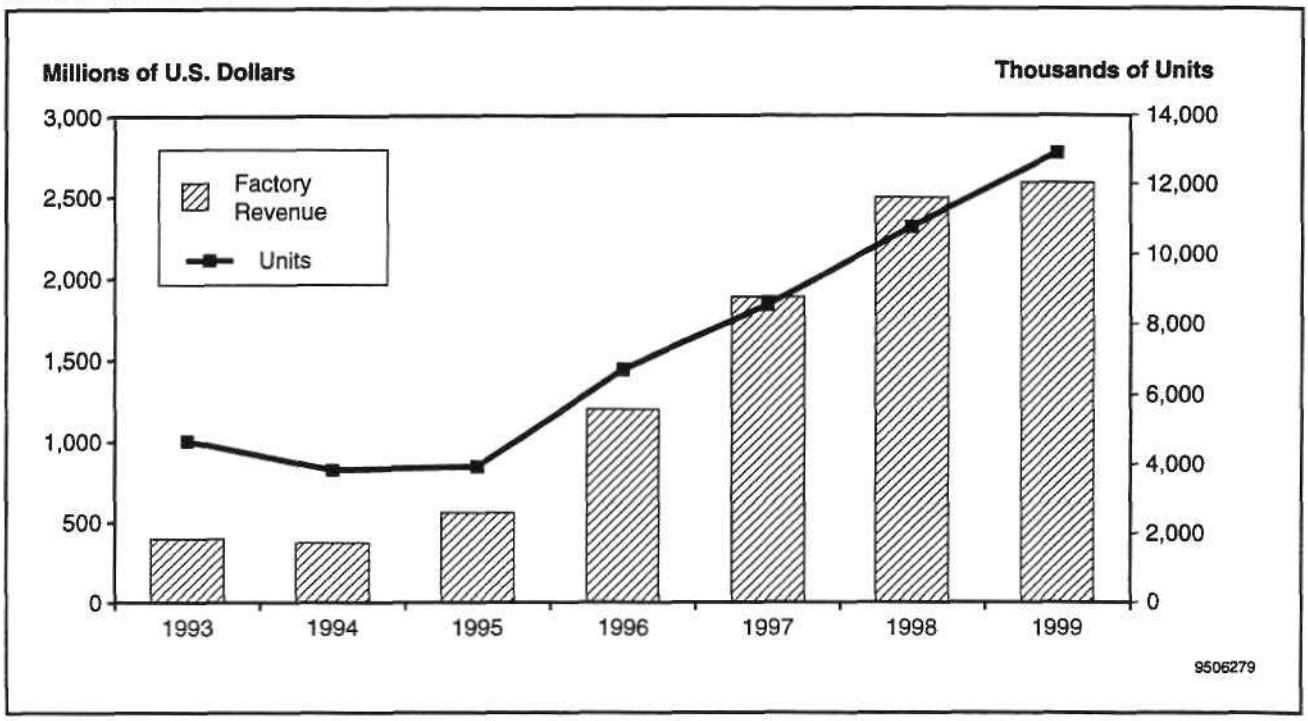
Source: Dataquest (November 1995)

Table 4-12
Asia/Pacific-ROW Video Game Controller Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	-17.8	2.4	70.5	27.3	26.0	19.7
Factory ASP	14.1	46.4	25.4	23.6	5.0	-13.4
Factory Revenue	-6.2	49.9	113.7	57.4	32.3	3.6
Semiconductor Content	26.9	96.3	31.3	33.1	10.9	-12.9
Semiconductor TAM	4.2	101.0	123.8	69.5	39.7	4.2

Source: Dataquest (November 1995)

Figure 4-6
Asia/Pacific-ROW Video Game Controller Production Forecast



Source: Dataquest (November 1995)

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Table 4-13
Asia/Pacific-ROW Video Game Cartridge Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	4,219	14,587	72,766	78,444	84,932	102,691	139,169	57.0
Factory ASP ($)	25	22	24	27	28	32	33	7.9
Factory Revenue ($M)	106	328	1,752	2,115	2,416	3,247	4,570	69.4
Semiconductor Content ($)	9	8	9	10	10	11	11	5.3
Semiconductor TAM ($M)	38	123	624	747	881	1,086	1,517	65.4

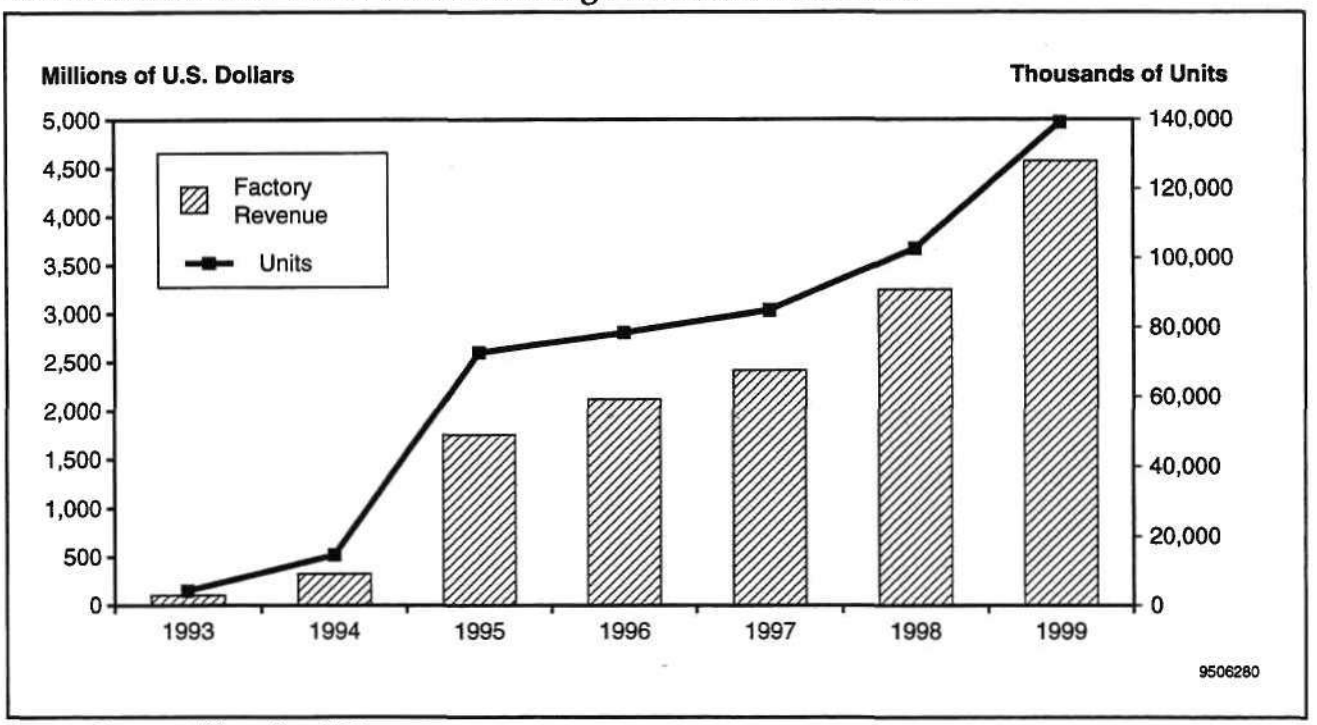
Source: Dataquest (November 1995)

Table 4-14
Asia/Pacific-ROW Video Game Cartridge Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	245.7	398.8	7.8	8.3	20.9	35.5
Factory ASP	-10.8	7.1	12.0	5.5	11.1	3.8
Factory Revenue	208.4	434.3	20.7	14.3	34.4	40.7
Semiconductor Content	-5.6	2.1	11.0	8.9	2.0	3.0
Semiconductor TAM	226.3	409.5	19.6	17.9	23.4	39.6

Source: Dataquest (November 1995)

Figure 4-7
Asia/Pacific-ROW Video Game Cartridge Production Forecast



Source: Dataquest (November 1995)

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Chapter 5
Transportation

This chapter covers automotive stereo and automotive electronic control units. Asia/Pacific automotive manufacturing is dominated by the Koreans such as giant Hyundai, Kia, and Daewoo, while Malaysian automotive manufacturer Proton is also ramping up production volumes. Most of the major automobile manufacturers have announced plans to manufacture or are already manufacturing via joint ventures in China, which is projected to be the world's single-largest automotive market.

Automotive Stereo

Malaysia is again the largest manufacturer of automotive stereo in Southeast Asia, given the presence of German-based Robert Bosch and Japanese companies such as Trio-Kenwood and Clarion. Automotive stereos are following the trend of home stereo equipment toward digital format, thereby bringing quality audio performance to automobile users. Production of automotive stereo will rise from 11 million units in 1994 to 18.4 million units in 1999 (see Table 5-1, Table 5-2, and Figure 5-1).

Table 5-1
Asia/Pacific-ROW Automotive Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	10,000	11,000	12,400	14,200	15,900	17,400	18,400	10.8
Factory ASP ($)	95	102	108	112	115	118	122	3.6
Factory Revenue ($M)	950	1,122	1,339	1,590	1,829	2,053	2,245	14.9
Semiconductor Content ($)	18	17	17	17	16	17	17	0
Semiconductor TAM ($M)	180	187	211	241	254	296	313	10.8

Source: Dataquest (November 1995)

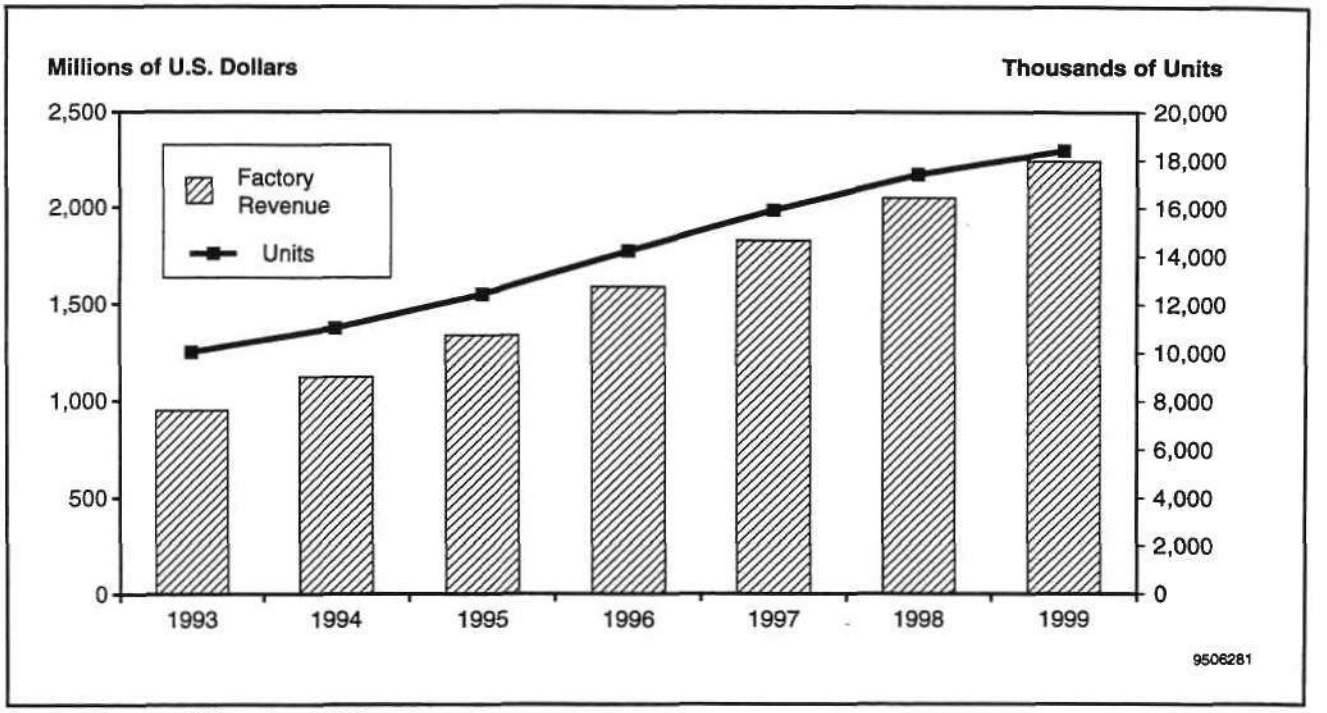
Table 5-2
Asia/Pacific-ROW Automotive Stereo Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	10.0	12.7	14.5	12.0	9.4	5.7
Factory ASP	7.4	5.9	3.7	2.7	2.6	3.4
Factory Revenue	18.1	19.4	18.8	15.0	12.3	9.3
Semiconductor Content	-5.6	0	0	-5.9	6.3	0
Semiconductor TAM	3.9	12.7	14.5	5.4	16.3	5.7

Source: Dataquest (November 1995)

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Figure 5-1
Asia/Pacific-ROW Automotive Stereo Production Forecast



Source: Dataquest (November 1995)

Automotive Electronic Control Unit

Employment of electronic control units will be more pervasive with the increasing trend toward integrating automotive control functions. Electronic control units will experience continuous improvement. The growth was first driven by the oil crisis in the 1970s, then by safety and environmental concerns in the 1980s and 1990s. The number of locally produced electronic control units will not be sufficient to feed the rapid growth in automotive assembly in the region, given the enormous opportunity offered by China. Delco Electronics in Singapore and Hyundai in Korea produce some of these control units. Semiconductor opportunities exist for suppliers of controllers, ASICs, power devices, hybrid devices, and sensors. Table 5-3, Table 5-4, and Figure 5-2 show our optimistic forecast of automotive electronic control unit production in Asia/Pacific.

Table 5-3
Asia/Pacific-ROW Automotive Control Unit Production Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	1,600	1,750	1,900	2,150	2,400	2,700	3,100	12.1
Factory ASP ($)	58	56	56	55	54	54	54	-0.9
Factory Revenue ($M)	92	99	106	117	129	146	167	11.1
Semiconductor Content ($)	24	24	24	25	25	26	26	1.6
Semiconductor TAM ($M)	38	42	46	54	60	70	81	13.9

Source: Dataquest (November 1995)

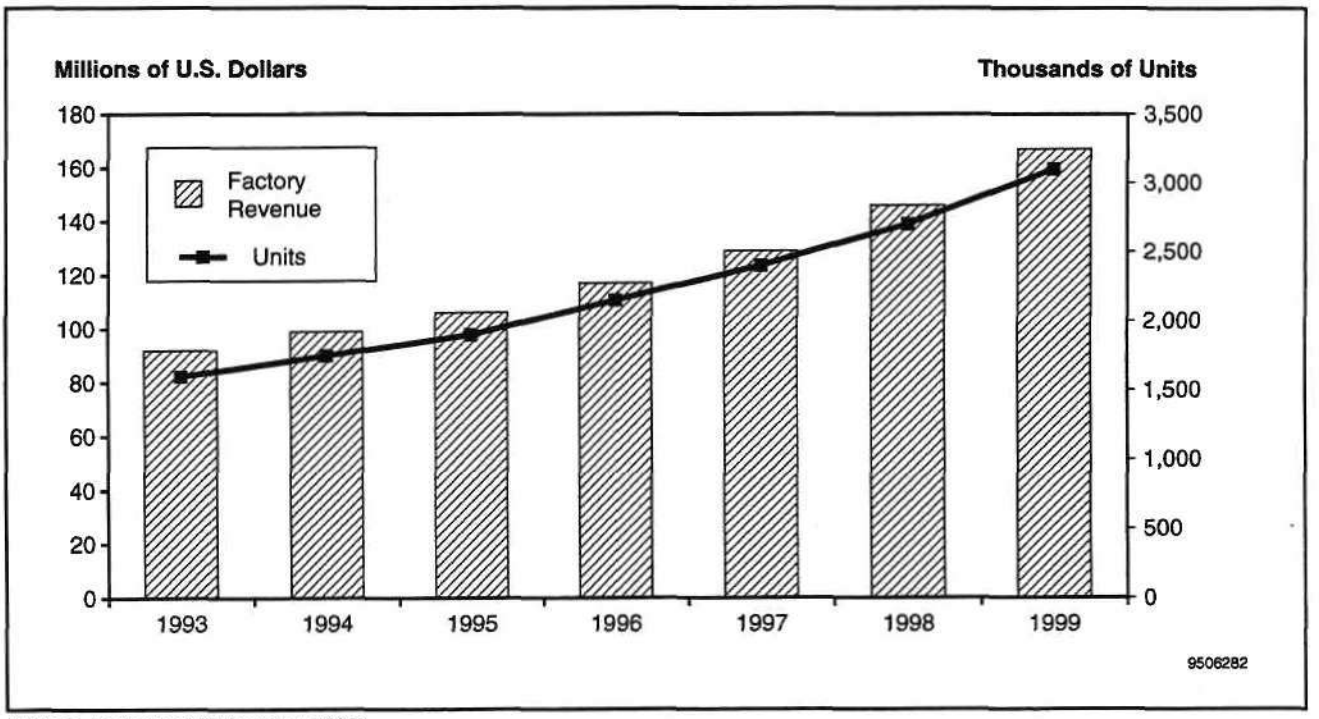
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Table 5-4
Asia/Pacific-ROW Automotive Control Unit Production Forecast, Annual Growth (Percent)

	1994	1995	1996	1997	1998	1999
Units	9.4	8.6	13.2	11.6	12.5	14.8
Factory ASP	-2.2	-1.0	-2.3	-1.8	1.1	-0.3
Factory Revenue	7.0	7.5	10.6	9.6	13.7	14.4
Semiconductor Content	0	0	4.2	0	4.0	0
Semiconductor TAM	9.4	8.6	17.9	11.6	17.0	14.8

Source: Dataquest (November 1995)

Figure 5-2
Asia/Pacific-ROW Automotive Control Unit Production Forecast



Source: Dataquest (November 1995)

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Chapter 6
Dataquest Perspective

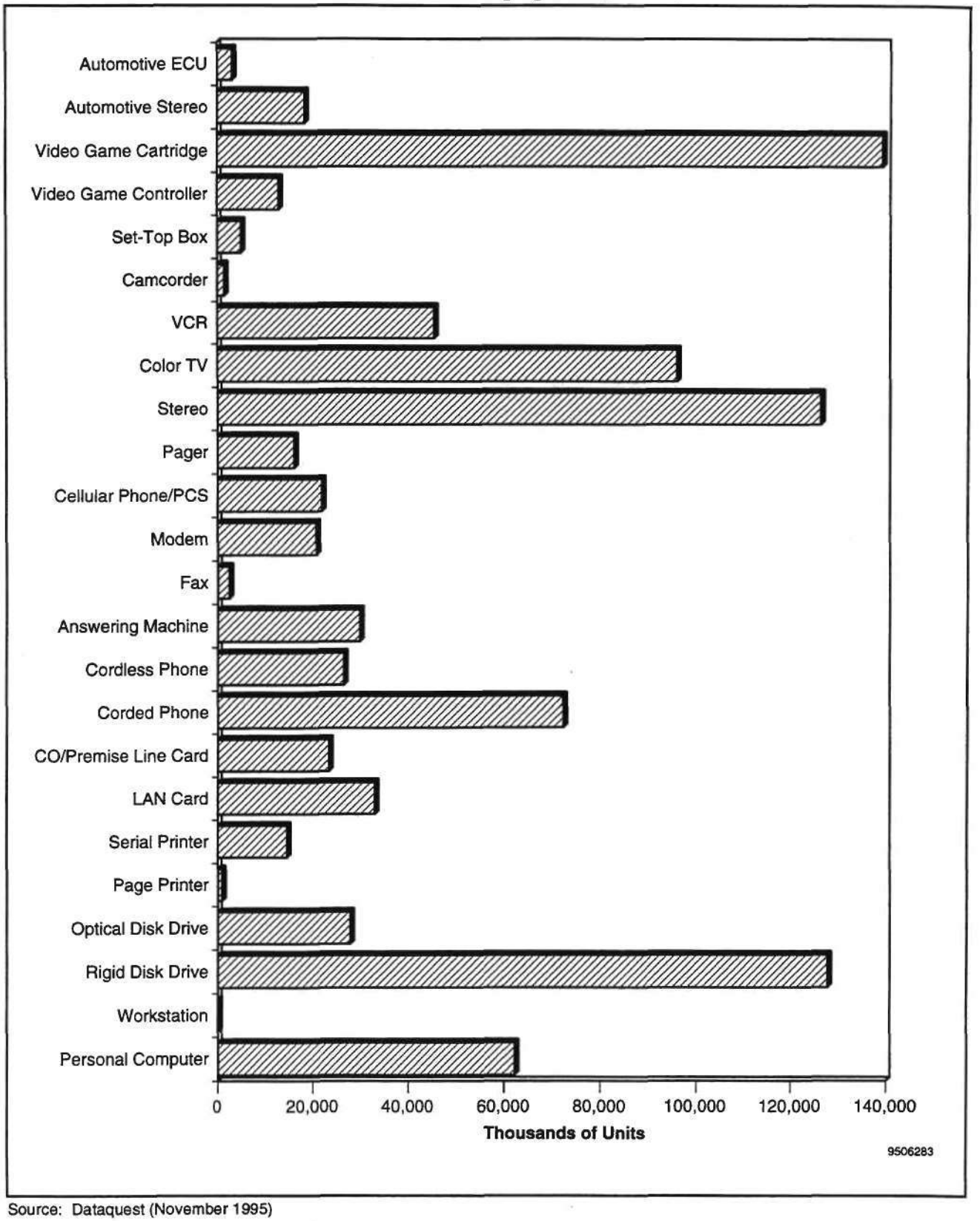
Vast opportunities await semiconductor suppliers in this region. Asia/Pacific's unit production of over 50 percent worldwide share includes video game controllers, personal/portable stereos, answering machines, rigid disk drives, modems, videocassette recorders, corded telephones, optical disk drives, color televisions, LAN cards, PCs, and cordless telephones.

Figure 6-1 shows our 1999 projection of unit volumes for all 24 electronic equipment segments we track. Video game cartridges and rigid disk drives are the top two largest equipment segments assembled in Asia/Pacific in terms of unit volume, surpassing stereo systems (which will be No. 3 in 1999). Color televisions and corded telephones will maintain their volume manufacturing lead, while there will be more PCs assembled than videocassette recorders.

Figure 6-2 shows that PCs remain the largest semiconductor market in Asia/Pacific. In addition to rigid disk drives, semiconductor opportunities are quickly opening to both video game controllers and cartridges. Based on our 1994-to-1999 CAGR expectations of the total application market, the following products represent the fastest-growth opportunities for semiconductor suppliers: video game cartridges (65 percent), video game controllers (62 percent), camcorders (57 percent), cellular telephones (39 percent), PCs (35 percent), and set-top boxes (30 percent).

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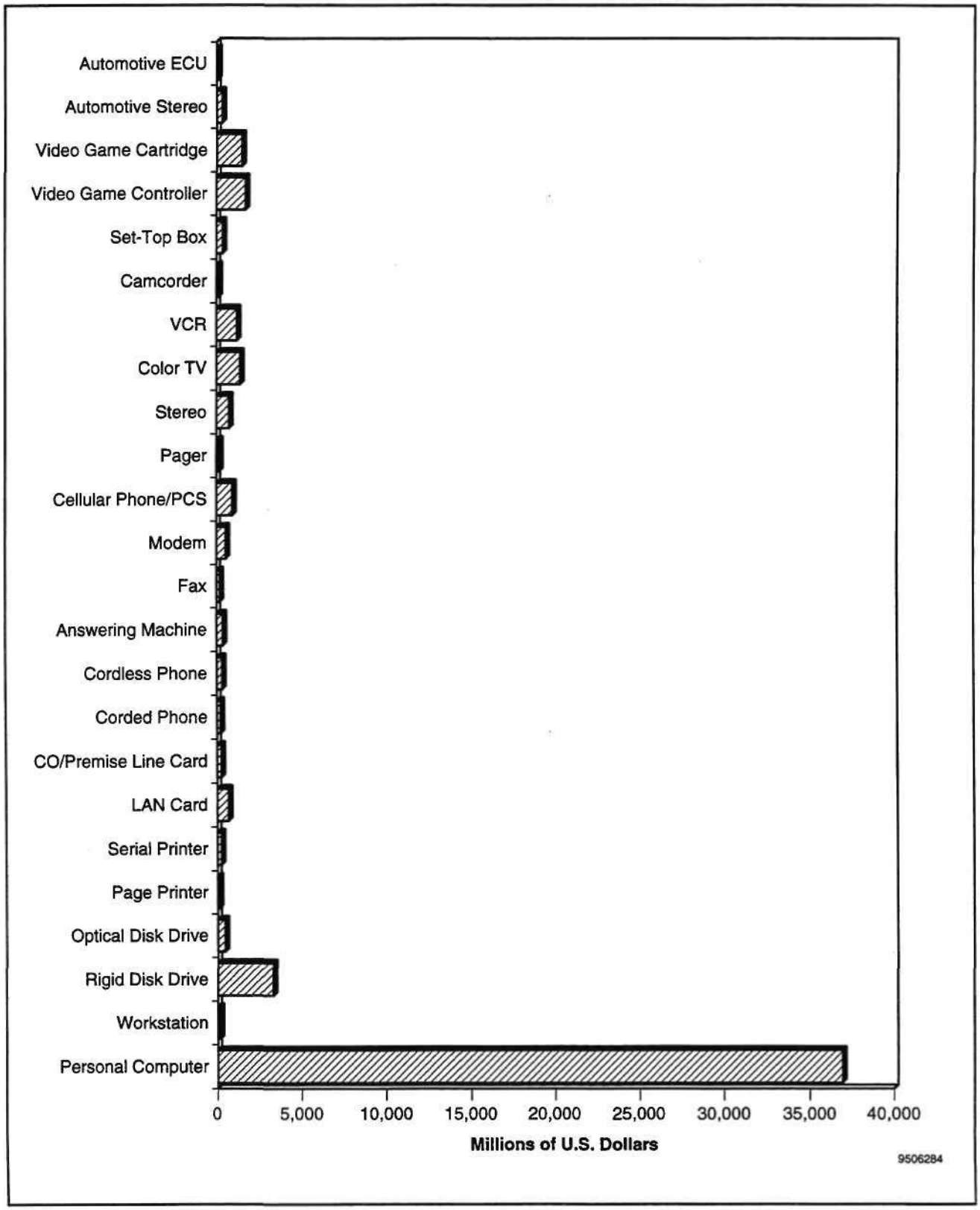
Figure 6-1
Asia/Pacific-ROW Production of Electronic Equipment, 1999 (Thousands of Units)



Source: Dataquest (November 1995)

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Figure 6-2
Asia/Pacific-ROW Semiconductor Consumption by Application, 1999
(Thousands of Units)



Source: Dataquest (November 1995)

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Market Analysis



Semiconductors Asia/Pacific

Market Analysis

Taiwanese Semiconductor Industry Update: Continued Strong Growth in Fabs

Abstract: *This document presents a fresh update of the manufacturing capacities and the development of Taiwan's semiconductor industry in 1995. Tremendous demand for semiconductors in the past three years has driven the industry to new records in both sales revenue and capital spending. Taiwanese manufacturers appear to have moved toward the more profitable areas of memory manufacturing and dedicated foundries. Along with expansion from all existing and new manufacturers, Taiwan is also attracting silicon suppliers that want to manufacture on the island. We believe Taiwan will continue to play a dominant role as a provider of dedicated foundries. Taiwan is aiming to develop its semiconductor industry in a manner similar to the way it successfully pushed its PC manufacturing to great global heights.*
By Ben F.P. Lee

Fab Fever Lasts Throughout the Year

In 1995, the Taiwanese semiconductor industry will perform much better than we had forecast earlier this year in our document, "Taiwanese Semiconductor Industry Update: Fab Fever!" (SEMI-AP-MA-9504, dated May 29, 1995). Sales revenue is expected to reach a record high of $4.2 billion in 1995 and experience a one-year growth rate of 79.6 percent. We expect the industry to expand rapidly with a compound annual growth rate (CAGR) of 69.5 percent from 1992 to 1995. The top six manufacturers – Taiwan Semiconductor Manufacturing Corporation (TSMC), United Microelectronics Corporation (UMC), Winbond, TI-Acer, Mosel-Vitelic, and Macronix – are expected to corner 90 percent of the total sales revenue in 1995. Further, we expect capital spending to reach $3 billion this year, another record.

Dataquest

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From 1995 to 1997, at least 13 new 8-inch fabs are expected to begin operations as dedicated foundries or as production houses for predominantly memory and, to a lesser extent, other devices.

There will also likely be five new fabs for DRAM manufacturing by late 1996 constructed by the following companies: Vanguard, TI-Acer, Nan-Ya, Powerchip, and Mosel-Vitelic. Vanguard, TI-Acer, and Mosel-Vitelic will each open an additional DRAM manufacturing fab this year. Powerchip and Nan-Ya are expected to follow suit in late 1996.

Dedicated foundry is a sector of the semiconductor business that has been attracting enormous investments following the success of TSMC. UMC, emulating the achievements of TSMC, is aggressively diversifying into the pure foundry business. UMC recently signed two joint-venture agreements with several U.S.-based fabless companies, and it is ready to announce a third joint-venture next month. UMC has shown its ambition to become the leading semiconductor company in Taiwan. The Asian Semiconductor Manufacturing Company (ASMC) is another company that has announced plans to set up a dedicated foundry in Taiwan. It is awaiting approval to construct a facility in Hsinchu Science Park. Moreover, Winbond, Macronix, Holtek, and UMC are also expanding their own existing wafer fabs this year.

Table 1 shows details of the wafer fab parameters. Almost every semiconductor manufacturer has plans to produce its own new 8-inch wafers. All manufacturers are maximizing their existing facilities in response to the consistently high demand for semiconductors. The monthly fab capacity forecast is shown in Table 2.

Sales Performance and Forecast

In this section, we characterize the semiconductor industry's revenue by three general categories: brand-name production (brand-name shipments to merchant and captive users), fabless (pure design house), and foundry/OEM (production for other semiconductor companies). For the purpose of this analysis, we incorporate Taiwan's only OEM supplier, TI-Acer, in our total foundry number. Notably, TSMC accounts for the market's highest share. Figure 1 summarizes the results of our recent survey of the Taiwanese industry and details the breakdown of brand-name, fabless, and foundry revenue as a means of assessing future company directions.

Revenue from foundry/OEM (products sold for a client company under that designer's brand name) will likely grow from $1.3 billion in 1994 to $1.9 billion in 1995 (48.7 percent growth). TSMC and TI-Acer are the main suppliers in this category. Expansion of these two companies, coupled with the entrance of newcomers (mainly UMC), will support continued high growth in the foundry/OEM. The $1.2 billion brand-name category is expected to double by the end of 1995 to $2.3 billion, with mass production from Mosel-Vitelic and Vanguard significantly contributing to this growth. Major suppliers such as UMC and Winbond are also expected to perform well this year. Sales revenue of design houses is expected to remain at a modest 20 percent growth, with system core logic and memory as the major products.

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Table 1
Current and Planned Wafer Fabs in Taiwan, Start Date, Capabilities, and Products

Company	Fab Name	Start	Process	Linewidth (µm)	Wafer Size (Inches)	Wafers (Units / Month)	Type	Cleanroom Class	Main Products
TSMC	Fab 1	1987	CMOS, BiCMOS	1.2	6	16,000	F	10	Memory, microcomponent, logic, analog
TSMC	Fab 2-A	1990	CMOS	0.8	6	37,500	F	1	Logic (foundry)
TSMC	Fab 2-B	1992	CMOS	0.7	6	37,500	F	1	Memory (foundry)
TSMC	Fab 3	1995	CMOS	0.35	8	30,000	F	1	Foundry
TSMC	Fab 4	1997	CMOS	0.25	8	25,000	F	1	Foundry
TSMC	Fab 5	1998	CMOS	0.25	8	25,000	F	1	Foundry
Nan-Ya	Fab 1	1996	CMOS	0.45	8	20,000	M	1	16Mb DRAM
UMC*	Fab 1	1/82	CMOS, NMOS	0.8/1	4	50,000	M	10	Consumer ICs
UMC	Fab 2	7/89	CMOS	0.5	6	45,000	M	1	PC chipsets, I/O, SRAM, ROM, CPU
UMC	Fab 3	1995	CMOS	0.35	8	25,000	M	1	CPU, SRAM, chipset, system-on-chip
Vanguard	Fab 1a	12/94	CMOS	0.5/0.4	8	14,000	M	1	Memory
Vanguard	Fab 1b	10/96	CMOS	0.4/0.3	8	18,000	M	1	Memory
Episil	Fab 1	3/86	EPI	NA	3-6	7,200	F	10	EPI wafer for mode transistor and IC use
Episil	Fab 2	10/91	Bipolar	5	5	6,000	F	10	Bipolar IC, power transistor
Mosel-Vitelic	Fab 1	2/95	CMOS	0.47	6	30,000	M	1	DRAM (graphics, standard)
Mosel-Vitelic	Fab 2	12/96	CMOS	0.4	8	25,000	M	1	DRAM, SRAM
TI-Acer	Fab 1a	7/91	CMOS	0.45	6	20,000	C	1	4Mb DRAM
TI-Acer	Fab 1b	7/95	CMOS	0.45	8	15,000	C	1	4/16 Mb DRAM
TI-Acer	Fab 2a	7/97	CMOS	0.35	8	20,000	C	1	DRAM
TI-Acer	Fab 2b	7/98	CMOS	0.3	8	20,000	C	1	DRAM
Winbond	Fab 1	10/88	CMOS	0.8	5	22,000	M	10	Telecommunications, dialer, speech
Winbond	Fab 2	9/92	CMOS	0.5	6	35,000	M	1	SRAM, flash, microcomponents

(Continued)

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Table 1 (Continued)
Current and Planned Wafer Fabs in Taiwan, Start Date, Capabilities, and Products

Company	Fab Name	Start	Process	Linewidth (µm)	Wafer Size (Inches)	Wafers (Units / Month)	Type	Cleanroom Class	Main Products
Winbond	Fab 3	1997	CMOS	0.35	8	40,000	M	1	Memory, microcomponents
HMC	Fab 1	6/88	CMOS	0.8	5	26,000	M	10	Telecommunications, consumer IC
HMC	Fab 1 exp.	10/94	CMOS	0.6	5	12,000	M	1	ROM, SRAM
HMC	Fab 2	6/96	CMOS	0.5	8	15,000	M	1	SRAM
Holtek	Fab 1	1/91	CMOS	1.2	5	30,000	M	10	PC peripheral, telecommunications, consumer IC, microcontroller
Holtek	Fab 2	6/98	CMOS	0.35	8	25,000	M	1	PC peripheral, microcontroller
Macronix	Fab 1	1994	CMOS	0.45	6	28,000	M	1	Nonvolatile memory, telecommunications IC
Macronix	Fab 2	1997	CMOS	0.35	8	40,000	M	1	Nonvolatile memory, telecommunications IC, system IC
Powerchip	Fab 1	6/96	CMOS	0.4	8	25,000	M	1	DRAM

Notes: M = Merchant, F = Foundry, C = Captive
NA = Not applicable
*Excludes the new dedicated foundry fabs announced recently by UMC
Source: Dataquest (October 1995)

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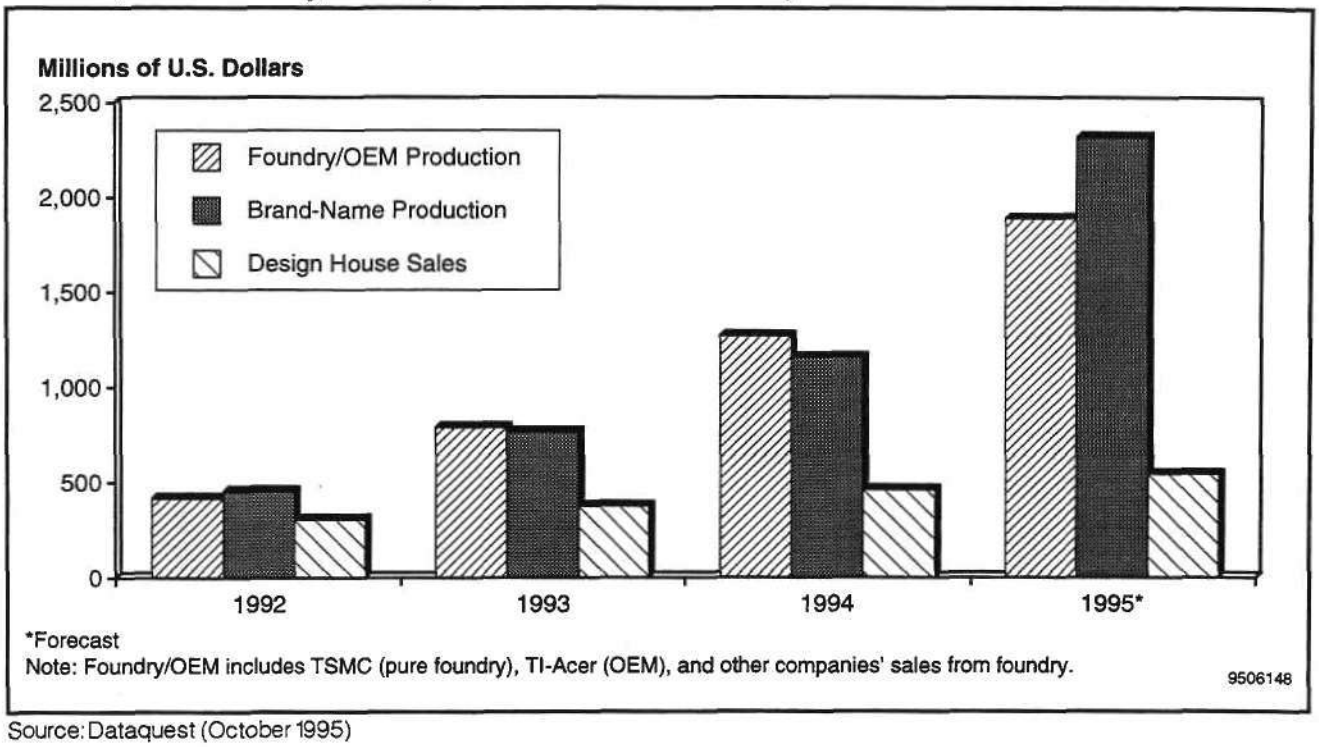
Table 2
Taiwanese Semiconductor for Monthly Fab Capacity and Linewidth Forecast

			1994		1995		1996		1997		1998		1999	
Company	Fab Name	Wafer Size (Inches)	Monthly Capacity (K)	Line-width (µm)	Monthly Capacity (K)	Line-width (µm)	Monthly Capacity (K)	Line-width (µm)	Monthly Capacity (K)	Line-width (µm)	Monthly Capacity (K)	Line-width (µm)	Monthly Capacity (K)	Line-width (µm)
TSMC	Fab 1	6	16	0.8	16	0.8	16	0.8	16	0.8	16	0.8	16	0.8
	Fab 2	6	64	0.6	73	0.5	75	0.5	75	0.5	75	0.5	75	0.5
	Fab 3	8	NA	NA	5	0.5	20	0.5	30	0.35	30	0.35	30	0.35
	Fab 4	8	NA	NA	NA	NA	NA	NA	12	0.35	25	0.35	25	0.25
	Fab 5	8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15	0.25
UMC*	Fab 1	4	45	1.0	50	1.0	50	0.8	50	0.8	50	0.8	50	0.8
	Fab 2	6	40	0.6	45	0.5	45	0.45	45	0.45	45	0.45	45	0.45
	Fab 3	8	NA	NA	5	0.4	15	0.35	20	0.25	25	0.25	25	0.25
TI-Acer	Fab 1a	6	16	0.55	20	0.45	20	0.45	20	0.4	20	0.4	20	0.4
	Fab 1b	8	NA	NA	8	0.45	15	0.45	15	0.35	15	0.3	15	0.3
	Fab 2a	8	NA	NA	NA	NA	NA	NA	6	0.35	15	0.35	20	0.3
	Fab 2b	8	NA	NA	NA	NA	NA	NA	NA	NA	6	0.3	15	0.25
Winbond	Fab 1	5	22	1.0	22	0.8	22	0.6	22	0.6	22	0.6	22	0.6
	Fab 2	6	24	0.5	28	0.45	35	0.45	35	0.45	35	0.45	35	0.45
	Fab 3	8	NA	NA	NA	NA	NA	NA	10	0.35	25	0.35	40	0.25
Mosel-Vitelic	Fab 1	6	NA	NA	15	0.47	23	0.45	30	0.45	30	0.45	30	0.45
	Fab 2	8	NA	NA	NA	NA	NA	NA	10	0.35	20	0.35	25	0.35
Macronix	Fab 1	6	21	0.6	25	0.5	28	0.45	28	0.35	28	0.35	28	0.35
	Fab 2	8	NA	NA	NA	NA	NA	NA	10	0.35	25	0.25	40	0.2
Holtek	Fab 1	5	18	1.2	22	0.8	26	0.6	30	0.5	30	0.5	30	0.5
	Fab 2	6	NA	NA	NA	NA	NA	NA	NA	NA	10	0.35	20	0.35
Vanguard	Fab 1a	8	NA	NA	10	0.5	14	0.4	14	0.4	14	0.35	14	0.35
	Fab 1b	8	NA	NA	NA	NA	NA	NA	8	0.3	18	0.3	18	0.3
Nan-Ya	Fab 1	8	NA	NA	NA	NA	NA	NA	10	0.45	15	0.35	20	0.35
Powerchip	Fab 1	8	NA	NA	NA	NA	NA	NA	15	0.4	25	0.35	25	0.35

NA = Not applicable
*Excludes the new dedicated foundry fabs announced recently by UMC
Source: Dataquest (October 1995)

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Figure 1
Taiwanese Semiconductor Industry Shipment Revenue by Business: Brand Name, Fabless, and Foundry/OEM (Millions of U.S. Dollars)



Source: Dataquest (October 1995)

Table 3 and Table 4 forecast sales revenue and percentage increases of major semiconductor manufacturers through 1996, while Table 5 and Table 6 provide estimates of Taiwanese companies' brand-name shipments in millions of U.S. dollars and annual percentage growth, respectively.

Table 3
Taiwan's Semiconductor Manufacturers' Forecast Revenue (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
TSMC	236	455	730	994	1,407
UMC	248	379	575	897	1,130
Winbond	117	189	325	685	888
TI-Acer	68	227	314	556	962
Mosel-Vitelic*	NA	NA	NA	454	890
Macronix	69	152	221	309	444
Vanguard	NA	NA	NA	111	444
HMC	87	95	89	97	107
Holtek	46	61	69	80	111
Others	NA	NA	40	61	85
Subtotal	871	1,558	2,363	4,244	6,468

*Mosel-Vitelic opened its own fab in 1995.
NA = Not applicable
Source: Dataquest (October 1995)

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Table 4
Taiwanese Semiconductor Manufacturers' Forecast Annual Growth Rate (Percent)

	1993	1994	1995	1996
TSMC	92.8	60.4	36.2	41.5
UMC	52.8	51.7	56.0	26.0
Winbond	61.5	72.0	110.8	29.6
TI-Acer	233.8	38.3	77.1	73.0
Mosel-Vitelic*	NA	NA	NA	96.0
Macronix	120.3	45.4	39.8	43.7
Vanguard	NA	NA	NA	300.0
HMC	9.2	-6.3	9.0	10.3
Holtek	32.6	13.1	15.9	38.8
Others	NA	NA	52.5	39.3
Subtotal	78.9	51.7	79.6	52.4

*Mosel-Vitelic opened its own fab in 1995.
NA = Not applicable
Source: Dataquest (October 1995)

Table 5
Worldwide Semiconductor Brand-Name Shipments Forecast by Major Taiwanese Companies (Millions of U.S. Dollars)

	1992	1993	1994	1995
UMC	198	309	418	718
Winbond	117	184	308	545
Mosel-Vitelic	161	223	259	454
Macronix	69	144	211	292
Silicon Integrated Systems	40	71	101	166
Vanguard	NA	NA	NA	111
HMC	75	83	89	97
Acer Labs	36	49	68	80
Holtek	46	61	69	80
Etron	NA	11	28	47
Subtotal	742	1,135	1,551	2,590

NA = Not applicable
Source: Dataquest (October 1995)

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Table 6
Annual Growth Rate of Worldwide Semiconductor Brand-Name Shipments by Major Taiwanese Companies (Percent)

	1993	1994	1995
UMC	56.1	35.3	71.8
Winbond	57.3	67.4	76.9
Mosel-Vitelic	38.5	16.1	75.3
Macronix	108.7	46.5	38.4
Silicon Integrated Systems	77.5	42.3	64.4
Vanguard	NA	NA	NA
HMC	10.7	7.2	9.0
Acer Labs	36.1	38.8	17.6
Holtek	32.6	13.1	15.9
Etron	NA	154.5	67.9
Subtotal	53.0	36.7	67.0

NA = Not applicable
Source: Dataquest (October 1995)

Capital Spending Reaches a New High

High profits in the semiconductor industry created fab fever all over Taiwan this year. More than 10 announced 8-inch wafer fabs broke ground in 1995, including TSMC (two fabs), TI-Acer, Winbond, Macronix, Mosel-Vitelic, Holtek, Vanguard, Nan-Ya, and Powerchip. There are another four dedicated foundry fabs being planned, three of which will belong to UMC. All these fabs will need tremendous capital investment for the next several years. We expect capital spending to expand by 193 percent this year and to increase by 21.4 percent to $3.6 billion in 1996. The fab fever will last as long as the strong demand for semiconductors continues. Table 7 shows the capital spending for major Taiwanese semiconductor manufacturers.

Table 7
Capital Spending Forecast for Taiwanese Fabs (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996
TSMC	85	160	100	140	307	528	745
Mosel-Vitelic	35	30	10	20	206	300	450
Vanguard	40	50	30	20	154	180	320
Macronix	20	160	15	60	120	120	200
Winbond	10	59	112	50	103	370	420
UMC*	102	21	54	56	54	380	420
TI-Acer	72	220	50	70	50	300	300
Holtek	NA	5	5	10	32	40	30
Episil	NA	NA	NA	NA	0	8	10
Powerchip	NA	NA	NA	NA	NA	400	400
Nan-Ya	NA	NA	NA	NA	NA	377	350
Total	364	705	376	426	1,026	3,003	3,645

NA = Not applicable
*Excludes the new dedicated foundry fabs announced recently by UMC.
Source: Dataquest (October 1995)

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Operating Statuses of Major Semiconductor Companies

UMC

As the oldest semiconductor manufacturer in Taiwan, UMC is very aggressive and eager to become the country's leading semiconductor company. But the sales revenue of TSMC has surpassed UMC every year since 1993, and the difference appears to have grown greater annually. This revenue gap is pushing UMC into the dedicated foundry business. UMC signed joint-venture plans with several U.S. fabless companies to set up at least three dedicated foundry fabs in Taiwan after July 1995. The projects call for capital spending of $10 billion, and the resulting fabs are expected to be capable of producing 15,000 8-inch wafers per month for each fab when running at full capacity.

The first joint-venture fab is with S3 and Alliance. The second fab is with Integrated Silicon Solutions Inc. (ISSI), OPTi, ATI Technologies, and Trident. The third fab is with Lattice. Most of these companies are clients of TSMC, and such strategic alliances offer UMC a jump-start into the dedicated foundry business with lower market risk.

UMC's Fab 1 and Fab 2 have already reached their full capacities and can create a maximum monthly sales revenue of $78 million. However, the 20 percent price cut in SRAM will reduce the monthly sales revenue, although the better yield rate and die shrinking will enlarge the total shipment quantity. SRAM and system core logic are UMC's major brand-name products, and they account for 55 percent of total company sales revenue. The dedicated foundry business constitutes 20 percent of the sales revenue. UMC's 486 microprocessor is another promising product, pending patent issues that must first be resolved with Intel.

Fab 3 is under pilot run and by October had reached 5,000 wafers per month. This new fab will attain its full capacity next year. UMC is expected to expand the capacity to 25,000 wafers per month in late 1998.

TSMC

TSMC has been the largest semiconductor manufacturer in Taiwan since 1993. However, it now faces UMC's challenge, and in light of the growing competition, TSMC asked clients to prepay a 20 to 30 percent foundry allocation fee that will guarantee supply for the next three years. By October, TSMC had sold 70 percent of its allocation for the next three years, thereby ensuring healthy sales revenue. The real competition in the dedicated foundry business will start after 1997, when UMC's new dedicated foundries are ready for mass production. For 1995, sales revenue of TSMC may reach a new high of $994 million, a growth of 36.2 percent from 1994 to 1995. The post-tax net profit is expected to hit $489 million, another new high. TSMC's Fab 1 and Fab 2 reached their full capacity this year, while Fab 3 is under pilot run and produces 5,000 8-inch wafers per month. The cumulative experience from Fab 1 and Fab 2 is expected to shorten Fab 3's learning curve. Fab 3 has a yield rate reaching 90 percent, and all its capacity has been reserved for next year. Dataquest projects TSMC's 1996 sales revenue to be $1.4 billion. TSMC is constructing Fab 4 and is expected to begin building Fab 5 by the end of this year.

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The dedicated foundry business promises good overall growth for the next few years, and TSMC's leading role remains, at least for the moment, intact. Moreover, confidential design issues offer TSMC another advantage because they allow TSMC to gain the trust of its clients.

Winbond

Winbond, the third largest semiconductor manufacturer in Taiwan, is expected to post sales revenue of $685 million in 1995. It went public in late October. We estimate Winbond's sales revenue will grow 110.8 percent in 1995. As with other semiconductor manufacturers, Winbond's Fab 1 and Fab 2 have reached their full capacities. Since Fab 3 will begin mass production in 1997, Winbond will stretch the capacity of Fab 2 from 28,000 wafers to 35,000 wafers per month to meet the strong market demand.

Memory items, including SRAM, flash, and EEPROM, are Winbond's major products and are expected to represent 47.8 percent of sales revenue in 1995. Foundry service provides an additional 20.4 percent of revenue, while microcontrollers take 15.8 percent and consumer ICs take 15.3 percent. Winbond is now the world's major supplier of high-speed SRAM; its recent price cut on SRAM has influenced the sales revenue.

In 1996, Winbond will concentrate its effort on core logic and flash memory. The company plans to allocate 10,000 wafers per month for the production of flash next year. The 1Mb flash memory is now ready for shipment, while high-capacity flash memory is expected to become popular next year.

TI-Acer

TI-Acer, a joint venture between Texas Instruments and Acer, produces only standard 4Mb and 16Mb DRAMs. We estimate its production revenue will grow by 77.1 percent to $556 million in 1995. Fab 1a has reached its full capacity of 20,000 6-inch wafers per month, while Fab 1b is now under pilot run. The capacity for this new fab so far reached 8,000 8-inch wafers per month, an amount that represents about half of full capacity.

TI-Acer upgraded the linewidth of Fab 1a from 0.55µm to 0.45µm this year, an evolution that can improve DRAM production volume to 5 million pieces per month. Fab 1b can produce 500,000 pieces of 16Mb DRAM per month. We expect Fab 1b to reach full production capacity next year, and company sales revenue to hit $960 million.

Fab 2 is ready to set up. Construction will start at the end of this year, and mass production is expected to begin during the second quarter of 1997. The initial full capacity will be 15,000 8-inch wafers per month, but it should expand to 30,000 8-inch wafers per month in late 1998.

Macronix International

Following the lead of UMC and TSMC, Macronix International went public in the second quarter of 1995. Its major products include nonvolatile memory (86 percent of the sales revenue), and microcontrollers (14 percent of the sales revenue). Fab 1 has reached its full capacity of 25,000 6-inch wafers per month, but it will expand to 28,000 wafers per month by the end of the year. The linewidth of this fab will be upgraded from 0.5µm to 0.45µm.

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Sales revenue for 1995 is expected to be $309 million, a 39.8 percent growth over 1994 figures. After the expansion and technology improvement, the sales revenue may reach $444 million in 1996, a growth 43.7 percent.

Fab 2 is in construction, and will likely start mass production in 1997. The full capacity of Fab 2 is 40,000 8-inch wafers per month. The linewidth is expected to be 0.2µm by 1999.

Mosel-Vitelic

Mosel-Vitelic began its own fab at the beginning of 1995, and went public in September. Mosel-Vitelic focuses on memory, and DRAM accounted for 86 percent of total sales revenue in 1995. SRAM and ROM accounted for 8 percent and 6 percent, respectively.

Sales revenue for 1995 is expected to reach an all-time high of $454 million, a 75.3 percent growth over 1994 revenue. Fab 1 can produce 15,000 6-inch wafers per month and will reach its full capacity in early 1997. The linewidth has improved from 0.55µm to 0.47µm and is expected to shrink to 0.45µm in 1996.

Mosel-Vitelic has become the major North American supplier of 2Mb DRAMs. This niche market provides a better profit margin than the market for standard 4Mb DRAMs. Profit after taxes can reach $230 million in 1995. This company's performance in profit is better than other semiconductor companies in Taiwan.

The production of Fab 1 will likely reach 23,000 6-inch wafers per month in 1996. A good yield rate and more production volume will push sales revenue to another record high. We expect the 1996 sales revenue to be $890 million, which would represent a growth of 96 percent.

Vanguard

Vanguard is a recent spin-off from Taiwanese government's Electronic Research & Services Organization (ERSO). This company privatized the submicron technology and started production at the end of 1994. It focuses on memory, mainly DRAM and, to a lesser extent, SRAM.

Fab 1 can produce 10,000 8-inch wafers per month with a linewidth of 0.5µm. Next year, it is expected to upgrade to its full capacity of 14,000 wafers per month with 0.4µm. We anticipate sales revenue to reach $111 million in 1995 and $444 million in 1996. After the mass production of Fab 2 begins in 1997, sales revenue should grow further.

Other New DRAM Makers: Powerchip and Nan-Ya

Powerchip, a joint venture between Taiwan's Elite/UMAX group and Japan's Mitsubishi Electronics, recently broke ground for its Fab 1 in Hsin-chu Science Park. The facility is slated to start mass production by the end of 1996. This fab will use 0.4mm technology to produce 16Mb DRAMs on 8-inch wafers. The capacity is expected to be 15,000 wafers per month. At the initial production stage, the DRAMs will be sold under the brand name of Mitsubishi.

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Nan-Ya, a subsidiary of the Formosa Plastics Group (FPG), announced plans to enter the 16Mb DRAM business in 1994. It is setting up its facility for mass production in 1996. Oki of Japan is providing the technology.

Fab Fever in the Semiconductor Industry

Fab fever in semiconductor manufacturing has created opportunities for major suppliers of silicon wafers. MEMC, Komatsu, and Shinetsu are planning to establish manufacturing plants in Taiwan due to the strong local demand for 8-inch wafers. As already noted, there are at least 14 8-inch fabs under construction or ready for groundbreaking. These fabs are expected to start mass production after 1997, creating a huge supply of 8-inch wafers at that time. Table 8 shows the plans of these new silicon suppliers.

Table 8
Wafer Manufacturers' Setup Plans in Taiwan

	Taiwan-Komatsu	Taisil	Shinetsu Taiwan
Investors	FPG, Komatsu	CSC (Taiwan), MEMC	Shinetsu (Japan), Topco
Technology Source	Komatsu (Japan)	MEMC (United States)	Shinetsu (Japan)
Capital (Millions of U.S. Dollars)	250	191	185
Capacity (8-Inch Wafers per Month)	200,000	215,000	200,000
Initial Capacity (8-Inch Wafers per Month)	80,000	80,000	70,000
Pilot Time	Third quarter of 1996	January 1996	July 1997
Initial Production Time	Fourth quarter of 1996	March 1996	September 1997
Final Capacity Realized	To be announced	Mid- to late 1997	Late 1997
Shareholders	Komatsu (51 percent), FPG (49 percent)	MEMC (45 percent), CSC (35 percent), others (20 percent)	Shinetsu (70 percent), Topco (15 percent), others (15 percent)
Location	Yun-Lin, Taiwan	Hsinchu Science Park	Hsinchu Science Park

Source: Dataquest (May 1995)

Dataquest Perspective

Taiwan's semiconductor industry is now entering its major expansion phase. We expect to see Taiwanese manufacturers setting records in capital spending and sales revenue, and we believe the industry will experience strong growth in next several years. Semiconductor manufacturers are coming to play major global roles in dedicated foundry and memory supply. The Taiwanese government has targeted semiconductor industry as the important sector for Taiwan in the year 2000, and it hopes to capture 10 percent of the worldwide market share by then. Dataquest believes this target is reachable.

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Market Analysis



Semiconductor Application Markets Worldwide

Market Analysis

Monitors: Strong Growth Ensures Revenue Leadership in Taiwan's Data Processing Industry

Abstract: *Monitors have been the largest single electronic product in terms of sales revenue in Taiwan. Fast expansion and severe competition have prompted Taiwanese manufacturers to set up overseas facilities. Taiwanese monitor manufacturers therefore have become the main supplier of monitors worldwide. According to our statistics, Taiwanese manufacturers in 1995 will produce 31.6 million units of monitors (domestic and overseas production), with total sales revenue of $7.3 billion. This article presents an update of Taiwanese monitor production volume and sales revenue. The huge production has created semiconductor opportunities, particularly for discrete and analog.*

By Ben F.P. Lee (Taiwan)

Monitors: Taiwan's Largest Electronic Production Segment

Taiwan's monitor production has been growing in tandem with the booming personal computer industry for 10 years, and monitors have become the largest group of electronic product in terms of sales revenue. Many manufacturers have expanded their assembly lines beyond the shores of Taiwan in an effort to beat rising domestic manufacturing costs for low-end products. Dataquest expects Taiwan to produce 31.6 million units of monitor in 1995, with sales revenue of $7.3 billion, for annual growth rates of 25.7 percent and 32.7 percent, respectively (see Table 1).

Taiwan will represent a worldwide market share of 65.5 percent of unit production in 1995 and will outperform global monitor producers.

We estimate that 18.1 million units, or 57 percent, of Taiwan's total unit production (domestic and overseas) will be produced in Taiwan, generating sales revenue of $4.7 billion in 1995. The corresponding annual growth in

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Table 1
Sales Revenue and Production Volume of Taiwanese Monitor Manufacturers, 1994 and 1995

	1994	1995*	Annual Growth Rate (%)
Sales Revenue (U.S.$M)			
Produced in Taiwan	3,862	4,670	20.9
Produced Abroad	1,659	2,657	60.2
Total	5,521	7,327	32.7
Production Volume (K Units)			
Produced in Taiwan	16,225	18,102	11.6
Produced Abroad	8,912	13,487	51.3
Total	25,137	31,589	25.7

*Forecast
Source: Dataquest (November 1995)

unit production will increase by a moderate 11.6 percent; however, sales revenue will increase by 20.9 percent, demonstrating Taiwan's ability to maintain higher value production in the country. In comparison, Dataquest estimates Taiwan's overseas monitor production to reach 13.5 million units, equivalent to $2.7 billion. These figures translate to dramatic growth rates of 51.3 percent and 60.2 percent, respectively. Taiwanese monitor manufacturers' network of overseas production will grow rapidly as an important competitive tool. We believe that Taiwanese manufacturers will still dominate the supply of worldwide monitor within the foreseeable future.

Company Ranking by Unit Production

Table 2 shows the unit production performance of major monitor manufacturers in Taiwan. Philips is still the leading manufacturer and is projected to increase its total country production share from 11.8 percent in 1994 to 12.9 percent this year. Philips has located its monitor manufacturing base in Taiwan. The next major manufacturers are Acer Peripheral, Lite-On, ADI, and Tatung. We expect these top five manufacturers to grow by more than 20 percent this year, with Lite-On being the fastest at 60 percent. However, GVC could claim the honor as the fastest-growing company, clocking 205 percent growth, or a tripling of its unit volume this year, given its low manufacturing base.

Overseas Facilities Sustain Competitiveness

As seen in Table 1, overseas production will provide the greatest momentum to Taiwan's overall growth in monitor manufacturing this year. Table 3 further details production according to domestic and overseas production. With the exception of Tatung, KFC, Sampo, and Matsushita, all other 15 monitor manufacturers have endorsed the competitive manufacturing advantage of establishing overseas manufacturing facilities. GVC and MAG decided to join the trend this year. Acer and Lite-On (as well as TVM, Essex, and Mitac), among the 10 in our table, are particularly dependent on their offshore facilities for generating their output, at the expense of reducing domestic volume in several cases (Essex, Royal, and TECO) or even leading to a complete hollowing-out (as in AOC). Overseas facilities have become an important recipient of low-end products, while the local assembling

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Table 2
Taiwanese Monitor Production (Local Production and Overseas Production), 1994 and 1995 (Thousands of Units)

	1994	1995*	Annual Growth Rate (%)
Philips	2,963	4,064	37.2
Acer Peripheral	2,590	3,643	40.7
Lite-On	1,769	2,829	59.9
ADI	2,038	2,779	36.4
Tatung	1,600	1,948	21.8
MAG	1,380	1,945	40.9
CTX	1,484	1,908	28.6
Shamrock	1,200	1,693	41.1
Cape	856	1,103	28.9
Royal	1,066	897	-15.9
KFC	691	889	28.7
Delta	625	866	38.6
AOC	792	854	7.8
Compal	713	789	10.7
TECO	823	788	-4.3
GVC	186	568	205.4
Sampo	514	547	6.4
TVM	521	512	-1.7
Matsushita	344	508	47.7
Essex	692	415	-40.0
Mitac	273	314	15.0
Others	2,017	1,730	-14.2
Total	25,137	31,589	25.7

*Forecast
Source: Dataquest (November 1995)

facilities are able to progress to higher-end products. Overseas facilities allow Taiwanese companies to maintain their market share leadership.

Most Taiwanese monitor manufacturers prefer to locate their alternative facilities in Malaysia, China, Thailand, and Indonesia, which offer competitive labor costs and land advantages. The General Agreement on Tariffs and Trade also provides tax deduction advantages to manufacturers in these countries. Table 4 outlines locations by country of the major Taiwanese monitor manufacturers.

OEM: Major Business Model

As in Taiwan's PC industry, monitor manufacturers rely on OEM/ODM orders. Only a few local manufacturers have their own brand and global selling channels, which are setting the trend for the other local manufacturers. Taiwan is attempting to improve its brand image. Table 5 highlights the major alliances between Taiwanese monitor manufacturers and their OEM/ODM accounts.

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Table 3
Taiwanese Monitor Production, 1994 and 1995 (Thousands of Units)

	1994 Production in Taiwan	Production Abroad	1995* Production in Taiwan	Production Abroad	Annual Growth Rate Production in Taiwan (%)	Annual Growth Rate Production Abroad (%)
Philips	2,613	350	3,437	627	31.5	79.1
Acer Peripheral	890	1,700	892	2,751	0.2	61.8
Lite-On	785	984	826	2,003	5.2	103.6
ADI	1,228	810	1,455	1,324	18.5	63.5
Tatung	1,600	0	1,948	0	21.8	-
MAG	1,380	0	1,590	355	15.2	-
CTX	1,068	416	1,030	878	-3.6	111.1
Shamrock	464	736	758	935	63.4	27.0
Cape	560	296	537	566	-4.1	91.2
Royal	580	486	365	532	-37.1	9.5
KFC	691	0	889	0	28.7	-
Delta	113	512	244	622	115.9	21.5
AOC	24	768	0	854	-	11.2
Compal	309	404	322	467	4.2	15.6
TECO	651	172	486	302	-25.3	75.6
GVC	186	0	555	13	198.4	-
Sampo	514	0	547	0	6.4	-
TVM	21	500	16	496	-23.8	-0.8
Matsushita	344	0	508	0	47.7	-
Essex	208	484	65	350	-68.8	-27.7
Mitac	101	172	96	218	-5.0	26.7
Others	1,895	122	1,536	194	-18.9	59.0
Total	16,225	8,912	18,102	13,487	11.6	51.3

*Forecast
Source: Dataquest (November 1995)

Table 4
Foreign Factory Location of Taiwanese Monitor Manufacturing

Foreign Location	Taiwanese Manufacturer
Malaysia	Acer Peripheral, Lite-On, TECO, Shamrock
China	ADI, MAG, AOC, TECO, Royal, Essex, Mitac
Thailand	ADI, CTX, Delta, Cape, Compal
Indonesia	MAG, TECO, TVM
Mexico	Philips

Source: Dataquest (November 1995)

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Table 5
Taiwan's Major OEM/ODM Partners and Products

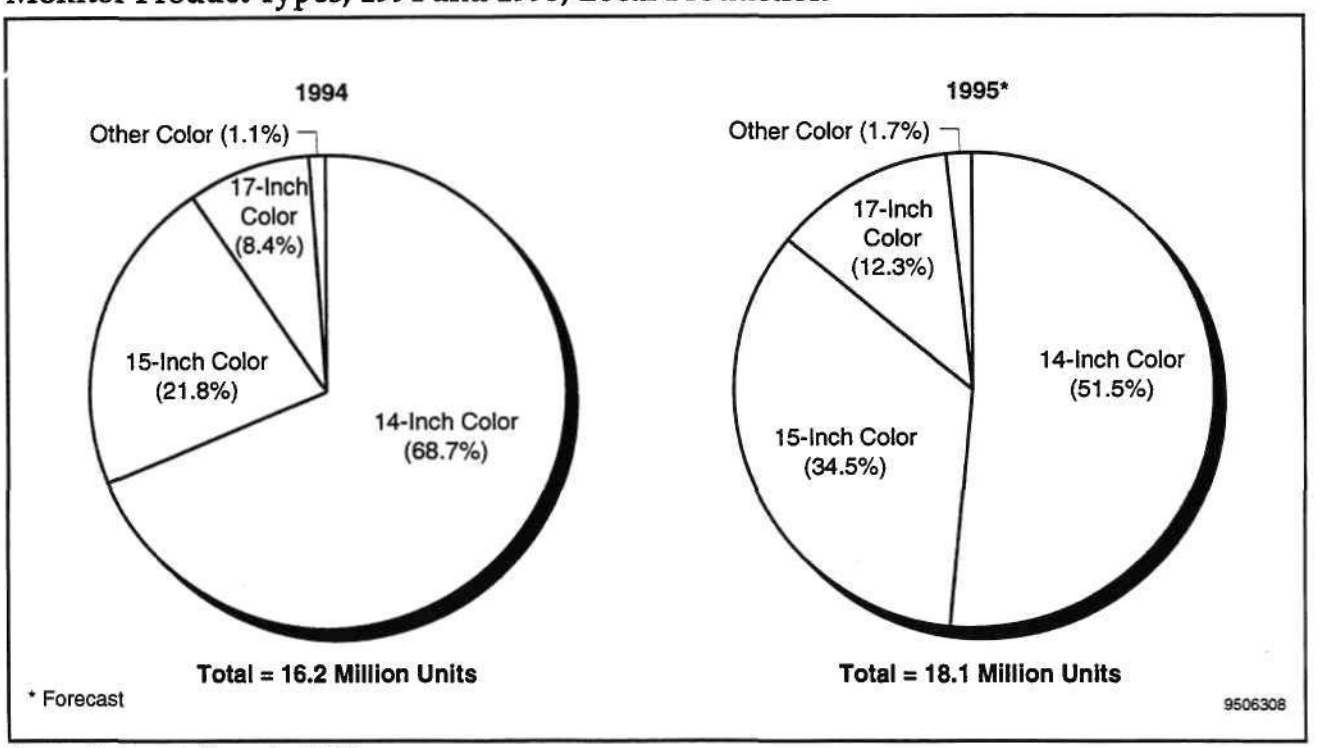
Taiwanese Manufacturer	OEM/ODM Partner
Acer Peripheral	ICL, NCR, Ambra, Fujitsu, Viewsonic
ADI	Compaq, Tulip, Hitachi
Tatung	Packard Bell, ICL, Apple, NEC, IBM
Lite-On	IBM, Dell, Packard Bell, DEC
MAG	Gateway 2000
Royal	Vobis, Dell
CTX	Escom, Zeos, Dell, Fujitsu

Source: Dataquest (November 1995)

SVGA Becomes Mainstream while 15-Inch Production Surges Rapidly

Figure 1 shows the percentage of color monitors produced in Taiwan, by size. SVGA has become the mainstream monitor for all different sizes. A huge portion of low-end products, the 14-inch monitors, is assembled abroad and has been replaced by 15-inch or larger monitors. Dataquest projects production of 14-inch monitor to decrease from 68.7 percent in 1994 to 51.5 percent this year. In turn, the production of 15-inch monitors will rise from 21.8 percent in 1994 to 34.5 percent in 1995. This switchover marks the trend of increasing monitor size, with the 15-inch type poised to become the dominant display in 1996.

Figure 1
Monitor Product Types, 1994 and 1995, Local Production

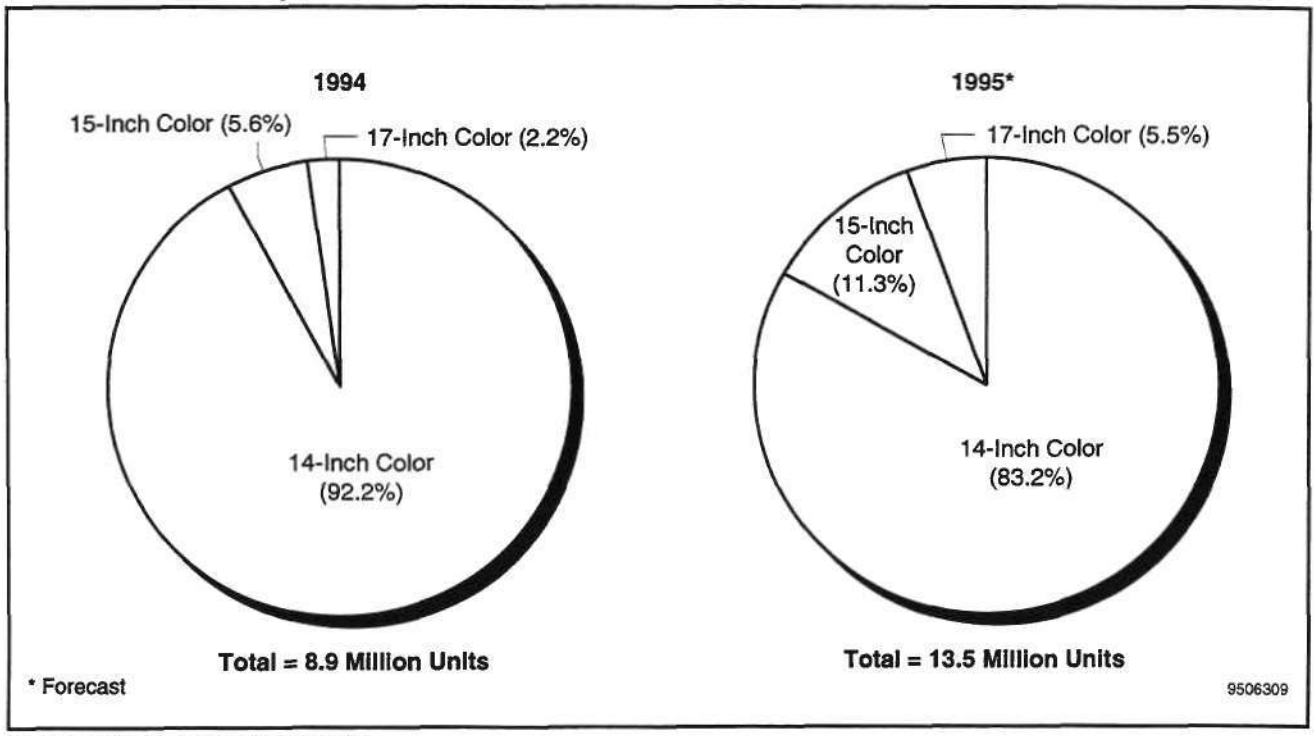


Source: Dataquest (November 1995)

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Figure 2 shows that Taiwan's overseas production focuses more than 80 percent volume on 14-inch monitors in 1995, with rising opportunities for the larger type monitors (15-inch and 17-inch monitors). Because of the rapid ramp-up from the overseas facilities this year, Taiwanese monitor manufacturers are able to extend product life cycles with stronger market competitiveness.

Figure 2
Monitor Product Type, 1994 and 1995, Overseas Production



Source: Dataquest (November 1995)

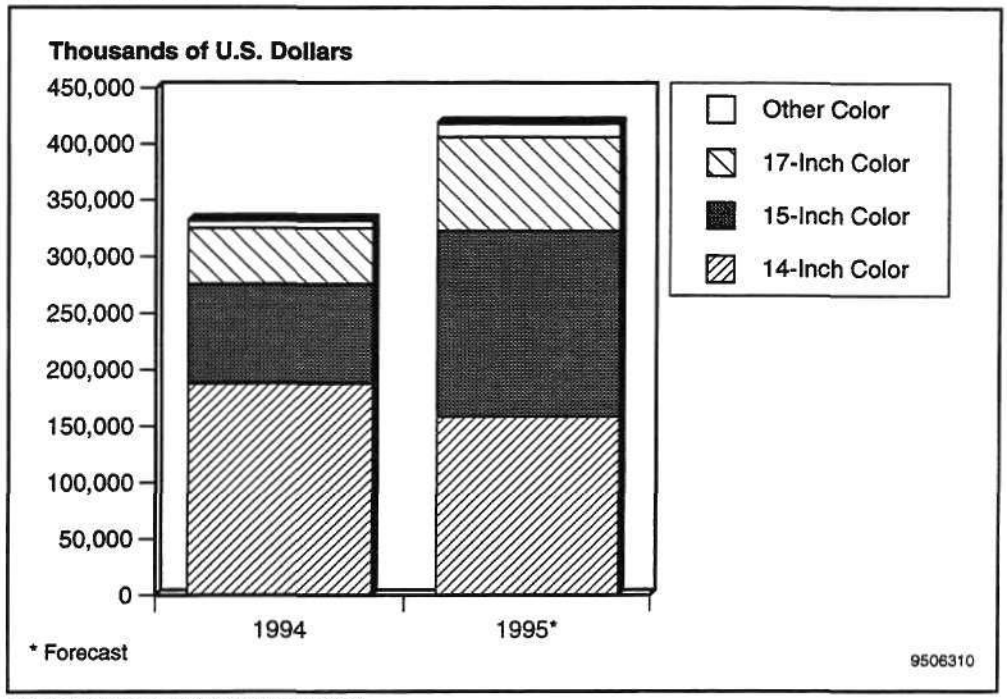
Huge Semiconductor Consumption in Monitors

Monitor production has created a huge demand for semiconductors. Monitor manufacturers purchase all semiconductor components from Taiwan for local consumption, while the overseas facilities receive 65 to 70 percent semiconductor requirements through Taiwan. Figures 3 and 4 show the semiconductor consumption by monitor size in both local and overseas manufacturing facilities. Although overseas production facilities continue to see the majority of demand from the 14-inch products, semiconductor opportunities are rising rapidly from the local 15-inch assembled displays. Table 6 shows semiconductor consumption by monitor type from 1994 to 1995.

Table 7 shows semiconductor consumption by device for all Taiwan-made monitors, both domestic and overseas. We project semiconductor demand to grow by 38 percent from $434.8 million in 1994 to $600 million this year. The larger-screen and higher-resolution monitors certainly require more semiconductor content. Analog content by value in monitors will increase the fastest—by 60 percent to $176.6 million—while other devices such as discretes, photocouplers, and microcontrollers also will show healthy growth rates. Japanese companies are the major semiconductor suppliers, followed by North American, Korean, and European companies.

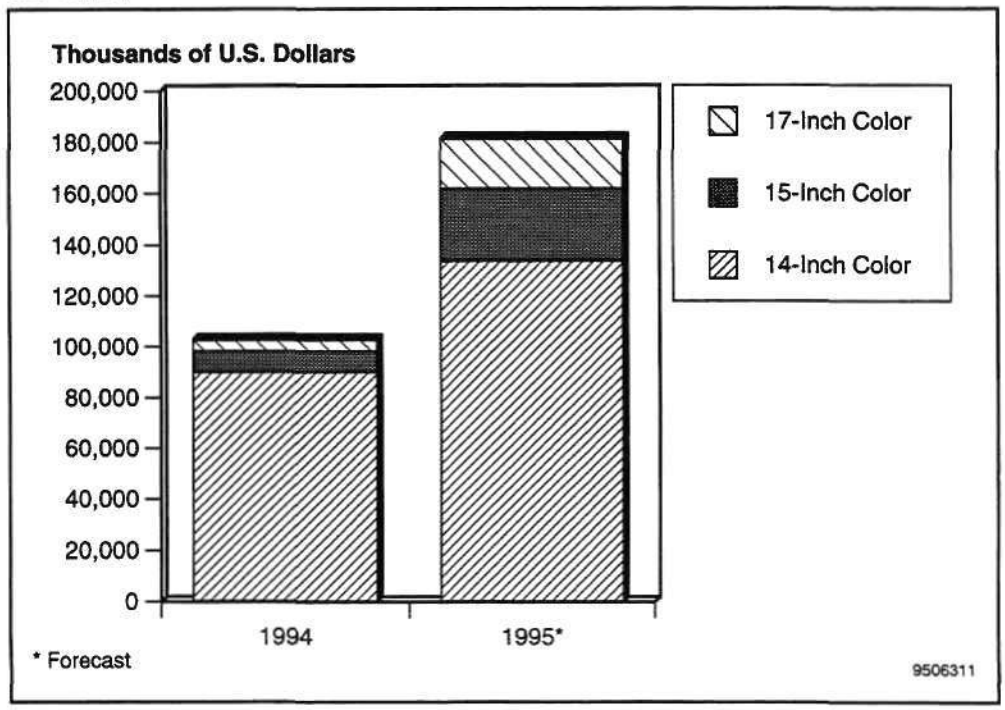
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Figure 3
Semiconductor Consumption by Monitors Used in Taiwan, 1994 and 1995



Source: Dataquest (November 1995)

Figure 4
Semiconductor Consumption by Monitors Used Abroad, 1994 and 1995



Source: Dataquest (November 1995)

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Table 6
Semiconductor Consumption by Monitor Size, 1994 and 1995
(Thousands of U.S. Dollars)

	1994	1995*
14 Inch	278,310	292,874
15 Inch	95,996	192,160
17 Inch	53,876	103,022
Others	6,659	11,872
Totals	434,840	599,928

*Forecast
Source: Dataquest (November 1995)

Table 7
Semiconductor Consumption by Device, 1994 and 1995
(Thousands of U.S. Dollars)

	1994	1995*	Annual Growth Rate (%)
Discrete			
Transistors	152,194	205,973	35.3
Diode	8,697	11,999	38.0
Rectifier	134,800	167,980	24.6
Optoelectronic			
Photocoupler	4,350	6,010	38.2
Analog			
Analog IC	110,452	176,616	60.0
Microcomponent			
Controller	24,347	31,350	28.8
Totals	434,840	599,928	38.0

*Forecast
Source: Dataquest (November 1995)

Dataquest Perspective

Monitors have become the single-largest electronic product for Taiwan by revenue and have created a tremendous market for related semiconductors. Taiwan's establishment of Asia/Pacific bases to justify the costs of manufacturing in the low end allows its continuous dominance in market share and graduation to higher-value/larger-size monitors. The overseas production network, particularly in Southeast Asia (Malaysia, Thailand, and Indonesia) increasingly contributes to the total production volume.

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Market Analysis



Semiconductors Asia/Pacific

Market Analysis

Singaporean Disk Drive Production: Strong Growth and Incorporation of Media Manufacturing

Abstract: *Singapore continues to expand its disk drive production volume in response to a continuous strong demand for personal computers. Capital investments continue to rise on the island, while other Asia/Pacific countries, wanting a piece of the action, are becoming involved in manufacturing activities as well. Singapore is also moving toward the manufacturing of recording media, deemed as a strategic move to maintain its lead as the manufacturing kingdom of disk drives.*
By Eddy Tan (Singapore)

Introduction

Asia/Pacific plays a pivotal role as the world's leading manufacturing base for rigid disk drives (RDD). The region's 61 percent of worldwide disk drive production in 1994 is expected to rise to 82 percent by 1999 largely because of the booming market for data processing equipment. Most of the major PC manufacturers have established manufacturing sites in the Asia/Pacific area in a bid to be closer to this burgeoning market, to reduce costs, and to create a 24-hour manufacturing operation. Players that have recently established themselves in this region include Dell (Penang, Malaysia), Gateway 2000 (Malacca, Malaysia), and Packard Bell (manufacturing site undecided).

Component suppliers such as disk drive manufacturers will find vast opportunities to ride on the computer wave. Disk drive manufacturers are ramping up unit output and aggressively raising storage capacities to meet the ever-changing demands of the PC industry's faster processing speeds, larger databases, and added computing features. Throughout the history of storage devices, storage capacity has doubled consistently each year, from 85MB in 1992 to 420MB in 1994. Mainstream capacity reached 850MB in 1995, and it is expected to breach the gigabyte mark early next year.

Dataquest

Program: Semiconductors Asia/Pacific
Product Code: SAMM-AP-MA-9505
Publication Date: October 23, 1995
Filing: Market Analysis

This document forecasts disk-drive production in Singapore vis-à-vis Asia/Pacific and the world. We furnish short updates on the manufacturers in Singapore and in the region. We also provide a teardown of a mainstream disk drive, which exposes its semiconductor makeup.

Singapore Cornered 47 Percent of Global Production

Singapore's early entry two decades ago into computer manufacturing has made the country the world's largest manufacturing base for disk drives. All the global players, especially North American companies, have announced plans to expand in both Singapore and the entire region.

Singaporean production of disk drives grew by an annual growth rate of 35 percent to 32.8 million units in 1994 (see Table 1), which was a good year for PC manufacturers and component suppliers. The country captured 77 percent of the market in Asia/Pacific and 47 percent globally. Figure 1 compares the disk drive unit production from Singapore vis-à-vis Asia/Pacific and worldwide. We expect Singapore's share of worldwide production to peak at 52 percent over the next two years, and then to stabilize at 50 percent for the following two years. We forecast Singapore to produce 77.9 million units of RDD in 1999. Dataquest estimates the semiconductor application market in disk drives to be $1.8 billion in 1994. Figure 2 shows how overall production peaked in 1994 but will maintain fairly healthy growth rates through 1999. Based on our current forecast, we anticipate this market to grow by a compound annual growth rate (CAGR) of 24 percent to $2.7 billion by 1999 (see Figure 3).

The 3.5-inch disk drive will continue to be the most accepted form factor throughout this decade. In 1994, the 201MB to 500MB, 3.5-inch RDD was the most prevalent storage device worldwide (54 percent of all disk drives), and it is expected to sustain its lead but at a reduced share of 38 percent this year. Dataquest projects that by 1999 the 1.1 to 2GB capacity 3.5-inch disk will be the leading device (28 percent share), followed by 2GB to 4GB (23 percent), and 1.1GB to 2GB (9 percent). The 2.5-inch disk drive, which is peaking with its 201MB to 500MB storage capacity this year, will see its 1.1GB to 2GB storage capacity rising to prominence (9 percent of total RDD worldwide) by 1999.

Disk Drive Manufacturers in Singapore

U.S. manufacturers dominate disk drive manufacturing in Singapore. Figure 3 shows our simple 1994 ranking in Singapore by total unit production and Figure 4 shows market shares of Conner Peripherals (13 percent). The giant manufacturers—Seagate Technology, Western Digital, Maxtor, and Conner Peripherals— are consolidating their

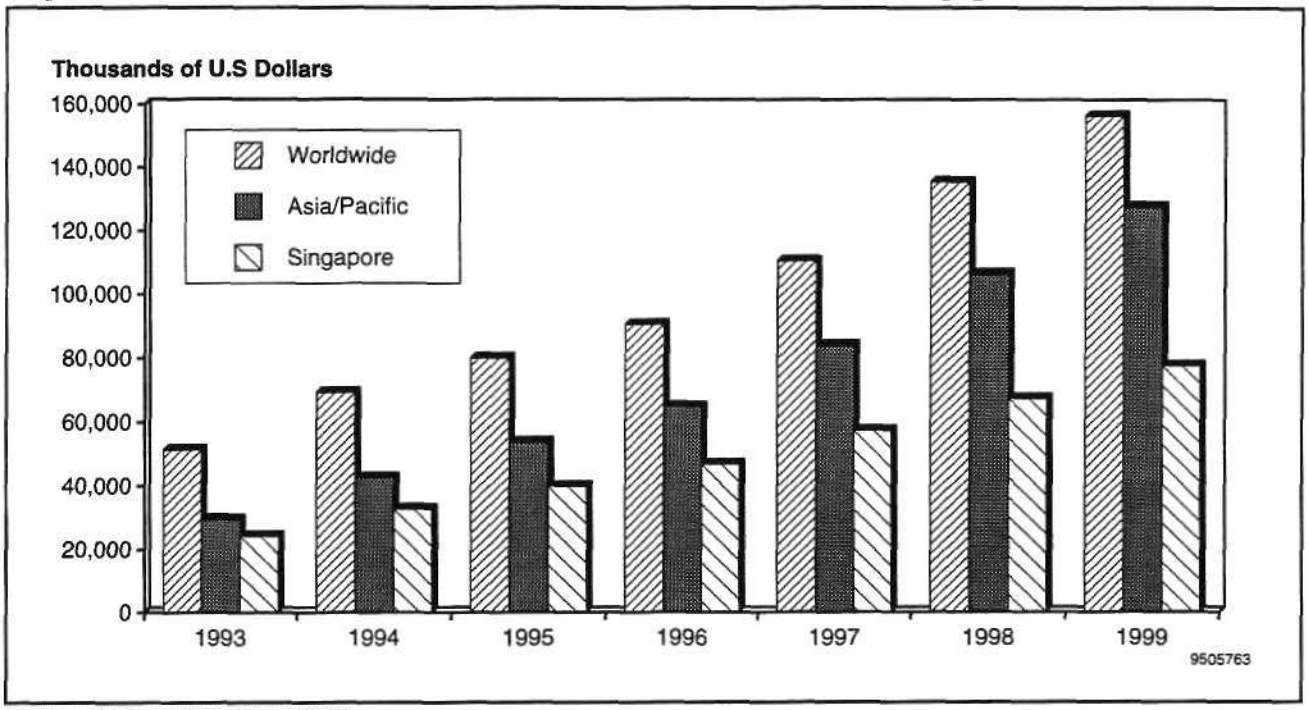
Table 1
Rigid Disk Drive Production: Worldwide, Asia/Pacific, and Singapore (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Worldwide	51,427	69,334	80,183	90,754	110,538	135,469	156,444	17.7
Asia/Pacific	29,547	42,628	53,773	64,932	84,145	106,454	127,681	24.5
Singapore	24,239	32,765	39,882	46,841	57,485	67,494	77,870	18.9

Source: Dataquest (October 1995)

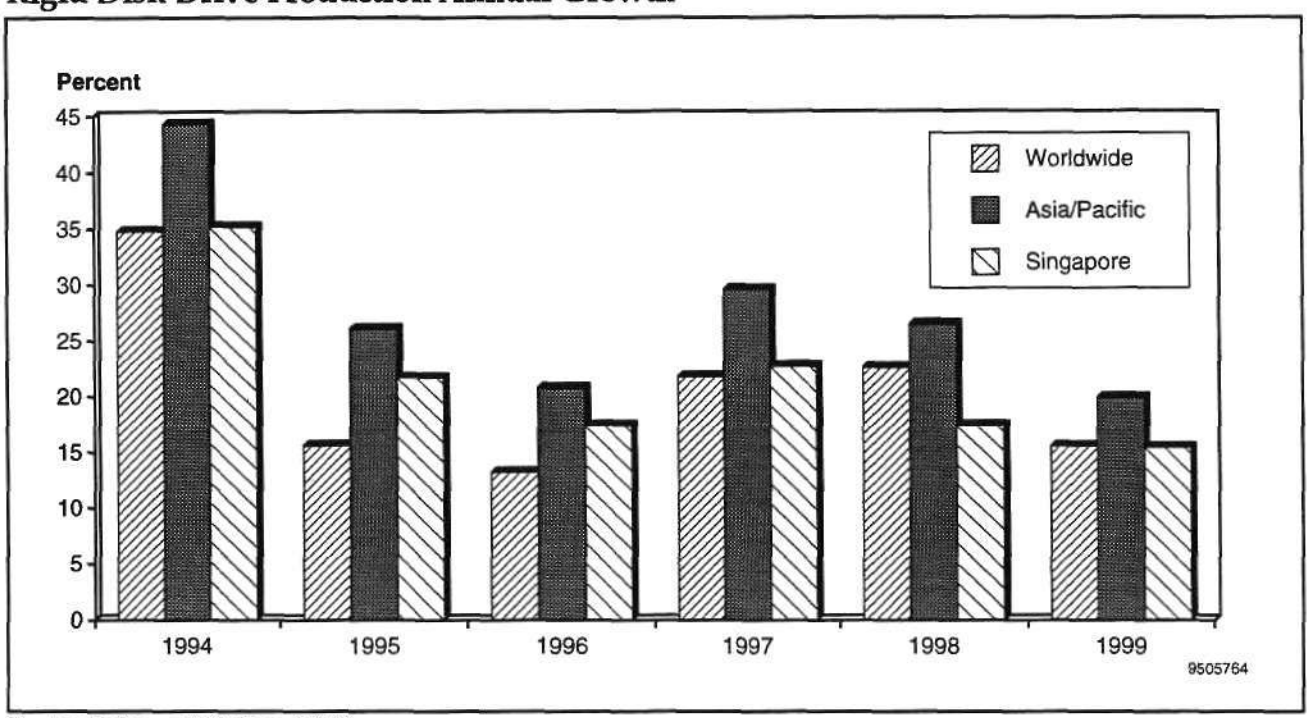
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Figure 1
Rigid Disk Drive Production: Worldwide, Asia/Pacific, and Singapore



Source: Dataquest (October 1995)

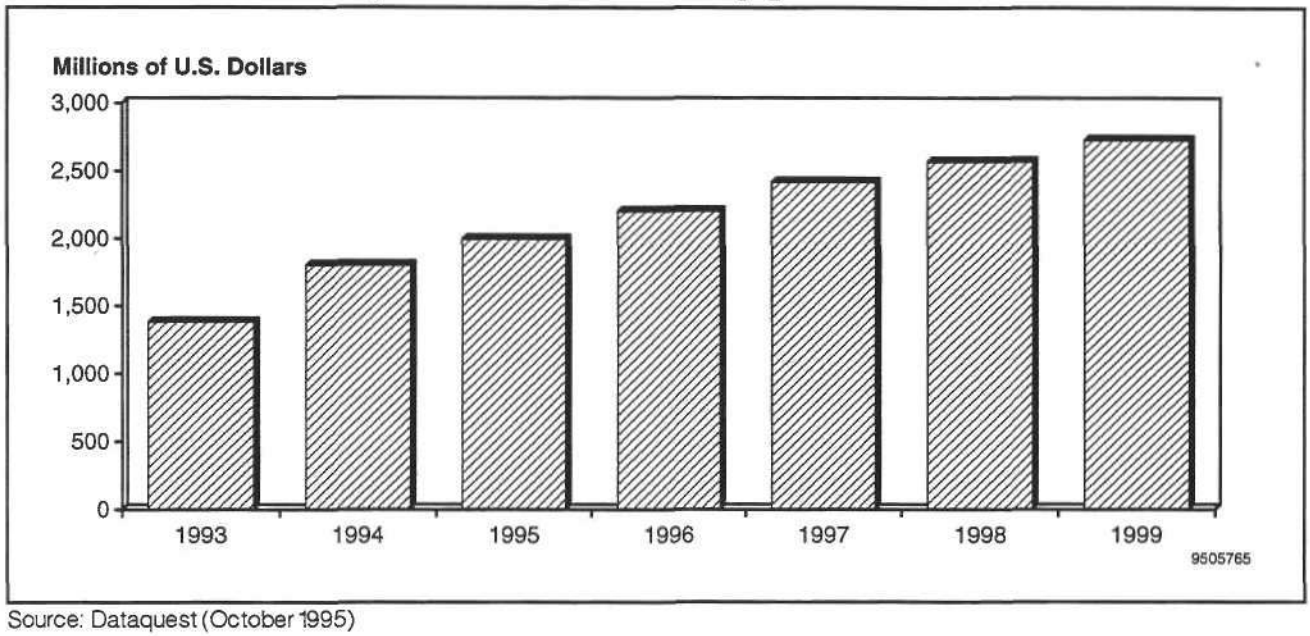
Figure 2
Rigid Disk Drive Production Annual Growth



Source: Dataquest (October 1995)

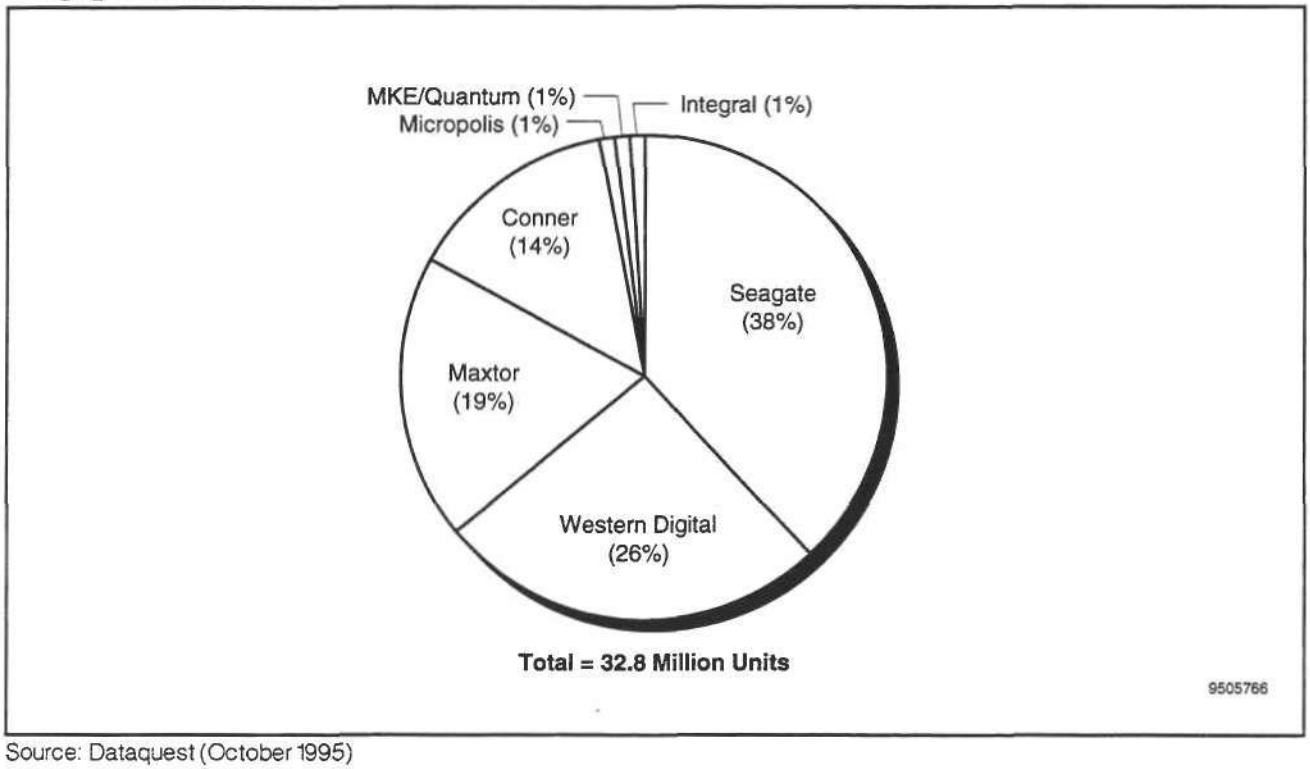
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Figure 3
Semiconductor Consumption in Disk Drives, Singapore



Source: Dataquest (October 1995)

Figure 4
Singaporean RDD Unit Production, 1994



Source: Dataquest (October 1995)

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manufacturing through the construction of new buildings and equipment upgrades in Singapore and in the region.

Seagate Technology plus Conner Peripherals

Seagate surprised the storage industry with the $1.1 billion in share swap with Conner Peripherals during the 1995 third quarter. Our 1994 worldwide disk drive unit share estimates showed Seagate cornering 18.7 percent and Conner owning 13.4 percent. Their marriage leads Seagate-Conner to become the largest manufacturer of disk drives in the world. The merger creates synergy between Seagate's strength in high-end drives and heads technology with Conner's advantage in desktop (and tape) drives and media technology.

Seagate's 15-year old Singaporean operation, which accounts for 90 percent of the company's worldwide output, is investing $137 million to construct its 1.2 million-square-foot "Seagate City" in Ang Mo Kio by mid-1996. The complex, claimed to be upon completion the largest single electronics manufacturing facility in Singapore, will consolidate Seagate's scattered RDD, PCB, administrative, and warehousing operations. With the new complex, Seagate hopes to boost its capacity by 25 percent. Seagate is expected to have four component facilities in Malaysia, one in Thailand, and a new RDD assembly facility in Wuxi, China by the end of this year.

Conner's maiden facility in Singapore, established in 1987, will continue to maintain its output of 750,000 drives per quarter. Singapore will be the center for assembling high-end 3.5-inch (1GB to 4GB) and 2.5-inch (350MB to 540MB) drives. Conner Penang in Malaysia produces another 1.5 million units a quarter. The 420,000-square-meter facility is the primary center for manufacturing midrange 3.5-inch (850MB and 1.2GB) drives, accounting for 60 percent of Conner's global capacity. A majority of the 850MB product is supplied to Packard Bell. Conner introduced the Cabo and Stingray series during the third quarter of 1995, and is expected to follow with the La Paz series in the fourth quarter. Conner also has a third new facility, a 100,000-square-foot site in Shenzhen, China, which was set up through a joint venture with Shenzhen Peripherals, a subsidiary of China Electronics Corp. The Chinese joint venture is expected to produce 250,000 units per quarter of midrange 3.5-inch drives in 1995.

Integral Peripherals

Integral is the dominant global force behind the 1.8-inch drive market, especially with the demise of Ministor in Singapore. Integral recently moved to a larger facility in Woodlands, north of Singapore, and it is expected to run three manufacturing lines by the end of 1995. This is part of Integral's three-year, $75 billion upgrade plan. Integral expects to increase significantly its 1.8-inch capacity in anticipation of growth potential in cameras and other portable equipment. It also plans to begin assembling 2.5-inch (1GB) drives in anticipation of a boom in the explosive notebook market.

Maxtor/Hyundai

Maxtor established its Bahamas-incorporated company in Singapore in 1983. The company's 5,000-person Singapore plant manufactures about 1.8 million units of 3.5-inch midrange drives per quarter, which represents almost all of Maxtor's global output. The Korean-based Hyundai, which had previously invested in Maxtor, recently bought out Maxtor's Asian operations, thereby establishing Korea's commitment to the industry. With the extra muscle from Maxtor and plans to build another disk drive facility

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in China, Hyundai aims to become a global storage manufacturer. Maxtor has designated Korea as its center for the assembly of 2.5-inch low-end drives, and with an initial investment of $6.3 million, Maxtor Korea expects to produce 200,000 units in 1995. Maxtor's PCB assembly facility in Hong Kong may relocate its board assembly to Singapore in order to focus on the more profitable manufacture of motherboards for AST and Apple.

Micropolis

Micropolis, a Singaporean operation founded in 1986, is one of the major players in the assembly of high-end gigabyte drives. In 1994, the Micropolis Singapore plant accounted for a total revenue of $400 million. It is investing $34 million in a new, 302,000-square-foot building. Included in this building will be a 40,000-square-foot, single-floor cleanroom that will accommodate the development of magneto-resistive (MR) technology and low-flying disk drive heads. The new facility, scheduled for completion in June 1996, could double Micropolis' production capacity to 1 million drives a year, including MR recording heads. Micropolis assembles its 3.5-inch to 5.25-inch drives in a ratio of 2:1 by unit volume. It has component assembly facilities in Thailand and the United States.

Western Digital

Western Digital set up its Singaporean facility in 1988. The 250,000-square-foot facility produces 2.2 million drives per quarter, and is capable of a 10 to 20 percent production increase. Adding to its core 3.5-inch products, Western Digital is now manufacturing a 1-inch 340MB disk drive and a 2.5-inch drive. WD Singapore is now constructing a second facility (82,000 square feet) in Singapore to assemble high-end drives. Expansion is also under way in its new Malaysian facility where current capacity stands at 500,000 units per quarter. Once the expansion is complete, WD Malaysia hopes to boost capacity to 1 million units a quarter and improve its global output by 25 percent.

Quantum/KEIS

Quantum stormed the disk drive industry through acquisition of Digital Equipment's storage division in October 1994. The buyout was seen as a way for Quantum to obtain critical mass, design resources, and establish production facilities of high-performance, high-storage-capacity disk drives. It is collaborating with Kotobuki Electronics Industries Singapore (KEIS), a subsidiary of Matsushita Kotobuki Electronics, to assemble 3.5-inch disk drives in Singapore. The company's 205,000-square-foot facility employs 600 workers. Quantum also has a Malaysian plant that is undergoing a $10-million expansion that will increase its current 10,000 square feet to 450,000 square feet. This plant, Quantum Storage Malaysia, assembles only 3.5-inch high-end drives with storage capacities exceeding 2GB for servers and workstations. Its other facility, Quantum Peripherals Malaysia, functions as a repair center and a consolidated, worldwide customer service operation. Quantum has also invested $65 million in a new, 100,000-square-foot component facility on Indonesia's Batam Island. Maximum capacity from this plant is estimated at 10 million head gimbals and 4 million head stacks for high-end applications. It is expected to be one of the first in the world to ship MR heads.

IBM

IBM is the last major U.S. disk-drive manufacturer to come to Singapore, although it has had a presence in Southeast Asia since 1991 through its contract manufacturer, Saha Union, in Thailand. It is moving into Singapore

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by transferring lines from its Minnesota and California plants. Dataquest estimates IBM is investing $52 million in a 230,000-square-foot Singaporean plant to produce 1GB and 5GB disk drives for file servers, workstations, and online systems. This facility will also assemble components such as head gimbals, head stacks, and head disks. The Thai facility, subcontracted to Saha Union, is estimated to produce 1 million units of low-capacity 3.5-inch disk drives per quarter. IBM is building a similar facility in Hungary that is expected to begin production next year.

Regional Competition in the Making

Singapore's reign in Southeast Asia as home to the giant manufacturers will not go unchallenged by neighboring countries, and its advantages of having an established industry infrastructure and highly skilled workforce may not be enough to keep manufacturers from moving to Malaysia, Thailand, and elsewhere. Recently, the Philippines has emerged as another attractive country for cheap labor and aggressive government incentives.

Malaysia

Malaysia is considered the second most economical manufacturing base after Singapore. Exports of disk drives leaped in 1993 as Conner began to ramp up its capacity. Hewlett-Packard also has operations in Penang, and Western Digital in Selangor, South of Penang. Malaysia's storage industry is also integrated with component assembly (Seagate, Quantum, and Read-Rite) and recording media manufacturing (Komag) facilities.

Hewlett-Packard

When Hewlett-Packard (HP) arrived in Penang, Malaysia, in 1972, it was already a pioneer in the electronics industry. Today, HP's existing assembly and optoelectronics test site now also functions as the company's global center for manufacturing high-capacity disk drives. This follows from the complete transfer of the 3.5-inch 1GB through 4GB disk drive manufacturing operation from Bristol, England, to a 600,000-square-foot Penang facility. HP is expected to invest over $200 million in its Penang facility over the next four years in an expansion effort that will make it the company's largest global RDD manufacturing facility. In the meantime, HP's Idaho plant will maintain its current production level of 75,000 to 100,000 units per month. Sixty percent of HP's current capacity is supplied to other vendors, including those with PC manufacturing operations in Asia.

Philippines

The Philippines is fast proving to be another investment hotbed for electronics manufacturers. After a period of political uncertainty, the country is pushing hard to develop its electronics infrastructure, particularly in the Laguna and Subic areas. Other industrial zones such as Clark are also being developed. In 1994, investment in the Philippines surged to an all-time high of $987 million, a remarkable 357 percent jump from 1993. The Philippines' existing electronics industry, which includes semiconductor packaging, floppy disk drive assembly, and the manufacture of disk drive components and communications products, will likely see a dramatic expansion in rigid disk drive assembly.

Hitachi, Fujitsu, and Toshiba have started or will soon start disk drive assembly in Laguna Technopark, 25 miles south of Manila. The location was chosen because of the full capacity of the country's other industrial parks, and because Technopark offers better infrastructure and facilities,

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and a good physical distribution network. What brought this Japanese team together was an earlier agreement among Fujitsu, Hitachi, NEC, and Toshiba to form a $2 million consortium to develop small form factor, large storage capacity disk drives in Japan. We expect NEC and IBM (Fujisawa, Japan) to announce a similar investment soon, in view of the onslaught of the yen on the domestic manufacturers. NEC is now subcontracting out an annual capacity of 1.5 million units of disk drives. Both Hitachi and Toshiba are using Integrated Microelectronics Inc. (IMI) as their subcontractor. However, some of the component supplies and PCB assembly will still come from either Singapore or Japan.

Hitachi

Hitachi has been involved in the high-end disk drive industry serving the mainframe markets for three decades. Hitachi's Data Storage and Retrieval Systems Division has been producing 3.5-inch and 5.25-inch disk drives. While its first two facilities, Hitachi Computer Products (America) Inc. in Oklahoma and Hitachi Computer Products (Europe) S.A. in France, deal with large disk-drive subsystems, Hitachi has recently announced that it is setting up a third storage manufacturing facility in Laguna Technopark. Established with a capital of $39 million, this facility is Hitachi's first 2.5-inch disk drive facility. Operating under Hitachi Computer Products (Asia) Corp., the 900,000-square-foot facility (floor space of 166,000 square feet) aims to manufacture two-thirds of Hitachi's 2.5-inch drives and magnetic heads. Hitachi began manufacturing in April of this year. Based on a capacity range of 60,000 to 90,000 units per month, Hitachi may achieve maximum capacity of 720,000 units this year. Hitachi is subcontracting out the board stuffing operation to Tri-M Singapore.

The Hitachi plant calls for a total investment of $90 million through 1999. During this four-year period, employment will be increased from 700 to 1,800, and Hitachi plans to increase revenue from $165 million to $584 million.

Fujitsu

Fujitsu plans to invest $300 million over five years on an 8-hectare lot at the Carnelray Industrial Park in Canlubang, Laguna. The operation will be managed by Fujitsu Philippines Inc., which is currently distributing computer-related systems principally for large capacity applications. The new facility is expected to be fully operational in 1998. Fujitsu hopes to have a monthly output of 1 million units of both CD-ROM drives and disk drives by 1997; the storage capacity of these disk drive ranges from 600MB to 4.4GB. The new operation will employ 1,600, and is expected to generate cumulative revenue of $300 million by 1999.

Toshiba

Toshiba is expected to spend an initial $50 million to build a 2.5-inch disk drive manufacturing facility in the Philippines. It is subcontracting out 100,000 units per month. After October 1996, Toshiba plans to assemble its own disk drives. Its target is to produce annually 1.8 million units of disk drive by October 1998. This facility will also be responsible for assembling CD-ROM drives (3.6 million units per year) and PC boards (360,000 units per year). The latter will be fed to Toshiba's PC manufacturing facilities in the United States and Germany. Toshiba is also considering expansion to manufacture laserdisks, videodisk drives, and personal computers. The CD-ROM drives will be sold to U.S. clients such as HP, Apple, and Compaq.

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Singapore Races Ahead by Incorporating Media Manufacturing

Singapore's recipe of two-decade success in the storage manufacturing industry does not include disk drive media. Market leader Komag, which is the pioneer media manufacturer in Malaysia, enjoys the privilege of being the region's major supplier. However, the picture will likely change this year because four companies have announced production plans in Singapore. Media manufacturing will likely play an important role in Singapore's long-term manufacturing success because it would "root" major disk drive manufacturers in the country by providing a closer source.

Hoya, StorMedia, and CDD are to be located in Tuas, west of Singapore, while Seagate Magnetics will set up in Woodlands, north of Singapore and away from its mega disk drive facility in Ang Mo Kio, central Singapore. Western Digital is expected to announce the establishment of its second disk drive media manufacturing facility in the region within a year. We could also expect several more new players to join these pioneers.

Hoya is the first and only Japanese company to announce manufacturing plans in Singapore. It is also the only company to manufacture glass-based media. Hoya's $30 million investment targets production of 1 million units per month by the end of the year. Hoya is seriously considering a second facility at a cost of $24 million.

StorMedia will invest $27 million in three lines to produce 1 million units of aluminum media per month. The 150-strong outfit will begin production at the end of the year. StorMedia plans to invest $40 million in a second facility at the end of next year. Its clients include Seagate, Quantum, Western Digital, and Maxtor.

Seagate's global media expansion in Fremont and Anaheim in California, and in Singapore, calls for an investment of $100 million. The expansion will double Seagate's output. StorMedia and Akashik are supplementing Seagate's demand for media.

CDD, a spin-off from Conner, will invest $44 million in an aluminum-based media facility, scheduled for initial production with the first line in early 1996. All three lines will be operational by middle 1996, which could produce 18,000 units per day. CDD plans to invest an additional $110 million next year, which will be accompanied by a rise in headcount from 230 to 600. CDD supplies 5 percent to the merchant market and plans to grow its merchant market segment.

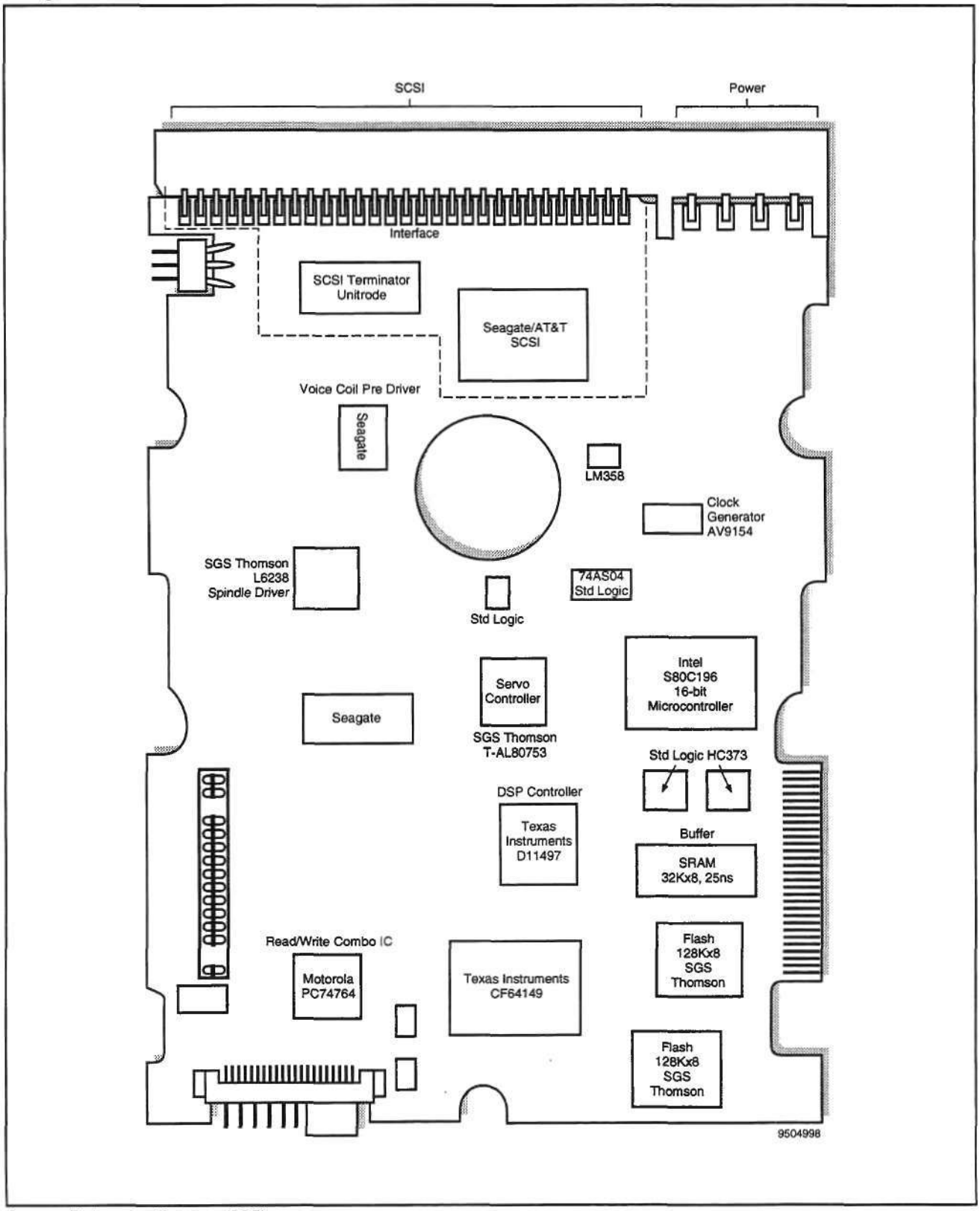
Komag Malaysia earlier announced the construction of its second plant, with floor space of 23,000 square feet, in the state of Sarawak, East Malaysia. The $100 million facility will begin producing only substrates in March 1996. Komag's current facility in Penang will get four additional media manufacturing lines and a $78 million expansion that will increase space by 50 percent to 123,000 square feet. The facility has a current capacity of 10,000 units per day.

Teardown Analysis

Figure 5 shows a schematic of a mainstream disk drives, taken from Seagate's 3.2GB board. Partial information of the material bill ia also provided (Mark Giudici, Scott Hudson, and Allen Leibovitch of the Semiconductor Procurement Worldwide program and Geoff Ballew of the Semiconductor Applicaiton Market Worldwide program contribuited to this section). Table 2 shows the bill of materials model for the same drive.

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Figure 5
Seagate Semiconductor Content



Source: Dataquest (October 1995)

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Table 2
Bill of Materials Model: Seagate's 3.5-Inch Disk Drive (Density 3.2GB)

Type	Manufacturer	Part Number	Function	1995 Cost ($)
Custom Device	Seagate	DC-3 9258 C9506 "Astra"	Voltage monitor	
Power MOSFET			External current regulator for spindle motor	0.50-1.00
ASIC/ Microprocessor		L6238SQA 1B85C9509 PHIL	Spindle driver	1.80
Resistor		WSC-1 2Q15 MC19430	Sense resistor for spindle, 0.2 ohms	0.30
Capacitor		4.7-50 FI	Charge pump capacitor for spindle driver IC (tantalum)	0.30
Custom Device	Seagate	BZ-3 9191 A9506	Skynet voice coil predriver to move actuator	
Power Transistors		D3A S2 4K	Drivers for actuator	0.20-0.30
SCSI Chip Controller		UC5601DWP U9510		21.50
ASIC Device	Seagate/AT&T	100095-501 Seagate AT&T 115003 9446J 3164374	Communicates with drive and host	
Capacitor		47-16 F3(2)	Decoupling capacitor (tantalum)	0.30
Dual Op Amp		LM358 51T AKNG		0.40
Op Amp		33272		0.23
Crystal Oscillator		ICS 6613 9434 AV9154A-22	Variable clock	1.50
Logic Gate		P49AB DM 74AS04M		0.50
MCU	Intel	S806196KC20 L5080883J (16-bit MCU, $3 to $4)	16-bit MCU	3.85
Logic Octal	TI	HC 373 52K C5NN		0.30
SRAM	Toshiba	TC 55328AJ-25 944 5 HAK	32Kx8 25ns SRAM	2.50
Flash	SGS-Thomson	7579 1929 S-LO	1Mb flash	4.30
Flash	SGS-Thomson	7579 1929 S-HI	1Mb flash	4.30
Servo Controller		T-AL80753 FK 11A9509 SGS-T	Identifies and positions head	
	TI	CF64149PGJ E 52A4K7W		2.00-3.00
DSP Controller		D11497PN (C) 92TI F-52AVCDW "Opus"	Controls position of servo head, obeys SOC 196 commands	
Read/Write Combo IC	Motorola	PC 74764CFU AAON9502		2.50

Source: Dataquest (October 1995)

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Dataquest Perspective

Asia/Pacific has been undergoing structural changes in the storage business. Quantum challenged Seagate through the acquisition of Digital's storage division to boost its unit volume. Seagate, already well-integrated and backed by a strong history of acquisitions (of Imprimus and several software companies), responded with the recent purchase of Conner Peripherals. Samsung was sidelined in this process, and is seen as waiting to pounce on another opportunity. Another Korean player, Hyundai Electronics, decided to gobble up the entire Maxtor operation in Asia/Pacific. And the Japanese (Hitachi, Fujitsu, and Toshiba) are busy aligning themselves in the Philippines. Further consolidation, where the large companies get larger, could spell less volatility in pricing and longer life cycles in disk drives.

Meanwhile, Singapore continues to ramp up production capacity, with emphasis on mainstream products. It is also emphasizing its lead through incorporating recording media manufacturing. The quick ramp-ups are putting a strain on component suppliers. Singapore will be the leading manufacturing base throughout this decade. Malaysia is Singapore's closest competitor. It has a head start in recording media manufacturing, but may lose out to Singapore unless it can convince other players to join Komag. Malaysia claims two of the finest global facilities (HP and Conner-Seagate) in the Penang/Prai area and several of the component assembly facilities. The Philippines joins the manufacturing arena through investments from Japanese disk drive manufacturers. As in the other countries in the region, the Philippines will start to assemble CD-ROM drives, again through the same Japanese storage manufacturers. Thailand will maintain its supply of assembled whole drives and components, while South Korea's semiconductor companies will push to diversify their manufacture of electronics systems.

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Analysis

Taiwan's Data Communications Equipment Outlook

Abstract: *In addition to Dataquest's revenue-based electronic equipment production forecasts and analysis, we have begun tracking unit-level data for high-volume electronic equipment production in Asia/Pacific. This report focuses on Taiwan's fastest-growing application market, communications, which is the second-largest end market, after data processing.*

By Ben F.P. Lee

Industry Overview

Taiwan's data communications equipment production has boomed along with the development of Taiwan's personal computer industry during the past few years. Dataquest expects Taiwan's modem and network equipment to continue its breakneck growth and to increase its share of worldwide production. Taiwan's successes and expertise in data processing systems design and manufacturing are key factors behind the rapid expansion and global competitiveness of data communications. We believe that radio communications equipment is one of the more promising areas for Taiwanese companies, although current production quantities are relatively small as compared with other sectors.

We are dividing our analysis of the communications industry in Taiwan into three sections: central office switching equipment, data communications equipment, and wireless communications equipment.

Top 10 Products

As shown in Table 1, the factory revenue from Taiwan's top 10 communications products was $2 billion in 1994. In this third-quarter survey, we estimate factory revenue will reach $2.2 billion in 1995, which represents growth of 6.1 percent. Central office switching equipment, which is sold primarily within Taiwan, is the largest communications sector in terms of revenue, followed by modems and transmission equipment, respectively.

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Data communications equipment, mainly modems and LAN cards, is showing growth consistent with the prosperity of personal computer industry in Taiwan. Taiwan is one of the world's largest exporters of modems and LAN cards. The combination of computer and communications technologies is creating huge demand in new application markets, in which Taiwan is likely to play a major role in the next few years.

With the worldwide explosion in mobile communications, Taiwan's industry and government research institutes are targeting wireless as a major area for Taiwan's next generation of information technology (IT) products. In the short term, we see pagers, walkie-talkies, and cellular phones as the primary high-volume products to be built in Taiwan.

Central Office Switching Equipment

Factory revenue from Taiwan's central office switching equipment industry reached about $573 million in 1994. We expect industry revenue to shrink to $552 million in 1995 because of increased competition in Taiwan's domestic market. Shipments to the domestic Taiwan market represent the lion's share of total production, as shown in Figure 1.

There are currently three major companies that produce central office switching equipment in Taiwan: Taiwan International Standard Electronics, Siemens Telecommunications Systems, and AT&T Taiwan. Taiwan International's technology source is Alcatel, which is based in France, but products are developed mainly in Taiwan for the local market. Siemens and AT&T in Taiwan rely more on their parent companies in Germany and the United States, respectively, for product development and designs. For a number of years, Taiwan government policy required foreign companies to procure key components from Taiwan in order to reduce reliance on imports and advance development of local industry. In 1992, these three companies started exporting their Taiwan-built equipment to Southeast Asia and China.

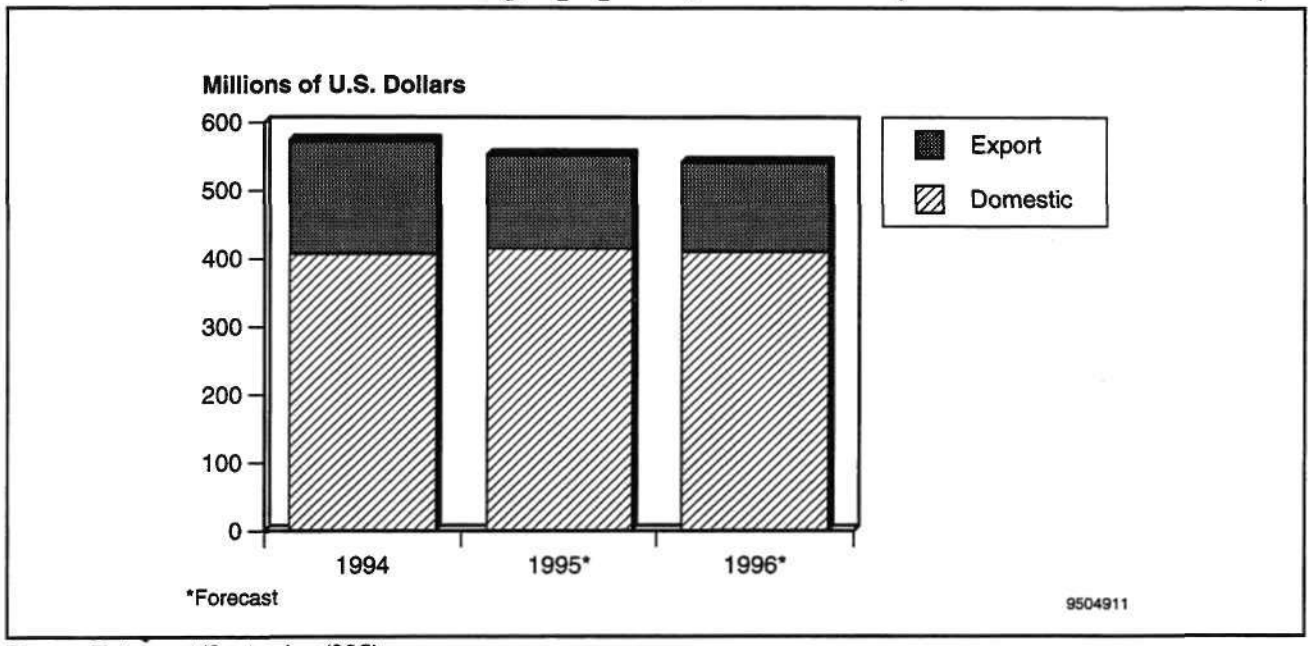
Table 1
Taiwan's Communications Equipment Production, 1994 to 1996
(Millions of U.S. Dollars)

	1994	1995*	1996*	CAGR (%) 1994-1996
Central Office Switching Equipment	573	552	541	-2.8
Modems	348	369	386	5.3
LAN Cards	223	254	294	14.8
Transmission Equipment	306	310	316	1.6
Cordless Telephones	183	204	234	13.1
Facsimiles	142	172	194	16.9
Pagers	99	118	135	16.8
Radio Receivers	85	96	108	12.7
GPS Receivers	41	48	56	16.9
Walkie-Talkies	42	44	41	1.2
Total	2,042	2,167	2,305	6.2

*Forecast
Source: Dataquest (September 1995)

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Figure 1
Taiwan's Central Office Switching Equipment, 1994 to 1996 (Millions of U.S. Dollars)



Source: Dataquest (September 1995)

Data Communications Equipment

Unlike the central office switching industry, Taiwan's data communications production has been spurred by volume exports to the United States, Europe, and Japan, in that order.

Modems

As shown in Figure 2, modems and LAN cards are two of Taiwan's largest-volume data communications products. After experiencing about 20 percent growth in 1994 in both revenue and units, modem production in Taiwan reached 6 million units, which translated into $348 million in production revenue. This represented roughly 50 percent of worldwide production during 1994. Taiwan's main manufacturers include the recognizable names GVC, Askey, Aceex, and Zyxel. We have seen two types of modem companies evolve in Taiwan. One group of companies, including GVC and Askey, competes with large-scale production, achieving lower cost through economies of scale. Another group of companies, including Zyxel and E-Tech, differentiates itself with advanced technology and can capture unique and lucrative niche markets. Zyxel, for instance, developed its own data pump to sustain its competitive advantage.

As shown in Figure 3, high-speed modems (faster than 14.4 Kbps) are the mainstream, with more than 80 percent of this market (see Figure 3). In 1996, the market for 28.8 Kbps modems will expand to 28 percent.

LAN Cards

Taiwan's production of LAN cards reached 5.6 million units in 1994 and is expected to grow by about 20 percent annually during the next two years. Related products such as hubs, bridges, and routers are growing rapidly in Taiwan, thanks to high-growth export markets in North America and Europe. About 70 percent of total shipments from Taiwan companies go to

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North America and Europe. Japan, which has recently begun importing from Taiwan, consumes only 8 percent of Taiwan's total shipments.

As shown in Figure 4, over 80 percent of Taiwan's LAN production is Ethernet cards. We believe that 100-Mbps Ethernet card production will accelerate rapidly after 1995. D-Link and Accton are two leading companies in Taiwan in terms of both technology leadership and production volume. Both companies design LAN card chipsets for their own use.

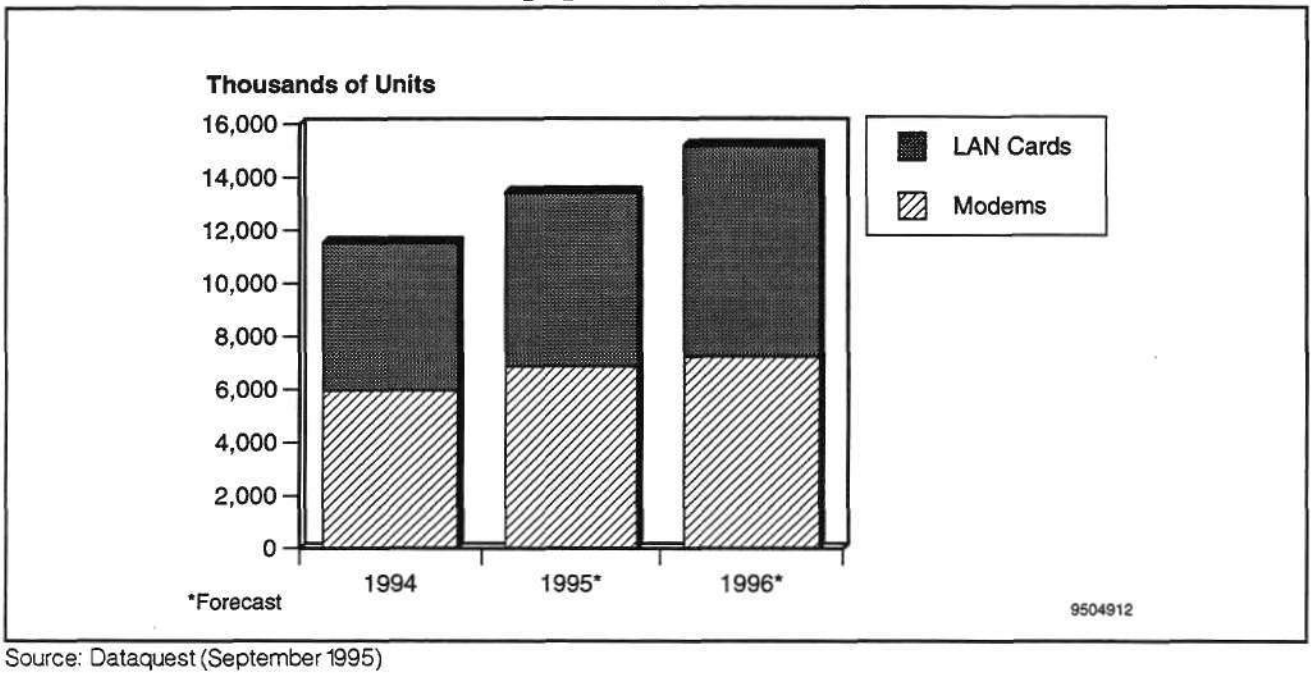
Taiwan has rapidly grown its modem and LAN card production in the past few years. However, most of its products are sold through OEM/ODM channels, as has been the case in the personal computer industry. Because of the very competitive and marketing-oriented U.S. and European markets, we do not expect Taiwanese companies to invest heavily in developing their own brand recognition but rather to focus on their technology and manufacturing competitive advantage.

Wireless Communications

Our survey of Taiwan's wireless communications equipment includes pagers, cellular phones, walkie-talkies, global positioning systems (GPS) receivers, and radio receivers (see Tables 2 and 3).

Although Taiwan's wireless markets have boomed in recent years, local producers have been unable to capitalize on market expansion in either Taiwan or China. Taiwan's companies have developed neither the manufacturing nor the technology building blocks for a wireless infrastructure.

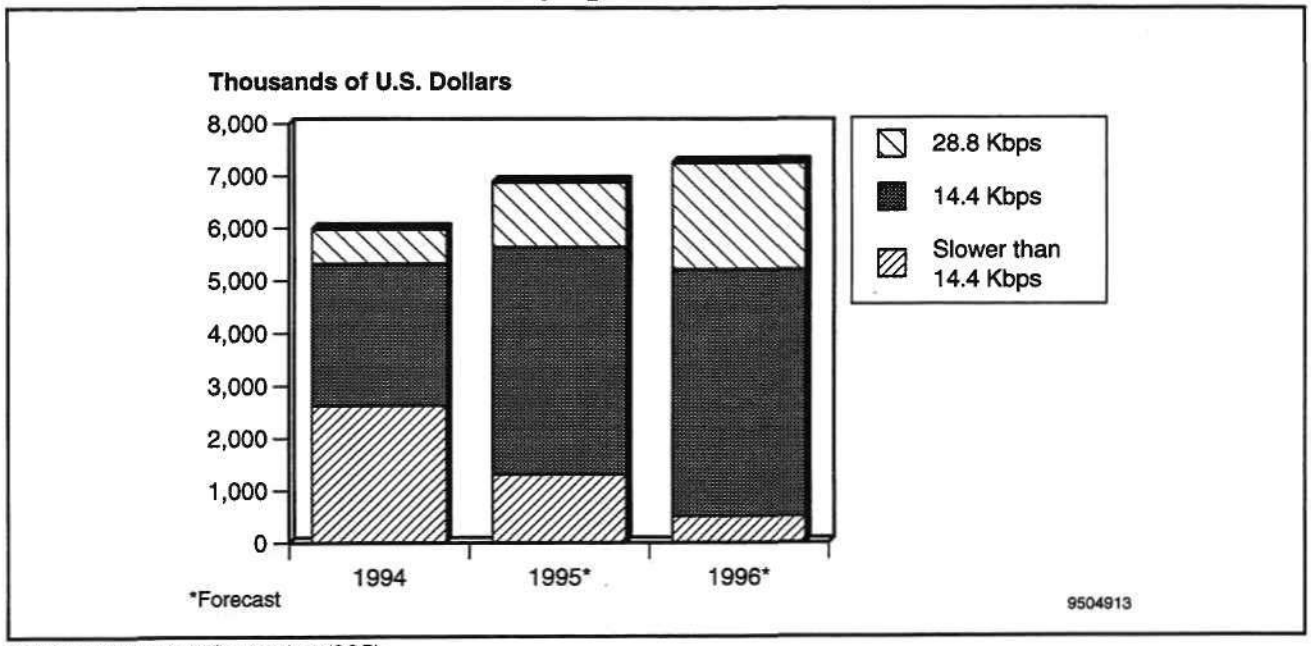
Figure 2
Taiwan's Data Communications Equipment, 1994 to 1996 (Thousands of Units)



Source: Dataquest (September 1995)

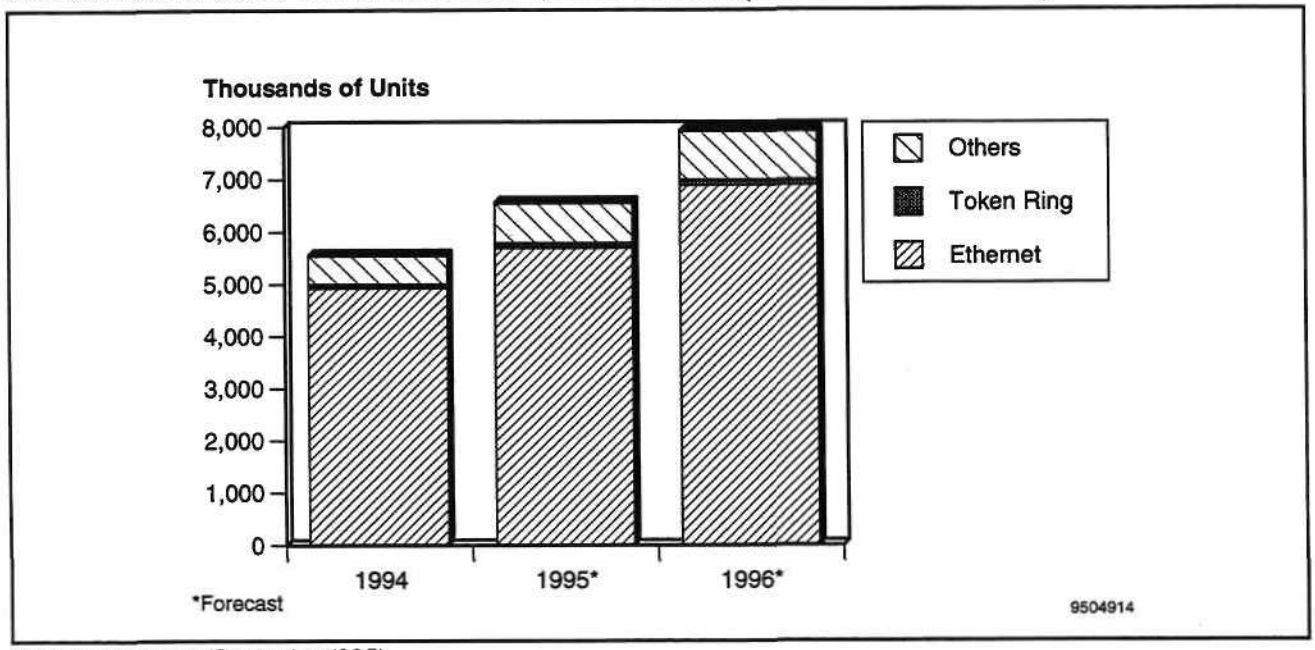
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Figure 3
Production of Modems in Taiwan, by Speed, 1994 to 1996 (Thousands of Units)



Source: Dataquest (September 1995)

Figure 4
Production of LAN Cards in Taiwan, 1994 to 1996 (Thousands of Units)



Source: Dataquest (September 1995)

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Table 2
Taiwan's Wireless Communications Equipment, 1994 to 1996 (Millions of U.S. Dollars)

	1994	1995*	1996*	CAGR (%) 1994-1996
Pagers	99	118	135	16.8
Cellular Telephones	7	10	12	30.9
Walkie-Talkies	42	44	41	1.2
GPS Receivers	41	48	56	16.9
Radio Receivers	85	96	108	12.7
Others	38	40	39	1.3
Total	312	356	391	11.9

*Forecast
Source: Dataquest (September 1995)

Table 3
Taiwan's Wireless Communications Equipment, 1994 to 1996 (Thousands of Units)

	1994	1995*	1996*	CAGR (%) 1994-1996
Pagers	1,540	1,875	2,230	20.3
Cellular Telephones	6	9	11	35.4
Walkie-Talkies	400	427	410	1.2
GPS Receivers	NA	NA	NA	

*Forecast
NA = Not available
Source: Dataquest (September 1995)

One of the main problems for Taiwan companies has been the lack of a clear worldwide standard to follow. Taiwan's companies have been forced to develop related products under at least four current standards: DECT, CT2, CDMA, and GSM. The different standards make it difficult for the companies to develop prototypes and mass-produce. Another problem has been the dominance of global players, such as Motorola, that have brand recognition, technology leadership, and competitive pricing. Local companies have therefore focused on the domestic or Asian markets, but still face mounting global competition.

Because the main products now made in Taiwan are wireless customer-premises equipment, including pagers, cellular phones, and walkie-talkies, we have generated a forecast that is conservative for the reasons stated. For the next few years we expect Taiwan's wireless production to grow because of the modest success of local companies in selling to the Greater China market (China, Hong Kong, and Taiwan).

Dataquest Perspective

Most of Taiwan's communications industries will be driven by local demand (including Greater China), with the important exception of data communications equipment, which will continue to be export-driven and increasingly linked to PC exports. Asia/Pacific is the fastest-growing telecommunications market in the world, and Taiwan companies are beginning

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to find opportunities in areas dominated by large multinationals, such as Siemens, AT&T, and Motorola. Alliances, partnering, and clearer global standards will play important roles in Taiwan's development as the electronics industry seeks to diversify and build on its PC-focused markets. This will be an important industry to watch in Taiwan.

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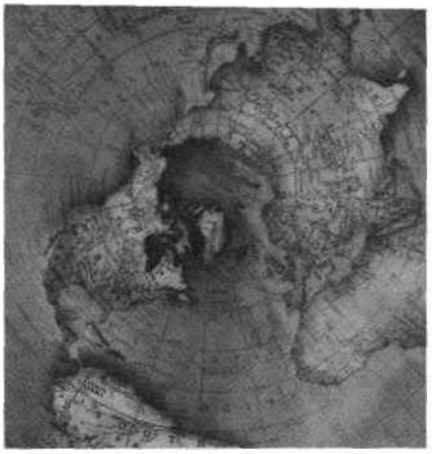
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Chinese Semiconductor Consumption by Application Market

Market Statistics

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Chinese Semiconductor Consumption by Application Market



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Note: All tables show estimated data.

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Chapter 1
Chinese Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in the month of January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications

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equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

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Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, power-train sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) electronics.

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- Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singaporean operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market—Database Tables

Section 1—Chinese Semiconductor Consumption by Application Market, History and Forecast

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Table 1-1
Chinese Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	8,102	10,549	14,241	18,334	23,885	31,697	40,908	52,022	63,635
Total Semiconductor	780	1,061	1,495	2,061	2,774	3,912	5,264	7,176	9,002
Total IC	646	883	1,250	1,724	2,344	3,313	4,502	6,176	7,744
Bipolar Digital	42	52	63	66	69	66	61	51	42
MOS Digital	352	508	750	1,101	1,508	2,175	3,071	4,437	5,489
MOS Memory	112	165	248	365	530	724	968	1,358	1,655
MOS Microcomponent	143	206	299	428	570	842	1,287	1,938	2,478
MOS Logic	97	138	203	307	408	609	816	1,141	1,356
Analog (Monolithic + Hybrid)	252	323	438	557	767	1,072	1,370	1,688	2,213
Total Discrete	110	142	191	265	344	484	615	815	1,019
Total Optoelectronic	25	36	54	72	85	115	148	186	239

Source: Dataquest (July 1995)

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Table 1-2
Chinese Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	766	1,357	2,079	2,838	3,848	5,225	6,935	8,976	11,354
Total Semiconductor	115	207	328	464	653	906	1,212	1,672	2,129
Total IC	111	199	313	443	627	863	1,152	1,592	2,021
Bipolar Digital	12	18	24	25	26	25	23	18	12
MOS Digital	88	158	250	360	511	707	937	1,319	1,709
MOS Memory	36	64	103	147	215	291	362	503	624
MOS Microcomponent	36	65	102	145	196	271	363	521	705
MOS Logic	16	29	45	68	100	145	212	295	380
Analog (Monolithic + Hybrid)	11	23	40	58	90	131	192	255	300
Total Discrete	3	5	8	12	15	25	35	45	58
Total Optoelectronic	1	3	7	9	11	18	25	35	50

Source: Dataquest (July 1995)

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Table 1-3
Chinese Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	939	1,329	2,194	3,181	4,572	6,943	9,768	13,523	16,678
Total Semiconductor	79	123	217	359	534	861	1,287	1,917	2,382
Total IC	65	101	178	303	455	743	1,145	1,761	2,197
Bipolar Digital	3	3	4	4	4	4	3	2	2
MOS Digital	43	69	124	224	331	549	857	1,354	1,645
MOS Memory	11	19	35	70	115	163	220	341	410
MOS Microcomponent	21	31	52	94	126	231	417	688	850
MOS Logic	11	19	37	60	90	155	220	325	385
Analog (Monolithic + Hybrid)	19	29	51	75	120	190	285	405	550
Total Discrete	11	17	29	44	65	100	120	130	155
Total Optoelectronic	3	5	10	12	14	18	22	26	30

Source: Dataquest (July 1995)

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Table 1-4
Chinese Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	320	367	443	510	685	856	1,158	1,427	1,695
Total Semiconductor	22	29	45	60	88	120	177	231	292
Total IC	17	23	36	48	70	93	135	180	226
Bipolar Digital	1	1	1	1	0	0	0	0	0
MOS Digital	12	17	26	34	51	66	103	140	196
MOS Memory	3	5	8	10	16	22	37	50	68
MOS Microcomponent	7	9	13	15	21	26	39	52	73
MOS Logic	2	3	6	9	14	18	27	38	55
Analog (Monolithic + Hybrid)	4	6	10	14	19	26	32	40	30
Total Discrete	4	5	7	9	14	22	35	42	55
Total Optoelectronic	1	1	2	3	4	5	7	9	11

Source: Dataquest (July 1995)

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Table 1-5
Chinese Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	5,528	6,817	8,528	10,565	13,222	16,732	20,599	25,010	29,977
Total Semiconductor	520	648	832	1,078	1,367	1,853	2,360	3,052	3,810
Total IC	414	514	660	843	1,077	1,462	1,865	2,372	2,959
Bipolar Digital	25	29	34	36	38	37	34	30	28
MOS Digital	179	229	301	412	519	725	1,002	1,392	1,643
MOS Memory	53	67	89	118	155	210	300	401	468
MOS Microcomponent	63	82	107	139	179	250	382	561	705
MOS Logic	63	80	105	155	185	265	320	430	470
Analog (Monolithic + Hybrid)	211	256	325	395	520	700	829	950	1,288
Total Discrete	88	110	140	190	237	321	405	570	711
Total Optoelectronic	18	24	32	45	53	70	90	110	140

Source: Dataquest (July 1995)

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Table 1-6
Chinese Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	203	301	592	660	798	1,001	1,267	1,632	2,138
Total Semiconductor	7	11	24	29	37	51	71	102	139
Total IC	6	10	22	27	34	47	65	92	123
Bipolar Digital	1	0	0	0	0	0	0	0	0
MOS Digital	4	7	17	21	27	37	50	75	102
MOS Memory	1	2	4	6	8	10	12	18	25
MOS Microcomponent	2	4	9	10	13	18	25	40	55
MOS Logic	1	2	4	5	6	9	13	17	22
Analog (Monolithic + Hybrid)	1	3	5	6	7	11	15	17	21
Total Discrete	1	1	1	2	2	3	5	9	14
Total Optoelectronic	1	1	1	1	1	1	1	1	2

Source: Dataquest (July 1995)

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Table 1-7
Chinese Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	346	378	405	579	760	941	1,182	1,454	1,793
Total Semiconductor	36	43	48	70	94	121	157	202	250
Total IC	32	37	41	60	81	106	139	179	218
Bipolar Digital	1	1	1	1	1	1	0	0	0
MOS Digital	25	29	33	50	69	91	122	157	194
MOS Memory	8	9	10	15	21	28	37	45	60
MOS Microcomponent	13	15	17	25	36	46	61	76	90
MOS Logic	4	5	6	10	13	17	24	36	44
Analog (Monolithic + Hybrid)	6	7	8	9	11	14	17	22	24
Total Discrete	3	4	6	8	11	13	15	19	26
Total Optoelectronic	1	2	2	2	2	2	2	4	6

Source: Dataquest (July 1995)

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Section 2—Chinese Consumption by Application Market, Annual Growth Rates

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Table 2-1
Chinese Semiconductor Consumption—Total Electronics (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	30.20	35.00	28.74	30.28	32.71	29.06	27.17	22.32	28.26
Total Semiconductor	36.02	40.90	37.88	34.60	41.03	34.58	36.32	25.44	34.30
Total IC	36.76	41.55	37.91	35.98	41.32	35.88	37.20	25.38	35.04
Bipolar Digital	24.29	21.07	4.43	4.70	-3.98	-8.61	-16.18	-17.77	-8.73
MOS Digital	44.36	47.54	46.88	37.00	44.21	41.19	44.48	23.71	37.90
MOS Memory	47.19	50.30	47.34	45.02	36.63	33.70	40.29	21.87	35.27
MOS Microcomponent	43.91	45.50	43.24	33.19	47.64	52.81	50.58	27.86	42.06
MOS Logic	41.75	47.27	51.70	32.78	49.28	34.01	39.83	18.84	34.58
Analog (Monolithic + Hybrid)	28.23	35.45	27.36	37.65	39.70	27.86	23.23	31.08	31.76
Total Discrete	29.41	34.65	38.73	30.03	40.62	27.07	32.46	25.09	30.94
Total Optoelectronic	46.12	49.44	34.21	18.52	34.78	28.77	25.59	28.73	27.17

Source: Dataquest (July 1995)

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Table 2-2
Chinese Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	77.2	53.2	36.5	35.6	35.8	32.7	29.4	26.5	32.0
Total Semiconductor	79.7	58.8	41.6	40.6	38.8	33.8	37.9	27.4	35.6
Total IC	79.0	57.7	41.7	41.4	37.7	33.5	38.2	27.0	35.4
Bipolar Digital	50.0	33.3	4.2	4.0	-3.8	-8.0	-21.7	-33.3	-13.7
MOS Digital	78.7	57.9	44.4	41.8	38.4	32.5	40.8	29.6	36.5
MOS Memory	75.8	60.2	43.8	46.0	35.2	24.4	39.0	24.1	33.5
MOS Microcomponent	80.6	56.9	42.2	35.0	38.4	33.9	43.5	35.3	37.2
MOS Logic	81.3	55.2	51.1	47.1	45.0	46.2	39.2	28.8	41.1
Analog (Monolithic + Hybrid)	114.3	75.6	46.8	55.2	45.6	46.6	32.6	17.9	38.9
Total Discrete	66.7	60.0	50.0	25.0	66.7	40.0	28.6	28.9	37.0
Total Optoelectronic	200.0	133.3	28.6	22.2	63.6	38.9	40.0	42.9	40.9

Source: Dataquest (July 1995)

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Table 2-3
Chinese Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	41.5	65.1	45.0	43.7	51.9	40.7	38.4	23.3	39.3
Total Semiconductor	55.2	76.1	65.5	48.7	61.1	49.6	49.0	24.2	46.0
Total IC	54.7	75.9	70.3	50.1	63.2	54.2	53.8	24.7	48.6
Bipolar Digital	6.7	9.4	5.7	5.4	-10.3	-14.3	-20.0	-37.5	-16.5
MOS Digital	60.5	79.0	81.7	47.6	65.8	56.1	58.0	21.5	48.9
MOS Memory	72.7	81.6	102.9	64.3	41.7	35.0	55.0	20.2	42.4
MOS Microcomponent	47.6	67.7	81.2	33.8	83.3	80.5	65.0	23.5	55.3
MOS Logic	72.7	94.7	62.7	49.8	71.8	41.9	47.7	18.5	44.9
Analog (Monolithic + Hybrid)	49.5	75.9	47.1	60.0	58.3	50.0	42.1	35.8	49.0
Total Discrete	54.5	70.6	51.7	47.7	53.8	20.0	8.2	19.4	28.6
Total Optoelectronic	66.7	100.0	20.0	16.7	28.6	22.2	18.2	15.4	20.1

Source: Dataquest (July 1995)

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Table 2-4
Chinese Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	14.7	20.7	15.1	34.4	24.9	35.4	23.2	18.8	27.1
Total Semiconductor	31.3	54.4	32.2	47.3	35.5	47.9	30.4	26.4	37.2
Total IC	33.3	56.9	31.9	46.5	31.6	46.2	33.1	25.7	36.3
Bipolar Digital	-30.0	-14.3	-16.7	-20.0	-25.0	-33.3	-50.0	-10.0	-29.0
MOS Digital	37.1	54.7	27.4	51.9	30.1	55.6	35.9	40.0	42.4
MOS Memory	66.7	66.0	14.5	70.5	35.8	68.2	35.1	36.0	48.2
MOS Microcomponent	21.6	38.9	20.0	36.7	26.8	50.0	33.3	40.4	37.2
MOS Logic	50.0	83.3	63.6	57.8	28.2	48.4	40.7	44.7	43.6
Analog (Monolithic + Hybrid)	37.5	72.7	47.4	35.7	36.8	23.1	24.4	-24.6	16.5
Total Discrete	25.0	40.0	28.6	55.6	57.1	59.1	20.0	31.0	43.6
Total Optoelectronic	20.0	66.7	50.0	36.7	29.3	32.1	30.0	20.9	29.7

Source: Dataquest (July 1995)

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Table 2-5
Chinese Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	23.3	25.1	23.9	25.1	26.5	23.1	21.4	19.9	23.2
Total Semiconductor	24.5	28.5	29.6	26.8	35.5	27.3	29.3	24.8	28.7
Total IC	24.0	28.5	27.7	27.7	35.8	27.5	27.2	24.7	28.5
Bipolar Digital	18.4	17.2	5.9	5.6	-2.6	-8.1	-11.8	-6.7	-4.9
MOS Digital	28.0	31.7	36.9	25.9	39.7	38.2	38.9	18.0	31.9
MOS Memory	26.7	33.8	32.6	31.4	35.5	42.9	33.7	16.7	31.7
MOS Microcomponent	30.2	30.5	30.0	28.7	39.7	52.8	46.9	25.7	38.3
MOS Logic	27.0	31.3	47.6	19.4	43.4	20.7	34.4	9.3	24.8
Analog (Monolithic + Hybrid)	21.3	27.0	21.5	31.6	34.6	18.4	14.6	35.6	26.7
Total Discrete	25.0	27.3	35.7	24.8	35.3	26.2	40.7	24.8	30.2
Total Optoelectronic	33.3	33.3	40.6	17.8	32.1	28.6	22.2	27.3	25.5

Source: Dataquest (July 1995)

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Table 2-6
Chinese Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	48.3	96.7	11.5	20.9	25.4	26.6	28.8	31.0	26.5
Total Semiconductor	65.2	107.9	24.1	26.9	37.9	38.7	43.6	35.3	36.4
Total IC	67.8	122.2	21.4	28.5	37.8	37.7	41.5	33.7	35.7
Bipolar Digital	-20.0	-25.0	-33.3	-50.0	-50.0	-20.0	-25.0	-66.7	-45.1
MOS Digital	47.7	156.9	22.8	32.7	34.9	36.2	50.0	36.0	37.8
MOS Memory	50.0	146.7	48.6	45.5	25.0	20.0	50.0	38.9	35.4
MOS Microcomponent	45.8	157.1	11.1	32.0	37.9	37.4	60.0	37.5	40.6
MOS Logic	50.0	166.7	25.0	20.0	41.7	52.9	30.8	29.4	34.5
Analog (Monolithic + Hybrid)	200.0	66.7	20.0	16.7	50.0	42.9	13.3	23.5	28.5
Total Discrete	40.0	14.3	112.5	17.6	50.0	66.7	80.0	55.6	52.5
Total Optoelectronic	60.0	12.5	11.1	0	20.0	8.3	7.7	14.3	9.9

Source: Dataquest (July 1995)

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Table 2-7
Chinese Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	9.2	7.1	43.0	31.2	23.9	25.5	23.1	23.3	25.4
Total Semiconductor	18.0	13.3	43.8	34.6	28.8	29.9	29.0	23.8	29.2
Total IC	14.6	10.6	46.6	34.9	30.7	32.1	28.6	21.7	29.5
Bipolar Digital	-10.0	-11.1	-25.0	16.7	-28.6	-20.0	-25.0	-33.3	-19.7
MOS Digital	15.1	12.1	53.8	38.0	31.9	34.1	28.7	23.6	31.1
MOS Memory	9.8	11.1	50.0	36.7	36.6	32.1	21.6	33.3	32.0
MOS Microcomponent	15.4	10.0	51.5	44.0	27.8	32.6	24.6	18.4	29.2
MOS Logic	25.0	20.0	66.7	25.0	36.0	41.2	50.0	22.2	34.5
Analog (Monolithic + Hybrid)	16.7	7.1	22.7	19.6	27.3	21.4	29.4	9.1	21.1
Total Discrete	33.3	50.0	33.3	37.5	18.2	15.4	26.7	36.8	26.6
Total Optoelectronic	80.0	-11.1	12.5	11.1	10.0	9.1	66.7	55.0	28.1

Source: Dataquest (July 1995)

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Section 3—Chinese Semiconductor Consumption by Application Market, Input/Output Ratios

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Table 3-1
Chinese Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	9.62	10.05	10.49	11.24	11.61	12.34	12.87	13.79	14.15
Total IC	7.97	8.37	8.78	9.40	9.82	10.45	11.00	11.87	12.17
Bipolar Digital	0.52	0.49	0.44	0.36	0.29	0.21	0.15	0.10	0.07
MOS Digital	4.34	4.82	5.26	6.00	6.31	6.86	7.51	8.53	8.63
MOS Memory	1.38	1.56	1.74	1.99	2.22	2.28	2.37	2.61	2.60
MOS Microcomponent	1.76	1.95	2.10	2.34	2.39	2.66	3.15	3.73	3.89
MOS Logic	1.20	1.30	1.42	1.68	1.71	1.92	1.99	2.19	2.13
Analog (Monolithic + Hybrid)	3.11	3.06	3.07	3.04	3.21	3.38	3.35	3.25	3.48
Total Discrete	1.35	1.34	1.34	1.44	1.44	1.53	1.50	1.57	1.60
Total Optoelectronic	0.30	0.34	0.38	0.39	0.36	0.36	0.36	0.36	0.38

Source: Dataquest (July 1995)

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Table 3-2
Chinese Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	15.00	15.22	15.78	16.36	16.97	17.34	17.48	18.62	18.75
Total IC	14.48	14.63	15.06	15.62	16.29	16.52	16.61	17.73	17.80
Bipolar Digital	1.57	1.33	1.15	0.88	0.68	0.48	0.33	0.20	0.11
MOS Digital	11.54	11.64	12.00	12.70	13.28	13.53	13.51	14.69	15.05
MOS Memory	4.75	4.72	4.93	5.19	5.59	5.57	5.22	5.60	5.50
MOS Microcomponent	4.70	4.79	4.91	5.11	5.09	5.19	5.23	5.80	6.21
MOS Logic	2.09	2.14	2.16	2.40	2.60	2.78	3.06	3.29	3.35
Analog (Monolithic + Hybrid)	1.37	1.66	1.90	2.04	2.34	2.51	2.77	2.84	2.64
Total Discrete	0.39	0.37	0.38	0.42	0.39	0.48	0.50	0.50	0.51
Total Optoelectronic	0.13	0.22	0.34	0.32	0.29	0.34	0.36	0.39	0.44

Source: Dataquest (July 1995)

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Table 3-3
Chinese Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	939	1,329	2,194	3,181	4,572	6,943	9,768	13,523	16,678
Total IC	6.96	7.61	8.11	9.53	9.95	10.69	11.72	13.03	13.17
Bipolar Digital	0.32	0.24	0.16	0.12	0.09	0.05	0.03	0.02	0.01
MOS Digital	4.58	5.19	5.63	7.05	7.24	7.91	8.77	10.01	9.86
MOS Memory	1.17	1.43	1.57	2.20	2.52	2.35	2.25	2.52	2.46
MOS Microcomponent	2.24	2.33	2.37	2.96	2.76	3.33	4.27	5.09	5.10
MOS Logic	1.17	1.43	1.69	1.89	1.97	2.23	2.25	2.40	2.31
Analog (Monolithic + Hybrid)	2.07	2.18	2.32	2.36	2.62	2.74	2.92	2.99	3.30
Total Discrete	1.17	1.28	1.32	1.38	1.42	1.44	1.23	0.96	0.93
Total Optoelectronic	0.32	0.38	0.46	0.38	0.31	0.26	0.23	0.19	0.18

Source: Dataquest (July 1995)

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Table 3-4
Chinese Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	7.00	8.01	10.25	11.76	12.90	14.00	15.30	16.19	17.23
Total IC	5.44	6.32	8.22	9.41	10.26	10.81	11.68	12.61	13.34
Bipolar Digital	0.31	0.19	0.14	0.10	0.06	0.04	0.02	0.01	0.01
MOS Digital	3.88	4.63	5.94	6.57	7.43	7.74	8.90	9.81	11.56
MOS Memory	0.94	1.36	1.87	1.86	2.36	2.57	3.20	3.50	4.01
MOS Microcomponent	2.31	2.45	2.82	2.94	2.99	3.04	3.37	3.64	4.31
MOS Logic	0.63	0.82	1.24	1.76	2.07	2.13	2.33	2.66	3.25
Analog (Monolithic + Hybrid)	1.25	1.50	2.14	2.75	2.77	3.04	2.76	2.79	1.77
Total Discrete	1.25	1.36	1.58	1.76	2.04	2.57	3.02	2.94	3.25
Total Optoelectronic	0.31	0.33	0.45	0.59	0.60	0.62	0.60	0.64	0.65

Source: Dataquest (July 1995)

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Table 3-5
Chinese Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	9.41	9.50	9.76	10.20	10.34	11.08	11.46	12.20	12.71
Total IC	7.49	7.53	7.74	7.98	8.15	8.74	9.05	9.48	9.87
Bipolar Digital	0.44	0.43	0.40	0.34	0.29	0.22	0.17	0.12	0.09
MOS Digital	3.23	3.35	3.53	3.90	3.93	4.33	4.86	5.57	5.48
MOS Memory	0.95	0.98	1.04	1.12	1.17	1.26	1.46	1.60	1.56
MOS Microcomponent	1.14	1.20	1.25	1.32	1.35	1.49	1.85	2.24	2.35
MOS Logic	1.14	1.17	1.23	1.47	1.40	1.59	1.55	1.72	1.57
Analog (Monolithic + Hybrid)	3.82	3.76	3.81	3.74	3.93	4.18	4.02	3.80	4.30
Total Discrete	1.59	1.61	1.64	1.80	1.79	1.92	1.97	2.28	2.37
Total Optoelectronic	0.33	0.35	0.38	0.43	0.40	0.42	0.44	0.44	0.47

Source: Dataquest (July 1995)

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Table 3-6
Chinese Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	3.40	3.79	4.00	4.45	4.67	5.14	5.63	6.28	6.48
Total IC	2.91	3.29	3.72	4.05	4.30	4.72	5.13	5.64	5.75
Bipolar Digital	0.25	0.13	0.05	0.03	0.01	0	0	0	0
MOS Digital	2.17	2.16	2.82	3.11	3.41	3.67	3.95	4.60	4.77
MOS Memory	0.49	0.50	0.63	0.83	1.00	1.00	0.95	1.10	1.17
MOS Microcomponent	1.18	1.16	1.52	1.52	1.65	1.82	1.97	2.45	2.57
MOS Logic	0.49	0.50	0.68	0.76	0.75	0.85	1.03	1.04	1.03
Analog (Monolithic + Hybrid)	0.49	1.00	0.84	0.91	0.88	1.05	1.18	1.04	0.98
Total Discrete	0.25	0.23	0.14	0.26	0.25	0.30	0.39	0.55	0.65
Total Optoelectronic	0.25	0.27	0.15	0.15	0.13	0.12	0.10	0.09	0.07

Source: Dataquest (July 1995)

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Table 3-7
Chinese Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	10.46	11.30	11.95	12.02	12.33	12.82	13.27	13.91	13.96
Total IC	9.31	9.76	10.07	10.33	10.62	11.21	11.80	12.33	12.17
Bipolar Digital	0.29	0.24	0.20	0.10	0.09	0.05	0.03	0.02	0.01
MOS Digital	7.28	7.67	8.02	8.63	9.08	9.67	10.33	10.79	10.82
MOS Memory	2.37	2.38	2.47	2.59	2.70	2.97	3.13	3.09	3.35
MOS Microcomponent	3.76	3.97	4.07	4.32	4.74	4.89	5.16	5.23	5.02
MOS Logic	1.16	1.32	1.48	1.73	1.65	1.81	2.03	2.48	2.45
Analog (Monolithic + Hybrid)	1.73	1.85	1.85	1.59	1.45	1.49	1.44	1.51	1.34
Total Discrete	0.87	1.06	1.48	1.38	1.45	1.38	1.27	1.31	1.45
Total Optoelectronic	0.29	0.48	0.40	0.31	0.26	0.23	0.20	0.28	0.35

Source: Dataquest (July 1995)

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Section 4—Chinese Semiconductor Consumption by Application Market, Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
Chinese Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronics Equipment	8,102	10,549	14,241	18,334	23,885	31,697	40,908	52,022	63,635
Data Processing	766	1,357	2,079	2,838	3,848	5,225	6,935	8,976	11,354
Computers	323	570	803	1,289	1,830	2,580	3,535	4,667	6,066
Data Storage	47	75	105	130	185	270	345	430	500
Input/Output	229	335	403	520	702	1,011	1,415	1,953	2,617
Dedicated System	131	246	484	574	752	963	1,215	1,487	1,710
Other Data Processing	36	131	284	326	378	400	425	440	461
Communications	939	1,329	2,194	3,181	4,572	6,943	9,768	13,523	16,678
Premise Telecommunications	608	809	1,534	2,240	3,236	4,964	7,000	9,716	11,756
Public Telecommunications	219	272	305	447	637	949	1,301	1,744	2,247
Mobile Communications	50	160	230	347	535	834	1,235	1,791	2,346
Broadcast and Studio	34	58	70	81	94	114	138	161	195
Other Communications	28	30	55	66	70	81	94	112	134
Industrial	320	367	443	510	685	856	1,158	1,427	1,695
Security and Energy Management	91	113	159	192	261	331	449	540	647
Manufacturing Systems/Instruments	184	203	223	246	332	408	562	691	809
Medical Equipment	25	28	34	41	55	70	89	121	145
Other Industrial	20	23	27	31	37	46	58	75	94
Consumer	5,528	6,817	8,528	10,565	13,222	16,732	20,599	25,010	29,977
Audio	1,091	1,611	1,914	2,354	2,924	3,672	4,521	5,470	6,504
Video	2,188	2,489	2,963	3,707	4,693	5,969	7,468	9,219	11,266
Personal Electronics	989	1,134	1,566	1,975	2,510	3,220	3,964	4,840	5,813
Appliances	1,015	1,249	1,632	1,958	2,370	2,938	3,500	4,081	4,713
Other Consumer	245	334	453	571	726	932	1,147	1,400	1,682
Military/Civil Aerospace	203	301	592	660	798	1,001	1,267	1,632	2,138
Transportation	346	378	405	579	760	941	1,182	1,454	1,793

Source: Dataquest (July 1995)

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Table 4-2
Chinese Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronics Equipment	30.2	35.0	28.7	30.3	32.7	29.1	27.2	22.3	28.3
Data Processing	77.2	53.2	36.5	35.6	35.8	32.7	29.4	26.5	32.0
Computers	76.5	40.9	60.5	42.0	41.0	37.0	32.0	30.0	36.3
Data Storage	59.6	40.0	23.8	42.3	45.9	27.8	24.6	16.3	30.9
Input/Output	46.3	20.3	29.0	35.0	44.0	40.0	38.0	34.0	38.2
Dedicated System	87.8	96.7	18.5	31.2	28.0	26.1	22.4	15.0	24.4
Other Data Processing	263.9	116.8	14.8	16.0	5.8	6.3	3.5	4.8	7.2
Communications	41.5	65.1	45.0	43.7	51.9	40.7	38.4	23.3	39.3
Premise Telecommunications	33.1	89.6	46.0	44.5	53.4	41.0	38.8	21.0	39.3
Public Telecommunications	24.2	12.1	46.6	42.5	49.0	37.1	34.0	28.9	38.1
Mobile Communications	220.0	43.8	51.0	54.0	56.0	48.0	45.0	31.0	46.5
Broadcast and Studio	70.6	20.7	15.7	16.0	21.3	21.1	16.7	21.1	19.2
Other Communications	7.1	83.3	20.0	6.1	15.7	16.0	19.1	19.6	15.2
Industrial	14.7	20.7	15.1	34.4	24.9	35.4	23.2	18.8	27.1
Security and Energy Management	24.2	40.7	20.8	36.0	26.9	35.6	20.1	19.9	27.5
Manufacturing Systems/Instruments	10.3	9.9	10.3	35.0	22.9	37.6	23.1	17.0	26.9
Medical Equipment	12.0	21.4	20.6	34.1	27.3	27.1	36.0	19.8	28.7
Other Industrial	15.0	17.4	14.8	19.4	24.3	26.1	29.3	25.3	24.8
Consumer	23.3	25.1	23.9	25.1	26.5	23.1	21.4	19.9	23.2
Audio	47.7	18.8	23.0	24.2	25.6	23.1	21.0	18.9	22.5
Video	13.8	19.0	25.1	26.6	27.2	25.1	23.5	22.2	24.9
Personal Electronics	14.7	38.1	26.1	27.1	28.3	23.1	22.1	20.1	24.1
Appliances	23.1	30.7	20.0	21.0	24.0	19.1	16.6	15.5	19.2
Other Consumer	36.3	35.6	26.1	27.1	28.3	23.1	22.1	20.1	24.1
Military/Civil Aerospace	48.3	96.7	11.5	20.9	25.4	26.6	28.8	31.0	26.5
Transportation	9.2	7.1	43.0	31.2	23.9	25.5	23.1	23.3	25.4

Source: Dataquest (July 1995)

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Table 4-3
Chinese Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	780	1,061	1,495	2,061	2,774	3,912	5,264	7,176	9,002
Data Processing	115	207	328	464	653	906	1,212	1,672	2,129
Computers	58	104	160	249	355	502	681	946	1,190
Data Storage	6	10	14	18	26	39	50	64	77
Input/Output	23	35	44	63	98	142	201	289	392
Dedicated System	11	23	59	74	99	138	189	268	355
Other Data Processing	17	35	50	60	75	85	91	105	115
Communications	79	123	217	359	534	861	1,287	1,917	2,382
Premise Telecommunications	59	93	169	267	395	615	880	1,245	1,423
Public Telecommunications	13	16	18	33	50	76	105	143	190
Mobile Communications	4	9	19	43	70	145	270	488	717
Broadcast and Studio	2	3	6	9	11	14	18	24	30
Other Communications	2	2	5	7	8	11	14	17	22
Industrial	22	29	45	60	88	120	177	231	292
Security and Energy Management	4	6	11	16	25	36	57	71	96
Manufacturing Systems/Instruments	15	19	30	39	55	74	106	140	169
Medical Equipment	1	2	2	3	4	6	8	11	15
Other Industrial	1	2	2	2	3	5	7	9	12
Consumer	520	648	832	1,078	1,367	1,853	2,360	3,052	3,810
Audio	97	119	145	185	237	308	400	490	600
Video	202	227	271	350	445	640	835	1,155	1,500
Personal Electronics	92	114	161	207	266	354	455	588	755
Appliances	104	152	205	271	336	440	530	645	744
Other Consumer	25	36	50	65	83	111	140	174	211
Military/Civil Aerospace	7	11	24	29	37	51	71	102	139
Transportation	36	43	48	70	94	121	157	202	250

Source: Dataquest (July 1995)

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Table 4-4
Chinese Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	36.1	40.9	37.9	34.6	41.0	34.6	36.3	25.5	34.3
Data Processing	80.0	58.5	41.6	40.6	38.8	33.8	38.0	27.3	35.6
Computers	79.3	53.8	55.6	42.6	41.4	35.7	38.9	25.8	36.7
Data Storage	61.2	41.6	26.4	44.4	50.0	28.2	28.0	20.3	33.7
Input/Output	50.3	28.5	42.5	54.6	45.1	41.5	43.8	35.6	44.0
Dedicated System	116.8	154.1	24.8	33.8	39.4	37.0	41.8	32.5	36.8
Other Data Processing	105.9	42.9	20.0	25.0	13.3	7.1	15.4	9.5	13.9
Communications	54.7	76.7	65.3	48.9	61.1	49.5	49.0	24.2	46.0
Premise Telecommunications	57.6	81.7	57.8	48.2	55.7	43.1	41.5	14.3	39.8
Public Telecommunications	23.1	12.5	83.6	50.6	52.3	38.7	36.2	32.6	41.9
Mobile Communications	116.6	115.9	129.8	62.8	107.1	86.2	80.7	46.9	75.6
Broadcast and Studio	80.8	106.4	44.7	22.2	27.3	28.6	33.3	25.0	27.2
Other Communications	24.4	138.1	37.5	19.2	28.6	25.3	25.2	29.4	25.5
Industrial	28.8	57.6	32.4	46.3	37.6	47.0	30.5	26.2	37.3
Security and Energy Management	39.5	78.0	47.9	60.3	44.4	56.9	24.3	35.2	43.6
Manufacturing Systems/Instruments	27.6	55.3	28.4	41.8	34.5	43.2	32.1	20.8	34.2
Medical Equipment	14.4	32.4	30.6	40.7	35.6	36.9	50.3	35.1	39.6
Other Industrial	24.3	35.3	13.7	34.7	37.9	42.1	36.9	29.2	36.1
Consumer	24.7	28.4	29.6	26.8	35.5	27.4	29.3	24.9	28.7
Audio	22.7	21.8	27.6	28.1	30.0	29.9	22.5	22.5	26.5
Video	12.4	19.4	29.2	27.2	43.8	30.5	38.3	29.9	33.8
Personal Electronics	24.5	41.1	28.6	28.3	33.3	28.5	29.2	28.4	29.5
Appliances	46.2	34.9	32.2	24.0	30.9	20.5	21.7	15.3	22.4
Other Consumer	44.0	38.9	30.0	28.3	33.1	26.1	24.3	21.3	26.6
Military/Civil Aerospace	55.0	117.0	21.6	27.4	37.2	38.6	43.4	36.5	36.5
Transportation	20.0	12.1	45.5	34.1	28.0	30.1	28.1	24.2	28.9

Source: Dataquest (July 1995)

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Table 4-5
Chinese Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronics Equipment	0.096	0.101	0.105	0.112	0.116	0.123	0.129	0.138	0.141
Data Processing	0.150	0.153	0.158	0.164	0.170	0.173	0.175	0.186	0.188
Computers	0.180	0.182	0.199	0.193	0.194	0.195	0.193	0.203	0.196
Data Storage	0.133	0.134	0.136	0.138	0.141	0.144	0.145	0.149	0.154
Input/Output	0.100	0.103	0.110	0.122	0.139	0.140	0.142	0.148	0.150
Dedicated System	0.082	0.095	0.123	0.129	0.132	0.143	0.156	0.180	0.208
Other Data Processing	0.472	0.267	0.176	0.184	0.198	0.213	0.214	0.239	0.249
Communications	0.085	0.092	0.099	0.113	0.117	0.124	0.132	0.142	0.143
Premise Telecommunications	0.097	0.115	0.110	0.119	0.122	0.124	0.126	0.128	0.121
Public Telecommunications	0.059	0.059	0.059	0.074	0.078	0.080	0.081	0.082	0.085
Mobile Communications	0.080	0.054	0.081	0.124	0.131	0.174	0.219	0.273	0.306
Broadcast and Studio	0.049	0.052	0.089	0.111	0.117	0.123	0.130	0.149	0.154
Other Communications	0.062	0.072	0.093	0.107	0.120	0.134	0.144	0.152	0.164
Industrial	0.070	0.078	0.102	0.117	0.128	0.141	0.153	0.162	0.172
Security and Energy Management	0.047	0.053	0.067	0.082	0.097	0.110	0.127	0.132	0.148
Manufacturing Systems/Instruments	0.083	0.096	0.135	0.158	0.166	0.181	0.189	0.203	0.209
Medical Equipment	0.058	0.060	0.065	0.070	0.074	0.079	0.085	0.094	0.106
Other Industrial	0.064	0.070	0.080	0.080	0.090	0.099	0.112	0.119	0.122
Consumer	0.094	0.095	0.098	0.102	0.103	0.111	0.115	0.122	0.127
Audio	0.089	0.074	0.076	0.079	0.081	0.084	0.088	0.090	0.092
Video	0.092	0.091	0.091	0.094	0.095	0.107	0.112	0.125	0.133
Personal Electronics	0.093	0.101	0.103	0.105	0.106	0.110	0.115	0.121	0.130
Appliances	0.102	0.122	0.126	0.138	0.142	0.150	0.151	0.158	0.158
Other Consumer	0.102	0.108	0.110	0.114	0.115	0.119	0.122	0.124	0.125
Military/Civil Aerospace	0.035	0.037	0.041	0.044	0.047	0.051	0.056	0.062	0.065
Transportation	0.104	0.114	0.120	0.122	0.124	0.128	0.133	0.139	0.140

Source: Dataquest (July 1995)

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Errata

The titles for Figure 1 and Figure 2 on page 5 of the Semiconductor Application Markets Asia/Pacific Market Analysis newsletter titled "Notebook PCs and PC Peripherals Dominate Taiwan's Data Processing Industry" (SAMM-AP-MA-9503, dated July 10, 1995) were inadvertently switched. The titles should be as follows:

Figure 1
Unit Shipments of Taiwanese Desktop PCs by Microprocessor Type (Thousand Units)

Figure 2
Unit Shipments of Taiwanese Notebook PCs by Microprocessor Type (Thousand Units)

Please note this change in your binder.

Dataquest apologizes for any inconvenience caused by this error.

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Analysis

Notebook PCs and PC Peripherals Dominate Taiwan's Data Processing Industry

Abstract: *Taiwan's PC industry continues to dominate the country's electronics equipment production. Products such as monitors, notebook PCs, and motherboards continue to flood the worldwide supply market. We expect Taiwan to maintain its high growth pace, driven by notebook PCs, multimedia-related products, scanners, and modems. This article highlights the recent development and manufacturing capacity of the Taiwanese data processing industry.*

By Ben F.P. Lee (Taiwan)

Notebooks: Taiwan's Rising Performer

Taiwan's last 10 years of effort to develop its own information technology (IT) industry has produced enviable success. Given the support from the Taiwanese government and the innovative/productive nature of the private sector, Taiwan was able to grow its 1994 data processing revenue by 10.2 percent to exceed $10 billion. Dataquest believes that Taiwan's data processing industry will see even better performance this year. We project the 1995 total revenue to reach $11.6 billion, or 12.8 percent growth (see Table 1). Table 2 enumerates Taiwan's data processing unit output from 1993 through 1995.

Taiwan is now the world's leading manufacturing base for monitors, notebook PCs, and desktop PCs (see Table 3). Combined with motherboards, these products together account for 79.8 percent of Taiwan's data processing total revenue in 1994. Notebook PCs will show the most robust growth, in terms of revenue, of these four products. In view of the migration to portability, we project notebook PC revenue to grow by 29.4 percent to $3.0 billion this year. Table 4 reveals Acer as the leader in notebook PC manufacturing in 1994, followed by Quanta, Twinhead, Compal, and

Dataquest

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Table 1
Taiwanese PC-Related Products, 1993 to 1995 (Millions of U.S. Dollars)

	1993	1994	1995*	Annual Growth Rate (%)
Monitor	2,889	3,034	2,973	-2.0
Notebook PC	2,167	2,601	3,433	32.0
Desktop PC	1,479	1,493	1,717	15.0
Motherboard	1,020	1,055	1,050	-0.5
Switching Power Supply	360	389	377	-3.0
Graphic Cards	350	385	354	-8.1
Modem	208	348	400	14.9
LAN Cards	260	299	308	3.0
Image Scanner	228	257	329	28.0
Mouse	121	130	122	-6.2
Keyboard	142	106	102	-3.8
Audio Cards	69	95	135	42.1
Video Cards	23	45	89	97.8
CD-ROM	-	12	173	1,341.7
Total	9,316	10,249	11,562	12.8

*Forecast
Note: Price is based on the OEM price, not end-user price.
Source: Dataquest (July 1995)

Table 2
Taiwanese PC-Related Products, 1993 to 1995 (Thousands of Units)

	1993	1994	1995*	Annual Growth Rate (%)
Monitor	15,897	16,225	15,542	-4.2
Notebook PC	1,713	2,334	3,020	29.4
Desktop PC	2,788	3,257	3,760	15.4
Motherboard	9,900	10,650	10,118	-5.0
Switching Power Supply	12,250	13,260	12,860	-3.0
Graphic Cards	4,800	5,392	5,050	-6.3
Modem	3,550	5,985	7,002	17.0
LAN Cards	7,385	8,530	8,957	5.0
Image Scanner	1,160	1,350	1,750	29.6
Mouse	21,550	23,500	22,325	-5.0
Keyboard	12,475	9,200	8,925	-3.0
Audio Cards	1,420	2,020	2,930	45.0
Video Cards	248	520	1,050	101.9
CD-ROM	-	105	1,575	1,400.0

*Forecast
Source: Dataquest (July 1995)

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Table 3
Market Share of Major Taiwanese PC-Related Products in 1994 (Thousands of Units)

	1994/Taiwan	1994/Worldwide	Market Share (%)
Monitor (Color)	16,225	37,922	42.8
Notebook PC	2,334	7,488	31.2
Desktop PC	3,257	32,248	10.1

Source: Dataquest (July 1995)

Table 4
Major Taiwanese PC Manufacturers' Average Monthly Production Quantity in 1994 (Thousands)

Motherboard Company	Quantity	Portable Company	Quantity	Desktop PC Company	Quantity	Monitor Company	Quantity
FIC	170	Acer	31	Acer	100	Philips	200
PC-Chip	160	Quanta	23	Tatung	70	Tatung	140
Elite Group	125	Twinhead	14	GVC	30	ADI	110
Dataexpert	93	Compal	13	DEC	20	MAG	100
Soyo	85	Inventec	12	Mitac	15	CTX	90
Asustek	70	Clevo	11	FIC	10	Acer Peripheral	80
GVC	70	ASE	11			Liteon	60
Mycomp	70	Arima	10			Royal	50
		FIC	8			KFC	50
		Chicony	8				
		Mitac	7				
		Featron	6				
		Chaplet	5				

Note: Quantities do not include production outside of Taiwan.
Source: Dataquest (July 1995)

Inventec. Revenue from desktop PCs will continue to show positive growth, at 15 percent this year, although the revenue gap with notebooks is quickly narrowing. Taiwan has spread its success in PCs to peripherals manufacturing. Dataquest projects comparable growth rates for image scanners and modems as for notebook PCs. Although CD-ROM drives, video cards, and audio cards are growing tremendously, the other PC peripherals are beginning to show signs of slowdown. At any rate, the PC segment will continue to drive Taiwan's reputation as a notable professional manufacturing base for data processing. Taiwan's aim now is to develop its domestic component supply system and its worldwide selling channel system.

Selling Channel: OEM/ODM Partnership, Brand Creation

Several Taiwanese local manufacturers attempted to create their own brands in the early 1990s, only to meet with little success because of poor timing. Taiwan's key success in promoting its data processing industry is attributed to OEM/ODM cooperation. A significant number of local

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manufacturers have established strong relationships with globally renowned PC manufacturers. The partnership has resulted in Taiwan's accumulation of improved mass production experience and of qualified R&D design engineers. Table 5 summarizes the relationship between Taiwanese manufacturers and their OEM/ODM partners, of which the majority are from North America.

Taiwanese PC manufacturers' next goal is to increase their global presence. Local companies such as FIC and GVC are emulating Acer and Mitac and have begun creating their own labels and developing their worldwide selling channels.

High-Performance and Multimedia as Trendsetters

Taiwanese-made PCs are becoming faster and more functional. High speed/high performance and multimedia have become essential features in the PC environment and will certainly set trends for Taiwanese PC manufacturers this year. Dataquest predicts that worldwide shipment of PCs will rise by 19.6 percent to 57.3 million units this year. Shipments of Pentium-based PCs, which represent 45.6 percent of total PC shipments, will see enormous growth, from 4 million units in 1994 to 26.1 million units this year, indicating higher local acceptance of Pentium microprocessors, particularly from notebook PC manufacturers. We project Taiwan to produce 3 million units of notebook PCs, 3.7 million units of desktop PCs, and 10.1 million pieces of motherboards this year. All three categories represent a total 16.9 million units of Taiwanese-made PC systems, or 29.5 percent of the 1995 worldwide PC shipment.

Figures 1 and 2 show unit shipments of Taiwanese notebook and desktop PCs by microprocessor type.

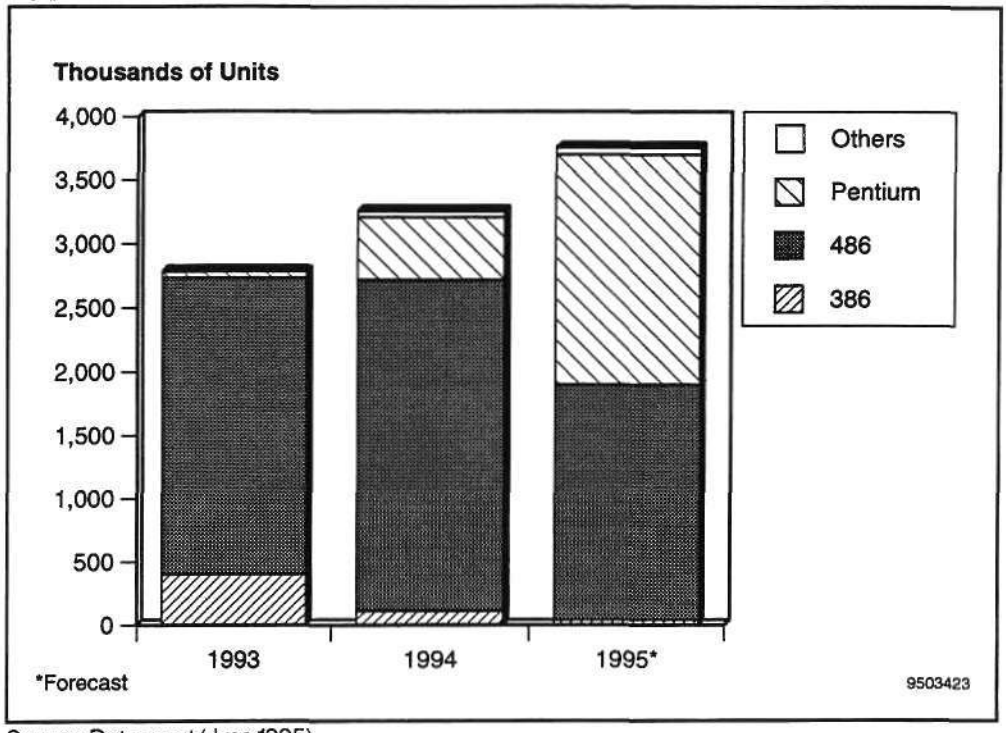
Table 5
Taiwan's Major OEM/ODM Partners and Products

Product	Taiwanese Manufacturer	OEM/ODM Partner
Motherboard	GVC	IBM, Packard Bell, Dell
	Acer	IBM
Desktop PC	Tatung	Apple, Packard Bell
	Mitac	Compaq
Notebook PC	Acer	Apple, Canon, Hitachi
	Quanta	AST, Dell, Siemens
	FIC	NEC, Fujitsu
	Inventec	Compaq, Zenith
	Compal	Epson, Peacock, Ambra
	Twinhead	Hewlett-Packard
Monitor	Acer Peripheral	ICL
	ADI	Compaq
	Tatung	Packard Bell
	Liteon	Apple
	MAG	Gateway 2000
	Royal	Vobis, Dell

Source: Dataquest (July 1995)

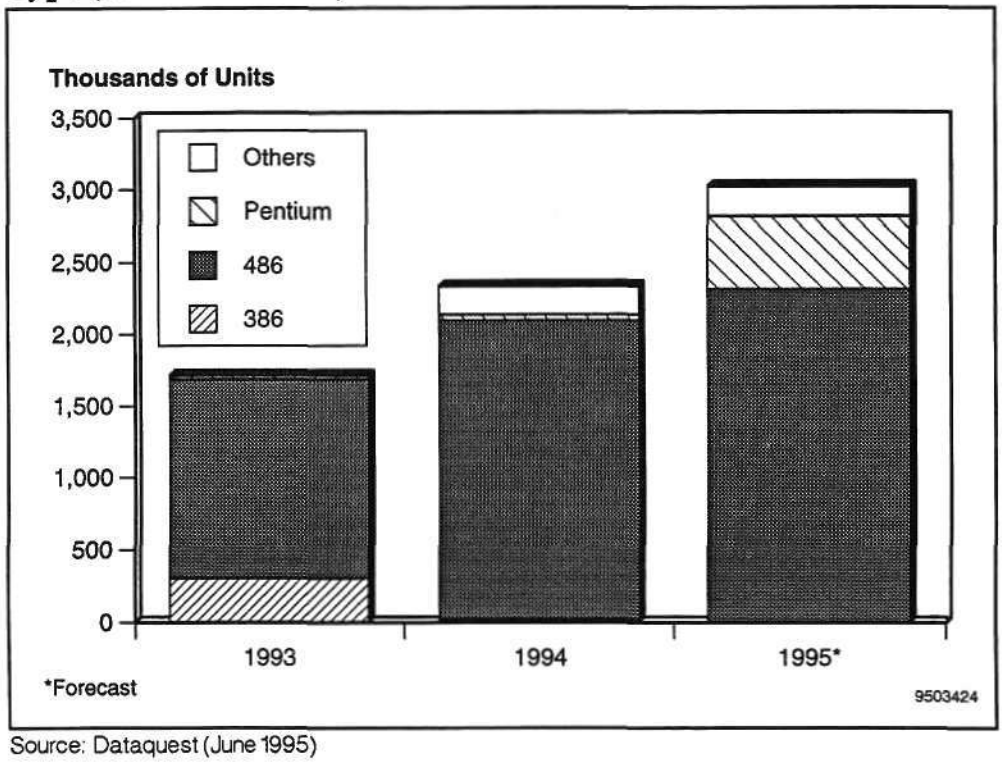
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Figure 1
Unit Shipments of Taiwanese Notebook PCs by Microprocessor Type (Thousand Units)



Source: Dataquest (June 1995)

Figure 2
Unit Shipments of Taiwanese Desktop PCs by Microprocessor Type (Thousand Units)



Source: Dataquest (June 1995)

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The year 1994 marks the beginning of Taiwan's CD-ROM drive manufacturing activity. From a modest output of 105,000 units in 1994, we project Taiwan's unit output to explode by 1,400 percent to 1.6 million units this year. This represents 5.4 percent of our projection of worldwide shipment of 29.3 million units. Acer Peripheral, Elite Group, FIC, and GVC have begun to assemble CD-ROM drives. As in other hot PC-related products, CD-ROM drives are slated to become an important, high-growth product in Taiwan within four years. We also expect excellent growth rates and shipment capacities for audio cards and video cards in Taiwan.

Dataquest Perspective

The electronic equipment industry has emerged as Taiwan's biggest manufacturing sector since 1989, surpassing textiles and plastics. The export-oriented electronic equipment industry has elevated Taiwan to be one of the world's significant PC vendors. We expect notebook PCs to rise as the top revenue-generator for Taiwan's data processing industry beginning this year. We also anticipate multimedia peripherals (such as CD-ROM drives, and audio and video cards) and other PC-related products (scanners and modems) to show healthy growth rates. Following successful OEM/ODM tie-ups, Taiwanese PC and peripherals manufacturers are gearing up to expand their global presence through increased selling channels and component supply sources, an important step for Taiwan in integrating its manufacturing-selling capabilities.

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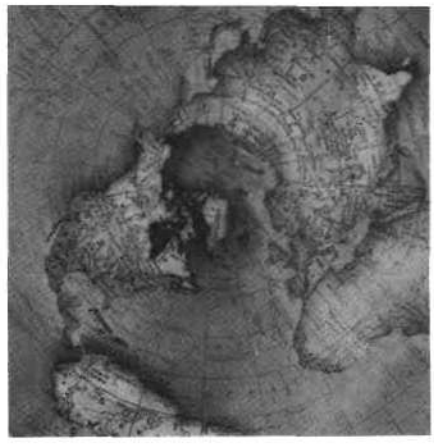
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Hong Kong/Shenzhen Semiconductor Consumption by Application Market

Market Statistics

Program: Semiconductor Application Markets Asia/Pacific
Product Code: SAMM-AP-MS-9506
Publication Date: July 10, 1995
Filing: Market Analysis

Hong Kong/Shenzhen Semiconductor Consumption by Application Market



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Note: All tables show estimated data.

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Note: All tables show estimated data.

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Chapter 1
Hong Kong/Shenzhen Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.
- Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate three or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications

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equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
  - Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

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Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed-circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) eletronics.

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  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Taiwan, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Taiwanese operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market Database Tables

Section 1—Hong Kong/Shenzhen Semiconductor Consumption by Application Market: Factory Revenue

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Table 1-1
Hong Kong/Shenzhen Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	5,951	6,090	6,740	7,257	7,948	8,580	9,417	10,078	10,873
Total Semiconductor	1,107	1,334	1,691	2,117	2,546	2,937	3,271	3,781	4,214
Total IC	930	1,138	1,469	1,836	2,208	2,567	2,862	3,312	3,691
Bipolar Digital	28	27	29	27	21	17	14	12	11
MOS Digital	658	835	1,117	1,452	1,803	2,143	2,430	2,850	3,180
MOS Memory	200	263	384	571	706	875	988	1,118	1,202
MOS Microcomponent	294	371	478	579	726	843	965	1,144	1,289
MOS Logic	164	201	255	302	371	424	476	588	689
Analog (Monolithic + Hybrid)	244	276	323	357	384	408	419	449	500
Total Discrete	155	167	190	240	290	316	350	402	444
Total Optoelectronic	22	29	33	41	48	54	59	67	79

Source: Dataquest (July 1995)

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Table 1-2
Hong Kong/Shenzhen Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	2,477	2,810	3,274	3,554	4,020	4,493	5,064	5,538	5,935
Total Semiconductor	707	885	1,178	1,523	1,866	2,175	2,390	2,761	3,040
Total IC	638	800	1,075	1,380	1,689	1,978	2,166	2,497	2,745
Bipolar Digital	21	21	24	22	17	13	11	9	8
MOS Digital	508	647	887	1,176	1,476	1,762	1,961	2,284	2,510
MOS Memory	140	185	287	450	570	720	790	880	920
MOS Microcomponent	240	305	395	487	615	710	805	952	1,055
MOS Logic	128	157	205	239	291	332	366	452	535
Analog (Monolithic + Hybrid)	109	132	165	182	196	202	195	203	227
Total Discrete	59	68	84	118	147	165	188	222	244
Total Optoelectronic	10	17	20	25	30	33	36	42	51

Source: Dataquest (July 1995)

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Table 1-3
Hong Kong/Shenzhen Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	695	784	930	1,010	1,073	1,148	1,283	1,355	1,476
Total Semiconductor	50	68	89	110	131	165	209	266	302
Total IC	41	57	76	94	112	142	183	234	265
Bipolar Digital	2	2	2	1	1	1	1	1	1
MOS Digital	30	40	55	67	81	105	139	181	203
MOS Memory	12	16	25	27	30	38	51	60	65
MOS Microcomponent	8	10	13	17	22	29	39	54	66
MOS Logic	10	14	17	23	29	38	49	67	72
Analog (Monolithic + Hybrid)	8	15	20	26	30	36	43	51	61
Total Discrete	7	9	10	13	16	19	22	27	31
Total Optoelectronic	2	2	2	3	3	4	5	6	6

Source: Dataquest (July 1995)

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Table 1-4
Hong Kong/Shenzhen Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	42	79	93	111	134	157	181	213	263
Total Semiconductor	18	19	24	30	38	47	59	74	95
Total IC	17	18	23	29	37	45	57	71	93
Bipolar Digital	1	1	1	0	0	0	0	0	0
MOS Digital	13	15	19	24	32	39	49	62	81
MOS Memory	3	3	4	5	7	9	11	15	20
MOS Microcomponent	5	6	9	12	16	20	26	33	45
MOS Logic	5	6	6	7	9	10	12	14	16
Analog (Monolithic + Hybrid)	3	3	3	4	5	6	7	9	11
Total Discrete	0	0	1	1	1	1	1	1	1
Total Optoelectronic	0	0	1	1	1	1	1	1	1

Source: Dataquest (July 1995)

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Table 1-5
Hong Kong/Shenzhen Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	2,362	2,142	2,239	2,390	2,540	2,614	2,733	2,825	3,074
Total Semiconductor	305	336	375	431	488	529	593	663	760
Total IC	216	246	278	318	355	389	445	499	578
Bipolar Digital	3	3	2	2	2	2	2	2	2
MOS Digital	93	120	144	173	203	226	271	314	378
MOS Memory	40	55	64	85	95	105	133	161	195
MOS Microcomponent	37	46	58	60	70	81	93	102	120
MOS Logic	16	19	22	28	38	40	45	51	63
Analog (Monolithic + Hybrid)	120	123	132	142	150	161	172	183	198
Total Discrete	80	82	88	102	120	125	133	146	162
Total Optoelectronic	9	9	9	11	13	15	16	18	20

Source: Dataquest (July 1995)

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Table 1-6
Hong Kong/Shenzhen Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	244	179	109	102	93	85	76	70	60
Total Semiconductor	8	7	7	6	5	5	4	3	3
Total IC	7	6	5	5	4	4	3	3	2
Bipolar Digital	1	0	0	0	0	0	0	0	0
MOS Digital	4	4	3	3	3	2	2	1	1
MOS Memory	1	1	1	1	1	1	1	0	0
MOS Microcomponent	1	1	1	1	1	1	0	0	0
MOS Logic	2	2	2	1	1	1	1	1	1
Analog (Monolithic + Hybrid)	2	2	2	1	1	1	1	1	1
Total Discrete	1	1	1	1	1	1	1	1	1
Total Optoelectronic	0	0	0	0	0	0	0	0	0

Source: Dataquest (July 1995)

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Table 1-7
Hong Kong/Shenzhen Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	130	97	95	90	88	83	80	77	65
Total Semiconductor	20	19	19	17	17	16	16	15	14
Total IC	12	12	11	11	10	10	9	9	8
Bipolar Digital	0	0	0	0	0	0	0	0	0
MOS Digital	10	10	9	9	9	8	8	7	7
MOS Memory	3	3	3	3	3	3	2	2	2
MOS Microcomponent	3	3	3	3	3	3	3	3	3
MOS Logic	4	3	3	3	3	3	3	3	2
Analog (Monolithic + Hybrid)	2	2	2	2	2	2	2	1	1
Total Discrete	6	6	6	6	6	6	5	5	5
Total Optoelectronic	1	1	1	1	1	1	1	1	1

Source: Dataquest (July 1995)

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Section 2—Hong Kong/Shenzhen Consumption by Application Market: Annual Growth Rates

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Table 2-1
Hong Kong/Shenzhen Semiconductor Consumption—Total Electronics (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	2.34	10.68	7.67	9.52	7.95	9.76	7.02	7.88	8.42
Total Semiconductor	20.55	26.74	25.17	20.29	15.35	11.38	15.59	11.45	14.76
Total IC	22.38	29.05	24.99	20.28	16.29	11.49	15.70	11.45	14.99
Bipolar Digital	-5.42	6.48	-6.50	-21.64	-18.42	-17.81	-13.81	-8.81	-16.21
MOS Digital	26.88	33.79	30.01	24.15	18.85	13.38	17.32	11.57	16.97
MOS Memory	31.52	45.80	48.87	23.58	24.02	12.93	13.16	7.53	16.06
MOS Microcomponent	26.12	29.00	21.15	25.30	16.16	14.47	18.55	12.60	17.33
MOS Logic	22.60	26.90	18.26	23.05	14.28	12.17	23.49	17.24	17.96
Analog (Monolithic + Hybrid)	13.47	16.94	10.42	7.65	6.13	2.75	7.24	11.22	6.96
Total Discrete	7.90	13.74	26.55	20.76	9.00	10.85	14.78	10.55	13.11
Total Optoelectronic	31.52	11.00	25.37	17.96	10.77	9.22	15.23	17.00	13.98

Source: Dataquest (July 1995)

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Table 2-2
Hong Kong/Shenzhen Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	13.44	16.51	8.55	13.11	11.77	12.71	9.35	7.17	10.80
Total Semiconductor	25.16	33.16	29.26	22.54	16.55	9.89	15.50	10.11	14.82
Total IC	25.33	34.45	28.31	22.46	17.07	9.52	15.26	9.95	14.75
Bipolar Digital	-1.43	14.01	-6.64	-23.79	-21.02	-19.69	-16.86	-10.38	-18.47
MOS Digital	27.36	37.03	32.60	25.57	19.37	11.27	16.50	9.88	16.38
MOS Memory	32.00	55.41	56.69	26.71	26.27	9.72	11.39	4.55	15.38
MOS Microcomponent	27.00	29.49	23.31	26.29	15.47	13.36	18.34	10.80	16.73
MOS Logic	22.97	30.05	16.71	21.96	14.09	10.17	23.49	18.30	17.50
Analog (Monolithic + Hybrid)	21.01	25.02	10.29	7.96	3.00	-3.81	4.52	11.64	4.53
Total Discrete	15.93	22.08	41.50	24.22	12.14	14.29	18.01	9.91	15.61
Total Optoelectronic	69.00	16.57	29.06	18.85	8.84	9.68	16.91	20.85	14.92

Source: Dataquest (July 1995)

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Table 2-3
Hong Kong/Shenzhen Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	12.81	18.62	8.60	6.24	6.99	11.76	5.61	8.93	7.88
Total Semiconductor	36.57	31.21	23.75	19.56	25.70	26.96	27.10	13.58	22.46
Total IC	41.23	33.22	23.74	19.03	26.46	28.61	27.97	13.52	22.97
Bipolar Digital	0	-18.18	-16.80	-18.15	-7.55	-13.45	-3.57	-4.48	-9.62
MOS Digital	32.01	37.25	21.81	21.12	29.65	32.31	30.36	12.07	24.87
MOS Memory	29.03	55.63	8.43	11.11	26.67	33.97	17.85	8.33	19.21
MOS Microcomponent	25.00	30.00	32.78	27.45	31.96	33.07	39.63	22.36	30.76
MOS Logic	41.41	21.43	33.01	28.25	30.99	30.07	36.01	7.14	26.07
Analog (Monolithic + Hybrid)	87.50	30.00	32.90	15.76	19.25	19.09	20.87	18.97	18.78
Total Discrete	17.81	19.77	22.54	24.23	21.12	16.93	21.87	15.22	19.83
Total Optoelectronic	5.88	22.22	29.91	16.51	21.43	15.85	18.34	8.10	15.96

Source: Dataquest (July 1995)

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Table 2-4
Hong Kong/Shenzhen Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	85.58	18.22	19.61	20.72	16.87	15.33	18.16	23.15	18.81
Total Semiconductor	8.18	23.42	26.86	27.86	23.40	24.68	25.41	29.36	26.12
Total IC	8.57	23.36	27.05	28.23	23.59	25.01	25.84	29.79	26.47
Bipolar Digital	-22.22	-28.57	-8.60	-12.25	-10.39	-2.47	-9.43	-1.19	-7.25
MOS Digital	11.58	28.03	28.16	29.62	24.08	25.62	26.04	30.79	27.20
MOS Memory	1.25	17.28	37.57	32.57	28.64	28.72	26.50	37.77	30.78
MOS Microcomponent	7.41	53.45	31.63	35.01	27.94	28.50	28.73	34.44	30.89
MOS Logic	23.40	8.62	17.58	19.01	13.56	17.05	19.60	14.86	16.79
Analog (Monolithic + Hybrid)	3.85	11.11	26.00	24.21	23.19	22.59	26.22	23.95	24.03
Total Discrete	0	25.00	19.61	18.52	20.65	17.03	18.55	16.81	18.30
Total Optoelectronic	0	25.00	25.15	19.85	16.67	14.94	7.94	14.71	14.76

Source: Dataquest (July 1995)

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Table 2-5
Hong Kong/Shenzhen Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	-9.33	4.55	6.74	6.28	2.91	4.55	3.37	8.81	5.16
Total Semiconductor	10.37	11.63	14.71	13.41	8.32	12.18	11.68	14.69	12.04
Total IC	13.82	13.36	14.18	11.77	9.52	14.31	12.19	15.80	12.70
Bipolar Digital	-7.14	-11.54	1.53	-7.62	-8.20	-11.98	-1.57	-4.77	-6.90
MOS Digital	29.06	19.93	20.60	17.06	11.33	19.86	15.96	20.34	16.86
MOS Memory	37.50	15.82	33.44	11.76	10.53	26.56	21.24	21.04	18.07
MOS Microcomponent	25.34	25.43	3.99	16.67	15.71	14.81	9.68	17.65	14.87
MOS Logic	16.67	18.52	26.87	33.72	5.26	12.50	13.33	23.53	17.26
Analog (Monolithic + Hybrid)	2.50	7.48	7.41	5.63	7.33	6.83	6.40	8.20	6.87
Total Discrete	2.12	7.58	15.65	17.91	4.17	6.13	9.90	11.22	9.77
Total Optoelectronic	1.14	1.12	22.06	18.96	13.84	7.33	12.41	12.06	12.86

Source: Dataquest (July 1995)

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Table 2-6
Hong Kong/Shenzhen Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	-26.68	-39.07	-6.42	-8.82	-8.60	-10.59	-7.89	-14.29	-10.07
Total Semiconductor	-14.88	-6.85	-10.72	-11.87	-11.88	-13.82	-16.49	-15.86	-14.00
Total IC	-16.91	-5.13	-9.59	-12.29	-12.06	-14.13	-17.01	-15.66	-14.25
Bipolar Digital	-66.67	-25.00	15.36	1.25	-3.59	-8.36	-14.89	-6.46	-6.57
MOS Digital	-6.58	-2.54	-10.40	-16.13	-15.38	-18.18	-22.22	-21.43	-18.72
MOS Memory	-15.38	0	-9.09	-20.00	-25.00	-16.67	-20.00	-25.00	-21.40
MOS Microcomponent	-1.11	-8.99	-13.58	-14.29	-16.67	-20.00	-50.00	-50.00	-32.24
MOS Logic	-2.50	-0.64	-9.68	-14.29	-8.33	-18.18	-11.11	-12.50	-12.94
Analog (Monolithic + Hybrid)	-5.56	-5.88	-12.50	-7.14	-7.69	-8.33	-9.09	-10.00	-8.46
Total Discrete	-7.69	-8.33	-9.09	-10.00	-11.11	-12.50	-14.29	-16.67	-12.94
Total Optoelectronic	0	-33.33	-50.00	-10.00	-11.11	-12.50	-14.29	-16.67	-12.94

Source: Dataquest (July 1995)

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Table 2-7
Hong Kong/Shenzhen Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	-25.69	-1.66	-5.26	-2.22	-5.68	-3.61	-3.75	-15.58	-6.30
Total Semiconductor	-1.93	-4.24	-5.56	-3.68	-3.61	-4.36	-5.82	-5.49	-4.60
Total IC	-1.98	-5.56	-4.73	-4.15	-3.98	-4.14	-6.40	-5.71	-4.88
Bipolar Digital	-13.33	-61.54	-29.33	-61.25	-25.91	-34.22	-19.93	-25.42	-35.37
MOS Digital	-1.03	-4.17	-4.35	-3.41	-3.53	-3.66	-6.33	-5.41	-4.47
MOS Memory	-6.45	-3.45	-3.57	-3.70	-3.85	-4.00	-8.33	-4.55	-4.90
MOS Microcomponent	10.00	-3.03	-3.13	-3.23	-3.33	-3.45	-3.57	-3.70	-3.46
MOS Logic	-5.56	-5.88	-6.25	-3.33	-3.45	-3.57	-7.41	-8.00	-5.18
Analog (Monolithic + Hybrid)	-4.76	-5.00	-5.26	-5.56	-5.88	-6.25	-6.67	-7.14	-6.30
Total Discrete	-1.56	-1.59	-6.45	-1.72	-1.75	-3.57	-3.70	-3.85	-2.92
Total Optoelectronic	-3.33	-5.17	-9.09	-10.00	-11.11	-12.50	-14.29	-16.67	-12.94

Source: Dataquest (July 1995)

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Section 3—Hong Kong/Shenzhen Semiconductor Consumption by Application Market: Input/Output Ratios

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Table 3-1
Hong Kong/Shenzhen Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	18.60	21.91	25.09	29.17	32.03	34.23	34.74	37.52	38.76
Total IC	15.63	18.69	21.79	25.29	27.78	29.92	30.40	32.86	33.95
Bipolar Digital	0.48	0.44	0.42	0.37	0.26	0.20	0.15	0.12	0.10
MOS Digital	11.06	13.71	16.57	20.01	22.68	24.97	25.80	28.28	29.25
MOS Memory	3.36	4.32	5.69	7.87	8.88	10.20	10.49	11.10	11.06
MOS Microcomponent	4.94	6.09	7.10	7.98	9.14	9.83	10.25	11.36	11.85
MOS Logic	2.76	3.30	3.79	4.16	4.67	4.95	5.05	5.83	6.34
Analog (Monolithic + Hybrid)	4.09	4.54	4.79	4.92	4.83	4.75	4.45	4.46	4.59
Total Discrete	2.60	2.74	2.81	3.31	3.65	3.68	3.72	3.99	4.09
Total Optoelectronic	0.38	0.48	0.49	0.56	0.61	0.62	0.62	0.67	0.73

Source: Dataquest (July 1995)

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Table 3-2
Hong Kong/Shenzhen Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	28.54	31.49	35.99	42.85	46.43	48.41	47.20	49.85	51.22
Total IC	25.75	28.45	32.83	38.81	42.02	44.01	42.77	45.08	46.25
Bipolar Digital	0.85	0.74	0.72	0.62	0.42	0.30	0.21	0.16	0.13
MOS Digital	20.51	23.02	27.08	33.08	36.72	39.22	38.72	41.25	42.29
MOS Memory	5.65	6.58	8.77	12.66	14.18	16.02	15.60	15.89	15.50
MOS Microcomponent	9.69	10.85	12.05	13.69	15.29	15.80	15.89	17.19	17.78
MOS Logic	5.17	5.60	6.25	6.72	7.25	7.40	7.23	8.17	9.01
Analog (Monolithic + Hybrid)	4.40	4.69	5.04	5.12	4.88	4.50	3.84	3.67	3.82
Total Discrete	2.38	2.43	2.55	3.32	3.65	3.66	3.71	4.01	4.11
Total Optoelectronic	0.40	0.60	0.60	0.72	0.75	0.73	0.71	0.76	0.86

Source: Dataquest (July 1995)

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Table 3-3
Hong Kong/Shenzhen Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	7.12	8.62	9.54	10.87	12.23	14.37	16.32	19.65	20.48
Total IC	5.83	7.30	8.19	9.34	10.46	12.36	14.23	17.24	17.97
Bipolar Digital	0.32	0.28	0.19	0.15	0.11	0.10	0.08	0.07	0.06
MOS Digital	4.36	5.10	5.90	6.62	7.55	9.15	10.83	13.37	13.75
MOS Memory	1.78	2.04	2.68	2.67	2.80	3.31	3.97	4.43	4.40
MOS Microcomponent	1.15	1.28	1.40	1.71	2.05	2.53	3.01	3.98	4.47
MOS Logic	1.42	1.79	1.83	2.24	2.70	3.31	3.85	4.96	4.88
Analog (Monolithic + Hybrid)	1.15	1.91	2.10	2.57	2.80	3.12	3.32	3.80	4.15
Total Discrete	1.05	1.10	1.11	1.25	1.46	1.65	1.73	2.00	2.11
Total Optoelectronic	0.24	0.23	0.24	0.28	0.31	0.35	0.37	0.41	0.41

Source: Dataquest (July 1995)

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Table 3-4
Hong Kong/Shenzhen Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	41.61	24.25	25.32	26.86	28.45	30.04	32.47	34.46	36.20
Total IC	39.72	23.24	24.25	25.75	27.36	28.93	31.36	33.40	35.20
Bipolar Digital	2.13	0.89	0.54	0.41	0.30	0.23	0.19	0.15	0.12
MOS Digital	31.44	18.90	20.47	21.94	23.55	25.01	27.24	29.06	30.86
MOS Memory	7.57	4.13	4.09	4.71	5.17	5.69	6.35	6.80	7.61
MOS Microcomponent	12.77	7.39	9.59	10.55	11.80	12.92	14.40	15.69	17.12
MOS Logic	11.11	7.39	6.79	6.67	6.58	6.39	6.49	6.57	6.13
Analog (Monolithic + Hybrid)	6.15	3.44	3.23	3.41	3.50	3.69	3.93	4.19	4.22
Total Discrete	0.95	0.51	0.54	0.54	0.53	0.55	0.55	0.56	0.53
Total Optoelectronic	0.95	0.51	0.54	0.56	0.56	0.56	0.56	0.51	0.47

Source: Dataquest (July 1995)

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Table 3-5
Hong Kong/Shenzhen Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	12.90	15.70	16.76	18.01	19.22	20.23	21.71	23.45	24.72
Total IC	9.13	11.46	12.43	13.30	13.98	14.88	16.27	17.66	18.79
Bipolar Digital	0.12	0.12	0.10	0.10	0.08	0.08	0.06	0.06	0.05
MOS Digital	3.93	5.60	6.42	7.26	7.99	8.65	9.91	11.12	12.30
MOS Memory	1.69	2.57	2.85	3.56	3.74	4.02	4.86	5.70	6.34
MOS Microcomponent	1.55	2.15	2.58	2.51	2.76	3.10	3.40	3.61	3.90
MOS Logic	0.69	0.88	1.00	1.19	1.50	1.53	1.65	1.81	2.05
Analog (Monolithic + Hybrid)	5.08	5.74	5.90	5.94	5.91	6.16	6.29	6.48	6.44
Total Discrete	3.39	3.82	3.93	4.26	4.72	4.78	4.85	5.16	5.28
Total Optoelectronic	0.37	0.42	0.40	0.46	0.51	0.57	0.58	0.64	0.65

Source: Dataquest (July 1995)

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Table 3-6
Hong Kong/Shenzhen Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	3.44	4.00	6.11	5.83	5.63	5.43	5.24	4.75	4.66
Total IC	2.79	3.16	4.92	4.75	4.57	4.40	4.22	3.80	3.74
Bipolar Digital	0.49	0.22	0.28	0.34	0.38	0.40	0.41	0.38	0.41
MOS Digital	1.56	1.98	3.17	3.04	2.80	2.59	2.37	2.00	1.83
MOS Memory	0.53	0.61	1.01	0.98	0.86	0.71	0.66	0.57	0.50
MOS Microcomponent	0.37	0.50	0.74	0.69	0.65	0.59	0.53	0.29	0.17
MOS Logic	0.66	0.87	1.42	1.37	1.29	1.29	1.18	1.14	1.17
Analog (Monolithic + Hybrid)	0.74	0.95	1.47	1.37	1.40	1.41	1.45	1.43	1.50
Total Discrete	0.53	0.67	1.01	0.98	0.97	0.94	0.92	0.86	0.83
Total Optoelectronic	0.12	0.17	0.18	0.10	0.10	0.09	0.09	0.09	0.08

Source: Dataquest (July 1995)

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Table 3-7
Hong Kong/Shenzhen Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	15.15	20.00	19.47	19.41	19.12	19.54	19.39	18.97	21.24
Total IC	9.31	12.28	11.79	11.86	11.62	11.83	11.77	11.44	12.78
Bipolar Digital	0.23	0.27	0.11	0.08	0.03	0.02	0.02	0.01	0.01
MOS Digital	7.46	9.94	9.68	9.78	9.66	9.88	9.88	9.61	10.77
MOS Memory	2.38	3.00	2.95	3.00	2.95	3.01	3.00	2.86	3.23
MOS Microcomponent	2.31	3.42	3.37	3.44	3.41	3.49	3.50	3.51	4.00
MOS Logic	2.77	3.52	3.37	3.33	3.30	3.37	3.38	3.25	3.54
Analog (Monolithic + Hybrid)	1.62	2.07	2.00	2.00	1.93	1.93	1.88	1.82	2.00
Total Discrete	4.92	6.52	6.53	6.44	6.48	6.75	6.75	6.75	7.69
Total Optoelectronic	0.92	1.20	1.16	1.11	1.02	0.96	0.88	0.78	0.77

Source: Dataquest (July 1995)

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Section 4—Hong Kong/Shenzhen Semiconductor Consumption by Application Market: Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
Hong Kong/Shenzhen Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronics Equipment	5,951	6,090	6,740	7,257	7,948	8,580	9,417	10,078	10,873
Data Processing	2,477	2,810	3,274	3,554	4,020	4,493	5,064	5,538	5,935
Computers	2,036	2,185	2,505	2,650	2,940	3,245	3,655	3,977	4,220
Data Storage	0	1	1	2	4	6	8	12	20
Input/Output	142	149	180	209	247	294	341	398	420
Dedicated System	269	425	518	593	689	750	805	851	905
Other Data Processing	30	50	70	100	140	198	255	300	370
Communications	695	784	930	1,010	1,073	1,148	1,283	1,355	1,476
Premise Telecommunications	499	540	589	620	645	655	685	700	730
Public Telecommunications	51	78	111	115	112	116	124	140	160
Mobile Communications	4	11	17	33	47	80	150	170	198
Broadcast and Studio	107	118	146	152	159	167	174	180	194
Other Communications	34	37	67	90	110	130	150	165	194
Industrial	42	79	93	111	134	157	181	213	263
Security and Energy Management	23	46	54	63	77	92	103	120	142
Manufacturing Systems/Instruments	19	32	38	45	53	59	70	83	107
Medical Equipment	0	0	0	2	2	3	3	3	4
Other Industrial	0	0	0	1	2	3	5	7	10
Consumer	2,362	2,142	2,239	2,390	2,540	2,614	2,733	2,825	3,074
Audio	268	286	321	335	347	358	367	387	402
Video	505	122	103	80	70	67	62	50	40
Personal Electronics	1,434	1,508	1,550	1,645	1,750	1,789	1,864	1,904	2,105
Appliances	110	171	195	235	268	288	315	345	376
Other Consumer	45	55	70	95	105	112	125	139	151
Military/Civil Aerospace	244	179	109	102	93	85	76	70	60
Transportation	130	97	95	90	88	83	80	77	65

Source: Dataquest (July 1995)

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Table 4-2
Hong Kong/Shenzhen Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	2.30	10.70	7.70	9.50	7.90	9.80	7.00	7.90	8.40
Data Processing	13.40	16.50	8.50	13.10	11.80	12.70	9.40	7.20	10.80
Computers	7.30	14.60	5.80	10.90	10.40	12.60	8.80	6.10	9.80
Data Storage	150.00	40.00	57.10	81.80	55.00	35.50	42.90	66.70	55.50
Input/Output	4.90	20.80	16.10	18.20	19.00	16.00	16.70	5.50	15.00
Dedicated System	58.00	21.90	14.50	16.20	8.90	7.30	5.70	6.30	8.80
Other Data Processing	66.70	40.00	42.90	40.00	41.40	28.80	17.60	23.30	29.90
Communications	12.80	18.60	8.60	6.20	7.00	11.80	5.60	8.90	7.90
Premise Telecommunications	8.20	9.10	5.30	4.00	1.60	4.60	2.20	4.30	3.30
Public Telecommunications	52.90	42.30	3.60	-2.60	3.60	6.90	12.90	14.30	6.80
Mobile Communications	175.00	54.50	94.10	42.40	70.20	87.50	13.30	16.50	43.10
Broadcast and Studio	10.30	23.70	4.10	4.60	5.00	4.20	3.40	7.80	5.00
Other Communications	8.80	81.10	34.30	22.20	18.20	15.40	10.00	17.60	16.60
Industrial	85.60	18.20	19.60	20.70	16.90	15.30	18.20	23.10	18.80
Security and Energy Management	100.00	17.40	16.70	22.20	19.50	12.00	16.50	18.30	17.60
Manufacturing Systems/Instruments	68.40	18.80	18.40	17.80	11.30	18.60	18.60	28.90	18.90
Medical Equipment	50.00	33.30	400.00	10.00	18.20	7.70	21.40	11.80	13.70
Other Industrial	100.00	100.00	150.00	80.00	66.70	60.00	45.80	42.90	58.50
Consumer	-9.30	4.50	6.70	6.30	2.90	4.60	3.40	8.80	5.20
Audio	6.70	12.20	4.40	3.60	3.20	2.50	5.40	3.90	3.70
Video	-75.80	-15.60	-22.30	-12.50	-4.30	-7.50	-19.40	-20.00	-12.90
Personal Electronics	5.10	2.80	6.10	6.40	2.20	4.20	2.10	10.60	5.10
Appliances	55.50	14.00	20.50	14.00	7.50	9.40	9.50	9.00	9.90
Other Consumer	22.20	27.30	35.70	10.50	6.70	11.60	11.20	8.60	9.70
Military/Civil Aerospace	-26.70	-39.10	-6.40	-8.80	-8.60	-10.60	-7.90	-14.30	-10.10
Transportation	-25.70	-1.70	-5.30	-2.20	-5.70	-3.60	-3.80	-15.60	-6.30

Source: Dataquest (July 1995)

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Table 4-3
Hong Kong/Shenzhen Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	1,099	1,328	1,678	2,076	2,539	3,032	3,495	4,030	4,812
Data Processing	710	889	1,178	1,504	1,879	2,295	2,689	3,120	3,817
Computers	659	810	1,031	1,316	1,634	1,996	2,325	2,683	3,340
Data Storage	0	0	0	0	1	1	1	1	3
Input/Output	22	25	34	41	46	54	66	77	84
Dedicated System	22	40	89	112	148	173	202	243	279
Other Data Processing	7	13	23	35	51	72	96	116	112
Communications	50	68	91	118	160	198	216	271	308
Premise Telecommunications	28	41	52	72	109	135	135	180	200
Public Telecommunications	4	6	9	10	10	9	9	10	12
Mobile Communications	1	2	3	5	9	15	29	35	41
Broadcast and Studio	14	16	20	21	22	25	28	29	35
Other Communications	3	4	7	9	11	13	15	17	21
Industrial	6	9	10	12	15	19	23	29	36
Security and Energy Management	4	6	6	7	9	12	14	17	21
Manufacturing Systems/Instruments	2	3	4	5	6	7	8	10	13
Medical Equipment	0	0	0	0	0	0	0	0	0
Other Industrial	0	0	0	0	0	0	1	1	1
Consumer	305	336	375	422	463	500	547	592	633
Audio	59	65	74	77	74	73	72	76	80
Video	38	34	28	23	20	18	16	14	11
Personal Electronics	177	187	215	245	279	312	347	365	389
Appliances	22	38	41	51	58	63	71	92	102
Other Consumer	9	13	17	27	31	33	40	45	51
Military/Civil Aerospace	8	7	6	6	5	5	5	4	4
Transportation	20	19	19	14	16	16	15	14	13

Source: Dataquest (July 1995)

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Table 4-4
Hong Kong/Shenzhen Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	20.90	26.30	23.70	22.30	19.40	15.20	15.30	19.40	18.30
Data Processing	25.20	32.50	27.70	24.90	22.10	17.20	16.00	22.30	20.50
Computers	23.00	27.30	27.60	24.20	22.10	16.50	15.40	24.50	20.50
Data Storage	179.90	25.10	39.20	48.40	40.00	36.80	47.50	69.60	48.00
Input/Output	16.80	35.90	19.00	12.80	17.00	21.80	17.90	8.20	15.50
Dedicated System	79.40	122.80	25.20	32.00	16.90	16.90	20.20	14.80	20.00
Other Data Processing	80.70	72.00	53.90	43.90	43.30	32.10	20.80	-2.90	26.20
Communications	37.10	32.60	30.10	35.90	23.40	9.40	25.50	13.50	21.20
Premise Telecommunications	46.40	26.80	38.50	51.40	23.90	0	33.30	11.10	22.70
Public Telecommunications	58.20	43.60	13.90	-7.00	-4.50	1.80	8.60	17.40	2.90
Mobile Communications	203.50	66.00	103.90	58.00	78.10	93.00	17.90	17.40	49.70
Broadcast and Studio	9.60	31.40	4.90	3.70	13.10	10.10	6.00	19.20	10.30
Other Communications	23.40	65.80	35.30	24.10	20.90	12.60	15.50	19.10	18.40
Industrial	60.50	11.30	21.00	25.90	23.60	18.80	26.90	25.10	24.00
Security and Energy Management	57.60	10.30	17.30	29.90	27.40	16.10	25.00	20.70	23.70
Manufacturing Systems/Instruments	65.40	12.10	21.80	18.80	14.80	21.30	28.50	30.70	22.70
Medical Equipment	33.30	64.10	343.20	23.50	26.30	9.70	31.70	7.40	19.30
Other Industrial	93.80	60.00	182.30	77.10	91.90	66.80	45.80	51.90	65.90
Consumer	10.20	11.50	12.60	9.70	8.00	9.40	8.20	7.00	8.50
Audio	10.20	13.40	4.80	-3.40	-2.20	-0.50	4.30	5.90	0.80
Video	-10.90	-16.30	-19.50	-11.10	-9.80	-10.10	-14.80	-19.50	-13.10
Personal Electronics	5.90	15.00	14.00	13.90	11.80	11.20	5.20	6.60	9.70
Appliances	68.30	8.70	23.30	15.70	8.40	12.10	29.60	10.40	15.00
Other Consumer	40.60	33.10	58.00	15.00	8.60	20.30	13.30	13.00	14.00
Military/Civil Aerospace	-19.00	-5.90	-6.30	-13.30	-3.80	-8.00	-4.30	-2.30	-6.40
Transportation	-4.90	-4.10	-22.70	11.80	-3.10	-1.90	-7.90	-5.70	-1.60

Source: Dataquest (July 1995)

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Table 4-5
Hong Kong/Shenzhen Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	0.185	0.218	0.249	0.286	0.319	0.353	0.371	0.400	0.443
Data Processing	0.287	0.316	0.360	0.423	0.467	0.511	0.531	0.563	0.643
Computers	0.323	0.371	0.412	0.497	0.556	0.615	0.636	0.675	0.792
Data Storage	0.183	0.205	0.183	0.162	0.133	0.120	0.121	0.125	0.127
Input/Output	0.152	0.169	0.190	0.195	0.186	0.183	0.192	0.194	0.199
Dedicated System	0.083	0.094	0.173	0.189	0.214	0.230	0.251	0.285	0.308
Other Data Processing	0.245	0.265	0.326	0.351	0.361	0.366	0.375	0.385	0.303
Communications	0.072	0.087	0.097	0.117	0.149	0.172	0.168	0.200	0.209
Premise Telecommunications	0.056	0.076	0.088	0.116	0.169	0.206	0.197	0.257	0.274
Public Telecommunications	0.078	0.080	0.081	0.089	0.085	0.079	0.075	0.072	0.074
Mobile Communications	0.131	0.145	0.156	0.164	0.181	0.190	0.195	0.203	0.205
Broadcast and Studio	0.132	0.131	0.140	0.141	0.139	0.150	0.159	0.163	0.180
Other Communications	0.094	0.107	0.098	0.098	0.100	0.102	0.100	0.105	0.106
Industrial	0.134	0.116	0.109	0.111	0.115	0.122	0.126	0.135	0.137
Security and Energy Management	0.154	0.121	0.114	0.115	0.122	0.130	0.135	0.144	0.147
Manufacturing Systems/Instruments	0.111	0.109	0.103	0.106	0.107	0.110	0.113	0.122	0.124
Medical Equipment	0.094	0.083	0.103	0.091	0.102	0.109	0.111	0.120	0.116
Other Industrial	0.129	0.125	0.100	0.113	0.111	0.128	0.133	0.133	0.142
Consumer	0.129	0.157	0.167	0.177	0.182	0.191	0.200	0.210	0.206
Audio	0.220	0.227	0.229	0.230	0.214	0.203	0.197	0.195	0.199
Video	0.075	0.278	0.275	0.285	0.290	0.273	0.265	0.280	0.282
Personal Electronics	0.123	0.124	0.139	0.149	0.159	0.174	0.186	0.192	0.185
Appliances	0.204	0.221	0.210	0.215	0.218	0.220	0.226	0.267	0.270
Other Consumer	0.200	0.230	0.241	0.280	0.291	0.297	0.320	0.326	0.339
Military/Civil Aerospace	0.034	0.038	0.059	0.059	0.056	0.059	0.061	0.063	0.072
Transportation	0.156	0.200	0.195	0.159	0.182	0.187	0.190	0.182	0.203

Source: Dataquest (July 1995)

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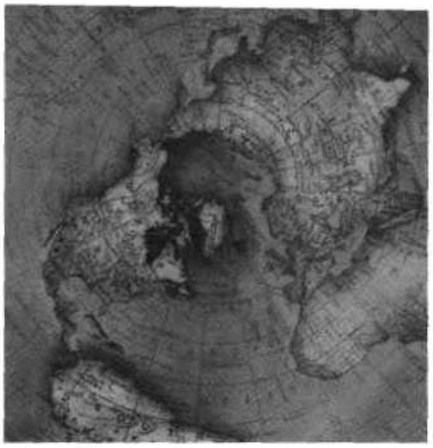
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South Korean Semiconductor Consumption by Application Market

Market Statistics

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South Korean Semiconductor Consumption by Application Market



Market Statistics

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Note: All tables show estimated data.

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Note: All tables show estimated data.

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Chapter 1
South Korean Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in the month of January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic

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goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

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Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing

[1] Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.

- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.

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- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) electronics.

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- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).
  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).
- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in South Korea, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's South Korean operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market—Database Tables

Section 1—South Korean Semiconductor Consumption by Application Market, Factory Revenue

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Table 1-1
South Korean Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	15,702	17,724	19,955	22,546	27,013	30,487	34,484	39,156	44,785
Total Semiconductor	1,956	2,290	2,771	3,450	4,399	5,313	6,402	7,696	9,156
Total IC	1,524	1,745	2,186	2,772	3,583	4,378	5,337	6,467	7,729
Bipolar Digital	84	76	80	78	67	60	46	37	33
MOS Digital	990	1,106	1,504	1,876	2,444	3,011	3,691	4,496	5,343
MOS Memory	353	377	538	652	829	995	1,190	1,442	1,733
MOS Microcomponent	337	360	458	693	969	1,265	1,624	2,041	2,420
MOS Logic	300	369	508	531	646	751	876	1,012	1,190
Analog (Monolithic + Hybrid)	450	563	601	818	1,071	1,306	1,600	1,934	2,352
Total Discrete	370	464	480	554	673	782	902	1,057	1,234
Total Optoelectronic	62	81	106	123	144	154	164	172	193

Source: Dataquest (June 1995)

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Table 1-2
South Korean Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	3,369	3,629	4,238	4,859	5,891	6,722	7,683	8,820	10,214
Total Semiconductor	669	693	911	1,091	1,369	1,631	1,937	2,314	2,746
Total IC	647	663	872	1,038	1,292	1,524	1,806	2,138	2,522
Bipolar Digital	30	21	23	23	20	18	16	12	9
MOS Digital	547	533	743	894	1,137	1,365	1,644	1,967	2,339
MOS Memory	221	210	302	369	460	538	645	776	919
MOS Microcomponent	158	141	203	282	383	491	615	767	929
MOS Logic	168	181	237	243	295	336	384	423	490
Analog (Monolithic + Hybrid)	70	109	106	121	135	141	146	159	174
Total Discrete	14	17	21	34	53	81	108	150	194
Total Optoelectronic	8	13	18	19	24	27	23	26	31

Source: Dataquest (June 1995)

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Table 1-3
South Korean Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	2,408	2,632	2,930	3,625	4,984	6,365	8,007	9,944	12,242
Total Semiconductor	209	249	306	435	648	917	1,265	1,700	2,252
Total IC	171	201	253	366	548	783	1,089	1,472	1,959
Bipolar Digital	5	5	6	7	5	6	8	10	12
MOS Digital	119	137	182	257	389	554	769	1,034	1,334
MOS Memory	28	26	47	65	100	140	192	268	355
MOS Microcomponent	55	61	67	105	164	242	344	457	588
MOS Logic	36	50	67	87	125	172	232	308	392
Analog (Monolithic + Hybrid)	47	59	66	101	155	223	312	428	612
Total Discrete	29	34	38	51	75	108	144	199	257
Total Optoelectronic	9	13	15	18	25	25	32	30	37

Source: Dataquest (June 1995)

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Table 1-4
South Korean Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	620	830	1,203	1,264	1,491	1,652	1,833	2,040	2,289
Total Semiconductor	52	69	105	130	170	210	262	314	376
Total IC	40	50	77	96	125	156	192	237	283
Bipolar Digital	8	7	7	6	6	5	5	4	3
MOS Digital	23	32	54	66	88	111	137	169	201
MOS Memory	6	8	18	23	31	40	48	57	69
MOS Microcomponent	10	12	19	25	36	46	62	80	96
MOS Logic	7	11	17	18	21	25	27	33	37
Analog (Monolithic + Hybrid)	10	12	17	24	31	40	49	63	78
Total Discrete	8	13	19	25	36	46	60	69	85
Total Optoelectronic	4	6	8	9	9	8	9	8	9

Source: Dataquest (June 1995)

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Table 1-5
South Korean Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	8,455	9,705	10,583	11,704	13,414	14,393	15,458	16,664	18,114
Total Semiconductor	881	1,102	1,248	1,599	2,011	2,346	2,718	3,125	3,504
Total IC	549	686	820	1,119	1,461	1,756	2,084	2,442	2,761
Bipolar Digital	37	39	42	40	35	29	15	10	8
MOS Digital	201	279	381	527	698	849	1,005	1,182	1,304
MOS Memory	60	78	106	140	188	230	263	299	344
MOS Microcomponent	80	107	125	234	335	432	541	667	725
MOS Logic	61	94	150	152	174	187	201	217	235
Analog (Monolithic + Hybrid)	311	369	397	552	728	878	1,064	1,250	1,449
Total Discrete	301	379	380	421	483	518	556	600	652
Total Optoelectronic	31	36	48	59	67	72	77	83	91

Source: Dataquest (June 1995)

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Table 1-6
South Korean Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	250	284	319	361	432	482	534	588	647
Total Semiconductor	41	49	54	53	56	62	68	74	83
Total IC	40	46	51	50	53	57	62	68	75
Bipolar Digital	4	3	2	2	2	2	1	1	1
MOS Digital	35	41	47	45	47	51	55	60	66
MOS Memory	13	16	19	18	19	21	23	25	27
MOS Microcomponent	14	16	17	16	16	17	18	20	23
MOS Logic	8	10	11	11	12	13	14	15	17
Analog (Monolithic + Hybrid)	1	2	2	3	4	5	6	7	8
Total Discrete	1	2	2	3	3	3	4	5	6
Total Optoelectronic	0	0	0	0	0	1	2	2	3

Source: Dataquest (June 1995)

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Table 1-7
South Korean Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	600	645	682	733	801	873	970	1,100	1,281
Total Semiconductor	104	130	147	142	146	148	154	167	193
Total IC	77	99	111	104	103	102	104	111	131
Bipolar Digital	1	1	1	0	0	0	0	0	0
MOS Digital	65	85	98	87	86	82	80	84	99
MOS Memory	25	39	46	37	32	26	19	17	19
MOS Microcomponent	20	23	27	30	34	38	44	51	60
MOS Logic	20	23	25	21	20	18	17	17	19
Analog (Monolithic + Hybrid)	11	12	13	16	18	20	23	28	32
Total Discrete	17	18	19	21	23	25	29	34	40
Total Optoelectronic	10	13	17	18	19	20	21	22	23

Source: Dataquest (June 1995)

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Section 2—South Korean Consumption by Application Market, Annual Growth Rates

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Table 2-1
South Korean Semiconductor Consumption—Total Electronics (Percentage Growth)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	13	13	13	20	13	13	14	14	15
Total Semiconductor	17	21	24	28	21	20	20	19	22
Total IC	15	25	27	29	22	22	21	20	23
Bipolar Digital	-9	5	-3	-14	-11	-24	-19	-10	-16
MOS Digital	12	36	25	30	23	23	22	19	23
MOS Memory	7	43	21	27	20	20	21	20	22
MOS Microcomponent	7	27	51	40	31	28	26	19	28
MOS Logic	23	37	5	22	16	17	16	18	18
Analog (Monolithic + Hybrid)	25	7	36	31	22	22	21	22	24
Total Discrete	26	3	16	21	16	15	17	17	17
Total Optoelectronic	30	31	16	17	7	7	5	12	9

Source: Dataquest (June 1995)

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Table 2-2
South Korean Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	8	17	15	21	14	14	15	16	16
Total Semiconductor	4	31	20	25	19	19	19	19	20
Total IC	2	32	19	25	18	19	18	18	19
Bipolar Digital	-30	10	-2	-11	-10	-11	-25	-25	-17
MOS Digital	-3	39	20	27	20	20	20	19	21
MOS Memory	-5	44	22	24	17	20	20	18	20
MOS Microcomponent	-11	44	39	36	28	25	25	21	27
MOS Logic	8	31	2	21	14	14	10	16	15
Analog (Monolithic + Hybrid)	56	-3	15	12	4	3	9	9	7
Total Discrete	24	22	61	56	52	33	39	29	42
Total Optoelectronic	59	40	9	21	14	-14	15	16	10

Source: Dataquest (June 1995)

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Table 2-3
South Korean Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	9	11	24	37	28	26	24	23	28
Total Semiconductor	19	23	42	49	41	38	34	32	39
Total IC	18	26	44	50	43	39	35	33	40
Bipolar Digital	17	11	24	-31	28	26	24	23	11
MOS Digital	15	33	42	51	42	39	35	29	39
MOS Memory	-6	78	39	53	40	37	40	32	40
MOS Microcomponent	10	11	56	56	47	42	33	28	41
MOS Logic	39	35	29	43	38	35	33	27	35
Analog (Monolithic + Hybrid)	26	11	54	52	44	40	37	43	43
Total Discrete	18	11	33	47	45	33	38	29	38
Total Optoelectronic	46	11	24	37	2	26	-7	23	15

Source: Dataquest (June 1995)

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Table 2-4
South Korean Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	34	45	5	18	11	11	11	12	13
Total Semiconductor	32	52	24	31	24	24	20	20	24
Total IC	24	54	24	30	25	23	23	19	24
Bipolar Digital	-10	-7	-8	-8	-2	-7	-16	-19	-11
MOS Digital	40	72	21	34	26	24	23	19	25
MOS Memory	38	117	26	38	27	20	20	20	25
MOS Microcomponent	31	55	31	42	29	35	28	21	31
MOS Logic	54	56	5	18	19	11	19	12	16
Analog (Monolithic + Hybrid)	16	45	43	30	27	25	28	23	27
Total Discrete	66	45	31	42	29	31	15	22	27
Total Optoelectronic	42	45	5	1	-8	11	-11	12	1

Source: Dataquest (June 1995)

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Table 2-5
South Korean Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	15	9	11	15	7	7	8	9	9
Total Semiconductor	25	13	28	26	17	16	15	12	17
Total IC	25	20	36	31	20	19	17	13	20
Bipolar Digital	5	9	-6	-13	-18	-46	-35	-20	-28
MOS Digital	39	37	38	32	22	18	18	10	20
MOS Memory	29	36	33	34	23	14	14	15	20
MOS Microcomponent	33	17	87	43	29	25	23	9	25
MOS Logic	54	60	1	15	7	7	8	9	9
Analog (Monolithic + Hybrid)	19	8	39	32	21	21	18	16	21
Total Discrete	26	0	11	15	7	7	8	9	9
Total Optoelectronic	16	33	23	15	7	7	8	9	9

Source: Dataquest (June 1995)

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Table 2-6
South Korean Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	13	13	13	20	12	11	10	10	12
Total Semiconductor	17	11	-3	7	9	10	10	12	10
Total IC	16	11	-4	7	8	8	9	10	8
Bipolar Digital	-14	-33	-15	-6	-6	-20	-17	-20	-14
MOS Digital	18	14	-5	5	8	8	8	11	8
MOS Memory	20	23	-6	5	11	10	9	8	8
MOS Microcomponent	11	6	-2	1	4	6	8	15	7
MOS Logic	28	13	-6	11	8	8	7	10	9
Analog (Monolithic + Hybrid)	42	13	29	35	24	22	20	10	22
Total Discrete	43	10	14	20	13	18	13	33	19
Total Optoelectronic	106	41	13	20	123	66	47	10	48

Source: Dataquest (June 1995)

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Table 2-7
South Korean Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	7	6	7	9	9	11	14	16	12
Total Semiconductor	25	14	-3	2	1	4	9	16	6
Total IC	27	13	-7	0	-1	2	7	18	5
Bipolar Digital	-8	-47	-41	-50	-50	-50	-20	-50	-45
MOS Digital	31	15	-11	-2	-4	-2	4	18	2
MOS Memory	55	20	-21	-13	-18	-26	-15	16	-12
MOS Microcomponent	16	15	13	12	12	16	16	19	15
MOS Logic	16	6	-16	-3	-8	-5	-5	16	-1
Analog (Monolithic + Hybrid)	11	6	24	9	14	16	18	16	15
Total Discrete	9	6	7	13	9	15	17	16	14
Total Optoelectronic	29	32	6	6	5	5	5	5	5

Source: Dataquest (June 1995)

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Section 3—South Korean Semiconductor Consumption by Application Market, Input/Output Ratios

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Table 3-1
South Korean Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.129	0.139	0.153	0.163	0.174	0.186	0.197	0.204
Total IC	0	0.098	0.110	0.123	0.133	0.144	0.155	0.165	0.173
Bipolar Digital	0	0.004	0.004	0.003	0.002	0.002	0.001	0.001	0.001
MOS Digital	0	0.062	0.075	0.083	0.090	0.099	0.107	0.115	0.119
MOS Memory	0	0.021	0.027	0.029	0.031	0.033	0.035	0.037	0.039
MOS Microcomponent	0	0.020	0.023	0.031	0.036	0.041	0.047	0.052	0.054
MOS Logic	0	0.021	0.025	0.024	0.024	0.025	0.025	0.026	0.027
Analog (Monolithic + Hybrid)	0	0.032	0.030	0.036	0.040	0.043	0.046	0.049	0.053
Total Discrete	0	0.026	0.024	0.025	0.025	0.026	0.026	0.027	0.028
Total Optoelectronic	0	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004

Source: Dataquest (June 1995)

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Table 3-2
South Korean Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.191	0.215	0.225	0.232	0.243	0.252	0.262	0.269
Total IC	0	0.183	0.206	0.214	0.219	0.227	0.235	0.242	0.247
Bipolar Digital	0	0.006	0.005	0.005	0.003	0.003	0.002	0.001	0.001
MOS Digital	0	0.147	0.175	0.184	0.193	0.203	0.214	0.223	0.229
MOS Memory	0	0.058	0.071	0.076	0.078	0.080	0.084	0.088	0.090
MOS Microcomponent	0	0.039	0.048	0.058	0.065	0.073	0.080	0.087	0.091
MOS Logic	0	0.050	0.056	0.050	0.050	0.050	0.050	0.048	0.048
Analog (Monolithic + Hybrid)	0	0.030	0.025	0.025	0.023	0.021	0.019	0.018	0.017
Total Discrete	0	0.005	0.005	0.007	0.009	0.012	0.014	0.017	0.019
Total Optoelectronic	0	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003

Source: Dataquest (June 1995)

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Table 3-3
South Korean Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.095	0.105	0.120	0.130	0.144	0.158	0.171	0.184
Total IC	0	0.077	0.087	0.101	0.110	0.123	0.136	0.148	0.160
Bipolar Digital	0	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
MOS Digital	0	0.052	0.062	0.071	0.078	0.087	0.096	0.104	0.109
MOS Memory	0	0.010	0.016	0.018	0.020	0.022	0.024	0.027	0.029
MOS Microcomponent	0	0.023	0.023	0.029	0.033	0.038	0.043	0.046	0.048
MOS Logic	0	0.019	0.023	0.024	0.025	0.027	0.029	0.031	0.032
Analog (Monolithic + Hybrid)	0	0.023	0.023	0.028	0.031	0.035	0.039	0.043	0.050
Total Discrete	0	0.013	0.013	0.014	0.015	0.017	0.018	0.020	0.021
Total Optoelectronic	0	0.005	0.005	0.005	0.005	0.004	0.004	0.003	0.003

Source: Dataquest (June 1995)

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Table 3-4
South Korean Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.083	0.087	0.103	0.114	0.127	0.143	0.154	0.164
Total IC	0	0.060	0.064	0.076	0.084	0.094	0.105	0.116	0.123
Bipolar Digital	0	0.008	0.005	0.005	0.004	0.003	0.003	0.002	0.001
MOS Digital	0	0.038	0.045	0.052	0.059	0.067	0.075	0.083	0.088
MOS Memory	0	0.010	0.015	0.018	0.021	0.024	0.026	0.028	0.030
MOS Microcomponent	0	0.015	0.016	0.020	0.024	0.028	0.034	0.039	0.042
MOS Logic	0	0.013	0.014	0.014	0.014	0.015	0.015	0.016	0.016
Analog (Monolithic + Hybrid)	0	0.014	0.014	0.019	0.021	0.024	0.027	0.031	0.034
Total Discrete	0	0.016	0.016	0.020	0.024	0.028	0.033	0.034	0.037
Total Optoelectronic	0	0.007	0.007	0.007	0.006	0.005	0.005	0.004	0.004

Source: Dataquest (June 1995)

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Table 3-5
South Korean Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.114	0.118	0.137	0.150	0.163	0.176	0.188	0.193
Total IC	0	0.071	0.078	0.096	0.109	0.122	0.135	0.147	0.152
Bipolar Digital	0	0.004	0.004	0.003	0.003	0.002	0.001	0.001	0
MOS Digital	0	0.029	0.036	0.045	0.052	0.059	0.065	0.071	0.072
MOS Memory	0	0.008	0.010	0.012	0.014	0.016	0.017	0.018	0.019
MOS Microcomponent	0	0.011	0.012	0.020	0.025	0.030	0.035	0.040	0.040
MOS Logic	0	0.010	0.014	0.013	0.013	0.013	0.013	0.013	0.013
Analog (Monolithic + Hybrid)	0	0.038	0.038	0.047	0.054	0.061	0.069	0.075	0.080
Total Discrete	0	0.039	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Total Optoelectronic	0	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Source: Dataquest (June 1995)

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Table 3-6
South Korean Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.171	0.169	0.146	0.130	0.128	0.127	0.127	0.129
Total IC	0	0.164	0.161	0.138	0.122	0.119	0.116	0.115	0.115
Bipolar Digital	0	0.011	0.006	0.005	0.004	0.003	0.002	0.002	0.001
MOS Digital	0	0.146	0.148	0.125	0.110	0.106	0.103	0.101	0.102
MOS Memory	0	0.055	0.060	0.050	0.044	0.044	0.043	0.043	0.042
MOS Microcomponent	0	0.055	0.052	0.045	0.038	0.035	0.034	0.033	0.035
MOS Logic	0	0.036	0.036	0.030	0.028	0.027	0.026	0.026	0.026
Analog (Monolithic + Hybrid)	0	0.007	0.007	0.008	0.009	0.010	0.011	0.012	0.012
Total Discrete	0	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.009
Total Optoelectronic	0	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.004

Source: Dataquest (June 1995)

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Table 3-7
South Korean Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0	0.201	0.216	0.194	0.182	0.169	0.159	0.152	0.151
Total IC	0	0.153	0.163	0.142	0.129	0.117	0.107	0.101	0.102
Bipolar Digital	0	0.002	0.001	0.001	0	0	0	0	0
MOS Digital	0	0.132	0.143	0.119	0.107	0.094	0.083	0.076	0.077
MOS Memory	0	0.060	0.068	0.050	0.040	0.030	0.020	0.015	0.015
MOS Microcomponent	0	0.036	0.039	0.041	0.042	0.043	0.045	0.046	0.047
MOS Logic	0	0.036	0.036	0.028	0.025	0.021	0.018	0.015	0.015
Analog (Monolithic + Hybrid)	0	0.019	0.019	0.022	0.022	0.023	0.024	0.025	0.025
Total Discrete	0	0.028	0.028	0.028	0.029	0.029	0.030	0.031	0.031
Total Optoelectronic	0	0.020	0.025	0.025	0.024	0.023	0.022	0.020	0.018

Source: Dataquest (June 1995)

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Section 4—South Korean Semiconductor Consumption by Application Market, Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
South Korean Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronics Equipment	15,782	17,724	19,955	22,546	27,013	30,487	34,484	39,156	44,785
Data Processing	3,369	3,629	4,238	4,859	5,891	6,722	7,683	8,820	10,214
Computers	800	834	950	1,208	1,546	1,852	2,222	2,679	3,257
Data Storage	94	108	244	315	410	515	647	817	1,041
Input/Output	1,864	2,036	2,375	2,633	3,027	3,316	3,601	3,968	4,412
Dedicated System	30	32	39	13	20	21	21	22	23
Other Data Processing	581	618	630	691	888	1,019	1,192	1,334	1,481
Communications	2,408	2,632	2,930	3,625	4,984	6,365	8,007	9,944	12,242
Premise Telecommunications	970	1,074	1,182	1,384	1,938	2,598	3,432	4,476	5,785
Public Telecommunications	841	906	903	953	1,144	1,241	1,327	1,401	1,466
Mobile Communications	222	257	402	591	945	1,388	1,956	2,599	3,360
Broadcast and Studio	100	107	127	271	353	415	480	548	621
Other Communications	275	288	316	425	604	722	811	920	1,009
Industrial	700	830	1,203	1,264	1,491	1,652	1,833	2,040	2,289
Security and Energy Management	68	71	77	96	116	134	157	183	216
Manufacturing Systems/Instruments	70	96	379	438	526	582	646	719	806
Medical Equipment	66	82	172	205	246	264	284	307	334
Other Industrial	600	581	575	525	605	672	746	831	933
Consumer	8,455	9,705	10,583	11,704	13,414	14,393	15,458	16,664	18,114
Audio	1,745	1,880	1,837	1,924	2,117	2,226	2,342	2,475	2,636
Video	3,350	3,845	4,184	4,643	5,339	5,729	6,153	6,633	7,210
Personal Electronics	100	228	443	494	593	687	796	927	1,089
Appliances	2,900	3,337	3,699	4,147	4,728	5,073	5,448	5,873	6,384
Other Consumer	360	415	420	496	638	679	718	756	795
Military/Civil Aerospace	250	284	319	361	432	482	534	588	647
Transportation	600	645	682	733	801	873	970	1,100	1,281

Source: Dataquest (June 1995)

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Table 4-2
South Korean Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	12.3	12.6	13.0	19.8	12.9	13.1	13.5	14.4	14.7
Data Processing	7.7	16.8	14.7	21.2	14.1	14.3	14.8	15.8	16.0
Computers	-75.3	-73.8	27.1	28.0	19.8	20.0	20.5	21.6	22.0
Data Storage	15.1	125.8	29.1	30.0	25.5	25.7	26.3	27.4	27.0
Input/Output	9.2	16.7	10.8	15.0	9.5	8.6	10.2	11.2	10.9
Dedicated System	7.7	19.9	-66.8	55.2	2.7	2.9	3.3	4.2	12.0
Other Data Processing	6.5	1.8	9.7	28.6	14.7	17.0	11.9	11.1	16.5
Communications	9.3	11.3	23.7	37.5	27.7	25.8	24.2	23.1	27.6
Premise Telecommunications	-55.4	-55.1	-52.8	-46.5	-47.9	-46.1	-44.1	-41.8	33.1
Public Telecommunications	7.8	-0.3	5.5	20.0	8.5	6.9	5.6	4.6	9.0
Mobile Communications	15.9	56.3	46.9	60.0	46.9	40.9	32.9	29.3	41.6
Broadcast and Studio	7.1	18.5	113.9	30.0	17.5	15.7	14.3	13.3	18.0
Other Communications	4.6	9.9	34.6	42.1	19.5	12.4	13.3	9.8	18.9
Industrial	18.6	44.9	5.1	18.0	10.8	10.9	11.3	12.2	12.6
Security and Energy Management	4.5	9.0	24.3	20.0	16.3	16.4	16.9	17.8	17.5
Manufacturing Systems/Instruments	37.6	293.6	15.5	20.0	10.8	10.9	11.3	12.2	13.0
Medical Equipment	23.7	110.1	19.3	20.0	7.5	7.6	8.0	8.8	10.3
Other Industrial	-3.2	-1.0	-8.7	15.2	11.1	11.1	11.4	12.2	12.2
Consumer	14.8	9.0	10.6	14.6	7.3	7.4	7.8	8.7	9.1
Audio	7.7	-2.3	4.8	10.0	5.2	5.3	5.6	6.5	6.5
Video	14.8	8.8	11.0	15.0	7.3	7.4	7.8	8.7	9.2
Personal Electronics	127.6	94.9	11.3	20.0	15.9	16.0	16.4	17.4	17.1
Appliances	15.1	10.8	12.1	14.0	7.3	7.4	7.8	8.7	9.0
Other Consumer	15.4	1.2	18.0	28.6	6.4	5.8	5.3	5.1	9.9
Military/Civil Aerospace	13.4	12.6	13.0	19.8	11.6	10.7	10.1	10.0	12.4
Transportation	7.5	5.8	7.5	9.2	9.0	11.1	13.5	16.4	11.8

Source: Dataquest (June 1995)

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Table 4-3
South Korean Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	2,019	2,341	2,822	3,494	4,445	5,330	6,380	7,660	9,104
Data Processing	667	733	951	1,132	1,410	1,660	1,944	2,320	2,747
Computers	160	192	332	462	587	685	811	972	1,156
Data Storage	15	15	33	39	49	62	78	98	125
Input/Output	170	210	273	326	415	514	587	734	838
Dedicated System	3	0	0	0	2	4	4	5	5
Other Data Processing	319	316	312	304	356	395	464	511	622
Communications	218	253	306	435	648	917	1,265	1,700	2,252
Premise Telecommunications	116	131	145	173	244	330	436	568	735
Public Telecommunications	49	54	58	66	85	96	106	118	129
Mobile Communications	22	31	58	100	180	292	450	663	907
Broadcast and Studio	10	13	18	52	76	108	157	200	236
Other Communications	21	24	26	45	64	92	115	151	246
Industrial	68	73	113	137	174	212	260	312	374
Security and Energy Management	5	5	5	8	12	16	21	30	40
Manufacturing Systems/Instruments	10	14	57	71	95	119	151	178	216
Medical Equipment	4	6	12	15	18	21	25	30	35
Other Industrial	49	48	38	43	49	56	63	75	82
Consumer	903	1,102	1,248	1,594	2,016	2,346	2,718	3,132	3,505
Audio	192	226	228	269	317	378	433	507	554
Video	335	404	456	543	662	739	812	909	1,009
Personal Electronics	11	25	51	71	95	119	143	176	212
Appliances	313	387	455	622	827	989	1,199	1,380	1,564
Other Consumer	52	60	58	88	114	120	130	160	166
Military/Civil Aerospace	44	51	57	56	57	53	46	38	41
Transportation	119	130	147	139	141	141	146	158	186

Source: Dataquest (June 1995)

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Table 4-4
South Korean Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	15.9	20.5	23.8	27.2	19.9	19.7	20.1	18.9	21.1
Data Processing	9.9	29.7	19.0	24.5	17.8	17.1	19.3	18.4	19.4
Computers	19.8	73.4	39.1	27.0	16.7	18.4	19.9	18.9	20.1
Data Storage	0.7	119.3	17.7	25.8	25.5	25.7	26.3	27.4	26.1
Input/Output	23.6	30.3	19.5	27.1	23.9	14.2	25.1	14.2	20.8
Dedicated System	-88.2	30.8	NM	NM	75.1	15.5	15.7	8.9	96.4
Other Data Processing	-0.9	-1.4	-2.5	17.1	11.0	17.5	10.0	21.8	15.4
Communications	15.9	21.0	42.4	48.9	41.5	37.9	34.4	32.5	38.9
Premise Telecommunications	12.5	11.0	19.0	41.1	35.1	32.1	30.4	29.3	33.5
Public Telecommunications	11.5	6.3	13.8	28.7	12.9	11.1	10.8	9.6	14.4
Mobile Communications	39.1	88.9	72.2	78.8	62.3	54.3	47.3	36.9	55.3
Broadcast and Studio	28.5	43.2	180.3	47.1	42.1	46.0	27.2	17.9	35.5
Other Communications	14.3	9.8	72.2	43.4	44.4	25.1	30.4	63.1	40.7
Industrial	6.4	54.8	21.7	26.7	22.2	22.7	19.9	19.7	22.2
Security and Energy Management	7.6	9.0	49.2	44.3	35.9	33.2	40.2	34.5	37.6
Manufacturing Systems/Instruments	42.3	293.6	25.5	32.5	26.2	26.6	18.0	21.2	24.8
Medical Equipment	29.2	110.1	21.1	25.1	13.3	20.0	20.4	18.9	19.5
Other Industrial	-3.2	-19.5	12.2	14.3	14.7	12.4	17.4	10.4	13.8
Consumer	22.0	13.3	27.8	26.5	16.4	15.9	15.2	11.9	17.1
Audio	17.5	0.9	18.3	17.9	19.2	14.5	17.1	9.1	15.5
Video	20.5	12.9	19.1	21.9	11.6	9.9	11.9	11.1	13.2
Personal Electronics	138.4	103.7	39.4	33.3	26.0	20.0	22.9	20.5	24.5
Appliances	23.6	17.5	36.7	33.0	19.6	21.2	15.2	13.3	20.3
Other Consumer	15.4	-3.6	52.1	29.4	4.9	8.8	22.6	3.7	13.4
Military/Civil Aerospace	15.6	12.3	-1.7	1.9	-6.8	-12.4	-19.0	8.3	-6.1
Transportation	9.1	13.7	-5.7	1.4	0.3	3.6	8.2	17.2	6.0

NM = Not meaningful

Source: Dataquest (June 1995)

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Table 4-5
South Korean Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.134	0.132	0.141	0.155	0.165	0.175	0.185	0.196	0.203
Data Processing	0.204	0.202	0.224	0.233	0.239	0.247	0.253	0.263	0.269
Computers	0.200	0.230	0.350	0.383	0.380	0.370	0.365	0.363	0.355
Data Storage	0.160	0.140	0.136	0.124	0.120	0.120	0.120	0.120	0.120
Input/Output	0.091	0.103	0.115	0.124	0.137	0.155	0.163	0.185	0.190
Dedicated System	0.100	0.011	0.012	0.014	0.105	0.179	0.201	0.225	0.235
Other Data Processing	0.550	0.512	0.496	0.440	0.401	0.388	0.390	0.383	0.420
Communications	0.096	0.096	0.104	0.120	0.130	0.144	0.158	0.171	0.184
Premise Telecommunications	0.120	0.122	0.123	0.125	0.126	0.127	0.127	0.127	0.127
Public Telecommunications	0.058	0.060	0.064	0.069	0.074	0.077	0.080	0.084	0.088
Mobile Communications	0.100	0.120	0.145	0.170	0.190	0.210	0.230	0.255	0.270
Broadcast and Studio	0.100	0.120	0.145	0.190	0.215	0.260	0.328	0.365	0.380
Other Communications	0.075	0.082	0.082	0.105	0.106	0.128	0.142	0.164	0.243
Industrial	0.099	0.088	0.094	0.108	0.116	0.128	0.142	0.153	0.163
Security and Energy Management	0.068	0.070	0.070	0.084	0.101	0.118	0.135	0.162	0.185
Manufacturing Systems/Instruments	0.145	0.150	0.150	0.163	0.180	0.205	0.234	0.248	0.268
Medical Equipment	0.067	0.070	0.070	0.071	0.074	0.078	0.087	0.097	0.106
Other Industrial	0.082	0.082	0.067	0.082	0.081	0.084	0.085	0.090	0.088
Consumer	0.114	0.114	0.118	0.136	0.150	0.163	0.176	0.188	0.194
Audio	0.110	0.120	0.124	0.140	0.150	0.170	0.185	0.205	0.210
Video	0.100	0.105	0.109	0.117	0.124	0.129	0.132	0.137	0.140
Personal Electronics	0.105	0.110	0.115	0.144	0.160	0.174	0.180	0.190	0.195
Appliances	0.108	0.116	0.123	0.150	0.175	0.195	0.220	0.235	0.245
Other Consumer	0.145	0.145	0.138	0.178	0.179	0.177	0.182	0.212	0.209
Military/Civil Aerospace	0.175	0.178	0.178	0.155	0.132	0.110	0.087	0.064	0.063
Transportation	0.198	0.201	0.216	0.190	0.176	0.162	0.151	0.144	0.145

Source: Dataquest (June 1995)

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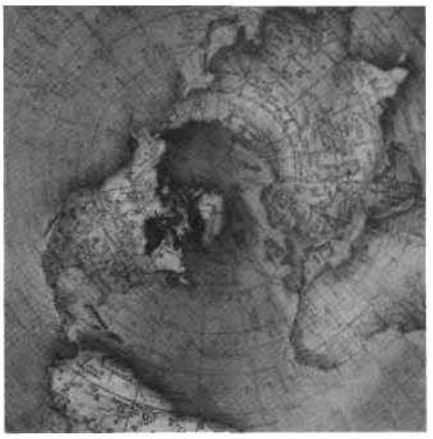
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Asia/Pacific Semiconductor Consumption by Application Market

Market Statistics

Program: Semiconductor Application Markets Asia/Pacific
Product Code: SAMM-AP-MS-9504
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Filing: Market Analysis

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Note: All tables show estimated data.

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Chapter 1
Asia/Pacific Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.
- Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate three or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications

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equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
  - Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

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Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed-circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) eletronics.

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  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Taiwan, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Taiwanese operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market—Database Tables

Section 1—Asia/Pacific Semiconductor Consumption by Application Market, History and Forecast

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Table 1-1
Asia/Pacific Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	84,747	96,873	114,523	134,654	155,414	176,397	201,009	231,195	267,585
Total Semiconductor	9,191	12,034	17,486	22,812	28,525	33,879	39,481	47,923	58,543
Total IC	7,605	10,109	14,988	19,767	24,971	29,794	34,981	42,735	52,574
Bipolar Digital	368	381	388	370	304	259	219	196	182
MOS Digital	5,284	7,264	11,229	15,085	19,542	23,650	28,040	34,441	42,588
MOS Memory	1,974	2,904	4,911	7,210	9,566	11,754	14,051	17,042	20,741
MOS Microcomponent	2,197	3,084	4,303	5,463	6,992	8,370	9,907	12,240	15,308
MOS Logic	1,113	1,276	2,015	2,412	2,984	3,526	4,082	5,159	6,539
Analog (Monolithic + Hybrid)	1,953	2,464	3,371	4,312	5,126	5,885	6,722	8,098	9,804
Total Discrete	1,386	1,649	2,080	2,524	2,934	3,377	3,718	4,283	4,926
Total Optoelectronic	200	276	418	521	620	708	782	905	1,043

Source: Dataquest (June 1995)

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Table 1-2
Asia/Pacific Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	31,502	36,420	44,140	53,881	63,967	72,565	82,959	96,334	113,502
Total Semiconductor	4,688	6,437	9,969	13,164	16,693	19,598	22,390	26,737	33,312
Total IC	4,404	6,093	9,443	12,434	15,795	18,596	21,255	25,351	31,616
Bipolar Digital	214	237	226	211	161	127	102	85	76
MOS Digital	3,654	5,215	8,432	11,358	14,700	17,507	20,227	24,299	30,362
MOS Memory	1,494	2,315	4,101	6,109	8,142	9,962	11,747	14,134	17,290
MOS Microcomponent	1,432	2,092	2,934	3,618	4,569	5,276	5,981	7,078	9,002
MOS Logic	728	808	1,397	1,630	1,989	2,269	2,499	3,086	4,070
Analog (Monolithic + Hybrid)	536	641	785	866	935	963	926	968	1,178
Total Discrete	220	252	408	577	717	804	919	1,133	1,391
Total Optoelectronic	64	92	118	152	181	197	216	253	305

Source: Dataquest (June 1995)

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Table 1-3
Asia/Pacific Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	11,480	13,353	15,570	17,604	19,914	22,681	25,992	29,934	34,588
Total Semiconductor	751	932	1,422	1,858	2,402	3,035	3,819	4,986	5,934
Total IC	597	760	1,203	1,587	2,069	2,631	3,348	4,415	5,282
Bipolar Digital	32	29	26	22	18	16	14	14	13
MOS Digital	383	490	686	912	1,236	1,642	2,176	3,001	3,604
MOS Memory	111	137	193	257	346	472	632	868	1,066
MOS Microcomponent	172	211	295	392	533	703	935	1,306	1,609
MOS Logic	100	142	198	263	357	468	608	827	929
Analog (Monolithic + Hybrid)	182	241	491	653	815	972	1,158	1,400	1,665
Total Discrete	128	142	182	223	277	336	392	478	551
Total Optoelectronic	26	30	37	48	56	68	79	93	101

Source: Dataquest (June 1995)

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Table 1-4
Asia/Pacific Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	3,530	4,022	4,621	5,132	5,706	6,404	7,273	8,355	9,619
Total Semiconductor	224	283	409	512	640	785	965	1,193	1,432
Total IC	154	205	293	372	474	586	732	921	1,115
Bipolar Digital	20	17	14	13	11	10	10	9	9
MOS Digital	90	133	206	267	348	436	550	694	836
MOS Memory	28	39	67	92	122	157	202	256	303
MOS Microcomponent	34	55	84	111	149	191	245	316	393
MOS Logic	28	39	55	65	77	87	102	122	141
Analog (Monolithic + Hybrid)	44	55	73	92	114	141	173	218	270
Total Discrete	60	67	100	120	142	171	200	237	277
Total Optoelectronic	10	11	16	20	24	28	32	35	40

Source: Dataquest (June 1995)

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Table 1-5
Asia/Pacific Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	32,204	36,469	42,835	49,897	56,753	64,533	73,200	83,332	94,658
Total Semiconductor	3,170	3,955	5,176	6,692	8,117	9,663	11,348	13,832	16,484
Total IC	2,189	2,736	3,672	4,938	6,131	7,382	8,924	11,158	13,506
Bipolar Digital	79	75	97	98	91	84	74	72	69
MOS Digital	983	1,211	1,645	2,244	2,899	3,631	4,553	5,777	6,984
MOS Memory	298	360	487	675	865	1,051	1,330	1,613	1,881
MOS Microcomponent	477	621	861	1,191	1,563	1,984	2,477	3,196	3,885
MOS Logic	208	230	297	377	471	596	746	968	1,218
Analog (Monolithic + Hybrid)	1,127	1,450	1,930	2,596	3,141	3,668	4,297	5,308	6,453
Total Discrete	895	1,098	1,285	1,486	1,668	1,918	2,036	2,238	2,489
Total Optoelectronic	86	121	219	267	318	362	389	437	489

Source: Dataquest (June 1995)

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Table 1-6
Asia/Pacific Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	3,907	4,239	4,680	5,218	5,855	6,633	7,569	8,644	9,923
Total Semiconductor	138	156	190	231	273	339	423	538	643
Total IC	114	127	155	189	223	276	346	441	531
Bipolar Digital	16	15	18	21	21	20	19	16	15
MOS Digital	69	81	100	123	150	193	249	327	404
MOS Memory	20	23	28	36	44	58	76	97	117
MOS Microcomponent	24	30	38	47	59	77	101	140	178
MOS Logic	25	28	34	40	47	58	71	90	109
Analog (Monolithic + Hybrid)	29	31	37	44	52	63	78	97	112
Total Discrete	21	22	26	32	36	44	53	64	71
Total Optoelectronic	3	7	9	11	14	19	25	33	41

Source: Dataquest (June 1995)

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Table 1-7
Asia/Pacific Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	2,124	2,371	2,676	2,922	3,220	3,581	4,018	4,596	5,295
Total Semiconductor	221	271	320	355	400	460	535	637	739
Total IC	148	188	222	247	279	321	376	450	525
Bipolar Digital	8	8	7	5	2	1	1	1	1
MOS Digital	105	134	160	181	208	241	285	342	399
MOS Memory	23	30	35	39	46	53	63	74	84
MOS Microcomponent	58	75	91	104	120	140	167	204	241
MOS Logic	24	29	34	37	43	48	54	64	73
Analog (Monolithic + Hybrid)	35	46	55	61	68	79	91	107	126
Total Discrete	62	68	79	87	95	105	117	133	148
Total Optoelectronic	11	15	19	22	27	34	42	54	66

Source: Dataquest (June 1995)

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Section 2—Asia/Pacific Semiconductor Consumption by Application Market, Annual Growth Rates

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Table 2-1
Asia/Pacific Semiconductor Consumption—Total Electronics (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	14.31	18.22	17.58	15.42	13.50	13.95	15.02	15.74	14.72
Total Semiconductor	30.93	45.30	30.46	25.05	18.77	16.53	21.38	22.16	20.74
Total IC	32.93	48.26	31.88	26.33	19.31	17.41	22.17	23.02	21.61
Bipolar Digital	3.53	1.84	-4.74	-17.85	-14.83	-15.32	-10.38	-7.23	-13.20
MOS Digital	37.47	54.58	34.34	29.54	21.02	18.56	22.83	23.65	23.07
MOS Memory	47.11	69.11	46.82	32.67	22.87	19.54	21.29	21.70	23.53
MOS Microcomponent	40.37	39.53	26.95	28.00	19.71	18.36	23.55	25.07	22.88
MOS Logic	14.65	57.92	19.71	23.69	18.17	15.77	26.38	26.76	22.07
Analog (Monolithic + Hybrid)	26.16	36.81	27.91	18.88	14.81	14.23	20.47	21.07	17.86
Total Discrete	18.98	26.14	21.36	16.24	15.11	10.07	15.20	15.03	14.31
Total Optoelectronic	38.00	51.45	24.57	19.07	14.19	10.42	15.74	15.25	14.90

Source: Dataquest (June 1995)

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Table 2-2
Asia/Pacific Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	15.61	21.20	22.07	18.72	13.44	14.32	16.12	17.82	16.07
Total Semiconductor	37.31	54.87	32.05	26.81	17.40	14.25	19.41	24.59	20.40
Total IC	38.35	54.98	31.68	27.03	17.74	14.30	19.27	24.71	20.52
Bipolar Digital	10.75	-4.64	-6.64	-23.79	-21.02	-19.69	-16.86	-10.38	-18.47
MOS Digital	42.72	61.69	34.70	29.42	19.10	15.54	20.13	24.95	21.73
MOS Memory	54.95	77.15	48.97	33.27	22.35	17.92	20.33	22.33	23.13
MOS Microcomponent	46.09	40.25	23.31	26.29	15.47	13.36	18.34	27.19	20.00
MOS Logic	10.99	72.90	16.71	21.96	14.09	10.17	23.49	31.85	20.07
Analog (Monolithic + Hybrid)	19.59	22.46	10.29	7.96	3.00	-3.81	4.52	21.68	6.35
Total Discrete	14.55	61.90	41.50	24.22	12.14	14.29	23.24	22.76	19.22
Total Optoelectronic	43.75	28.26	29.06	18.85	8.84	9.68	16.91	20.85	14.92

Source: Dataquest (June 1995)

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Table 2-3
Asia/Pacific Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	16.31	16.61	13.06	13.12	13.89	14.60	15.17	15.55	14.46
Total Semiconductor	24.10	52.58	30.64	29.31	26.33	25.85	30.56	19.00	26.14
Total IC	27.30	58.29	31.89	30.41	27.16	27.24	31.87	19.64	27.19
Bipolar Digital	-9.38	-10.34	-16.80	-18.15	-7.55	-13.45	-3.57	-4.48	-9.62
MOS Digital	27.94	40.00	33.01	35.46	32.87	32.48	37.96	20.06	31.61
MOS Memory	23.42	40.88	33.36	34.57	36.22	33.97	37.36	22.78	32.87
MOS Microcomponent	22.67	39.81	32.78	35.97	31.96	33.07	39.63	23.19	32.65
MOS Logic	42.00	39.44	33.01	35.57	30.99	30.07	36.01	12.26	28.67
Analog (Monolithic + Hybrid)	32.42	103.73	32.90	24.97	19.25	19.09	20.87	18.97	20.61
Total Discrete	10.94	28.17	22.54	24.23	21.12	16.93	21.87	15.22	19.83
Total Optoelectronic	15.38	23.33	29.91	16.51	21.43	15.85	18.34	8.10	15.96

Source: Dataquest (June 1995)

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Table 2-4
Asia/Pacific Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	13.94	14.90	11.05	11.17	12.24	13.56	14.88	15.13	13.39
Total Semiconductor	26.34	44.52	25.14	24.98	22.78	22.83	23.65	20.03	22.85
Total IC	33.12	42.93	27.03	27.33	23.73	24.90	25.74	21.06	24.53
Bipolar Digital	-15.00	-17.65	-8.60	-12.25	-10.39	-2.47	-9.43	-1.19	-7.25
MOS Digital	47.78	54.89	29.81	30.30	25.01	26.28	26.21	20.44	25.61
MOS Memory	39.29	71.79	37.57	32.57	28.64	28.72	26.50	18.23	26.84
MOS Microcomponent	61.76	52.73	31.63	35.01	27.94	28.50	28.73	24.39	28.87
MOS Logic	39.29	41.03	17.58	19.01	13.56	17.05	19.60	14.86	16.79
Analog (Monolithic + Hybrid)	25.00	32.73	26.00	24.21	23.19	22.59	26.22	23.95	24.03
Total Discrete	11.67	49.25	19.61	18.52	20.65	17.03	18.55	16.81	18.30
Total Optoelectronic	10.00	45.45	25.15	19.85	16.67	14.94	7.94	14.71	14.76

Source: Dataquest (June 1995)

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Table 2-5
Asia/Pacific Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	13.24	17.46	16.49	13.74	13.71	13.43	13.84	13.59	13.66
Total Semiconductor	24.78	30.87	29.28	21.30	19.05	17.44	21.89	19.17	19.76
Total IC	25.02	34.21	34.48	24.16	20.41	20.88	25.03	21.04	22.29
Bipolar Digital	-4.46	29.33	1.53	-7.62	-8.20	-11.98	-1.57	-4.77	-6.90
MOS Digital	23.19	35.84	36.39	29.21	25.26	25.39	26.88	20.89	25.50
MOS Memory	20.81	35.28	38.70	28.10	21.48	26.56	21.24	16.62	22.73
MOS Microcomponent	30.19	38.65	38.36	31.18	26.93	24.86	29.04	21.55	26.67
MOS Logic	10.58	29.13	26.87	24.98	26.65	25.11	29.74	25.80	26.44
Analog (Monolithic + Hybrid)	28.66	33.10	34.52	20.99	16.76	17.16	23.54	21.56	19.97
Total Discrete	22.68	17.03	15.65	12.22	15.04	6.13	9.90	11.22	10.86
Total Optoelectronic	40.70	80.99	22.06	18.96	13.84	7.33	12.41	12.06	12.86

Source: Dataquest (June 1995)

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Table 2-6
Asia/Pacific Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	8.50	10.40	11.50	12.21	13.29	14.10	14.21	14.80	13.72
Total Semiconductor	13.45	21.79	21.62	18.25	23.95	24.91	27.12	19.65	22.73
Total IC	11.89	22.05	21.63	18.40	23.71	25.15	27.52	20.50	23.01
Bipolar Digital	-3.23	20.00	15.36	1.25	-3.59	-8.36	-14.89	-6.46	-6.57
MOS Digital	17.39	23.46	23.44	21.82	28.23	29.03	31.59	23.34	26.75
MOS Memory	15.00	21.74	30.05	20.92	32.63	30.39	27.02	20.82	26.26
MOS Microcomponent	25.00	26.67	24.22	24.74	30.59	31.99	38.43	26.72	30.41
MOS Logic	12.00	21.43	17.13	19.19	21.24	23.69	26.71	20.77	22.29
Analog (Monolithic + Hybrid)	6.90	19.35	19.78	16.89	21.67	24.07	24.67	15.36	20.47
Total Discrete	4.76	18.18	21.33	14.23	20.83	21.18	20.71	11.48	17.61
Total Optoelectronic	133.33	28.57	22.29	27.20	35.71	29.99	35.22	23.94	30.33

Source: Dataquest (June 1995)

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Table 2-7
Asia/Pacific Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	11.63	12.86	9.19	10.20	11.21	12.20	14.39	15.21	12.63
Total Semiconductor	22.62	18.08	11.07	12.63	14.86	16.34	19.04	16.02	15.76
Total IC	27.03	18.09	11.10	13.04	15.22	17.20	19.44	16.78	16.32
Bipolar Digital	0	-12.50	-29.33	-61.25	-25.91	-34.22	-19.93	-25.42	-35.37
MOS Digital	27.62	19.40	12.89	15.41	15.73	18.10	20.00	16.61	17.16
MOS Memory	30.43	16.67	12.70	16.80	15.19	19.18	17.19	13.81	16.42
MOS Microcomponent	29.31	21.33	14.57	14.86	17.07	19.32	21.68	18.41	18.25
MOS Logic	20.83	17.24	8.61	15.48	12.54	13.33	18.12	14.14	14.70
Analog (Monolithic + Hybrid)	31.43	19.57	11.04	12.06	14.81	15.37	18.07	17.62	15.57
Total Discrete	9.68	16.18	9.83	8.91	10.63	11.85	13.80	10.96	11.22
Total Optoelectronic	36.36	26.67	15.85	22.66	25.93	22.08	30.24	22.21	24.58

Source: Dataquest (June 1995)

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Section 3—Asia/Pacific Semiconductor Consumption by Application Market, Input/Output Ratios

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Table 3-1
Asia/Pacific Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	10.85	12.42	15.27	16.94	18.35	19.21	19.64	20.73	21.88
Total IC	8.97	10.44	13.09	14.68	16.07	16.89	17.40	18.48	19.65
Bipolar Digital	0.43	0.39	0.34	0.27	0.20	0.15	0.11	0.08	0.07
MOS Digital	6.24	7.50	9.80	11.20	12.57	13.41	13.95	14.9	15.92
MOS Memory	2.33	3.00	4.29	5.35	6.16	6.66	6.99	7.37	7.75
MOS Microcomponent	2.59	3.18	3.76	4.06	4.50	4.75	4.93	5.29	5.72
MOS Logic	1.31	1.32	1.76	1.79	1.92	2.00	2.03	2.23	2.44
Analog (Monolithic + Hybrid)	2.30	2.54	2.94	3.20	3.30	3.34	3.34	3.50	3.66
Total Discrete	1.64	1.70	1.82	1.87	1.89	1.91	1.85	1.85	1.84
Total Optoelectronic	0.24	0.28	0.36	0.39	0.40	0.40	0.39	0.39	0.39

Source: Dataquest (June 1995)

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Table 3-2
Asia/Pacific Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	14.88	17.67	22.58	24.43	26.10	27.01	26.99	27.75	29.35
Total IC	13.98	16.73	21.39	23.08	24.69	25.63	25.62	26.32	27.85
Bipolar Digital	0.68	0.65	0.51	0.39	0.25	0.18	0.12	0.09	0.07
MOS Digital	11.60	14.32	19.10	21.08	22.98	24.13	24.38	25.22	26.75
MOS Memory	4.74	6.36	9.29	11.34	12.73	13.73	14.16	14.67	15.23
MOS Microcomponent	4.55	5.74	6.65	6.71	7.14	7.27	7.21	7.35	7.93
MOS Logic	2.31	2.22	3.16	3.03	3.11	3.13	3.01	3.20	3.59
Analog (Monolithic + Hybrid)	1.70	1.76	1.78	1.61	1.46	1.33	1.12	1.00	1.04
Total Discrete	0.70	0.69	0.92	1.07	1.12	1.11	1.11	1.18	1.23
Total Optoelectronic	0.20	0.25	0.27	0.28	0.28	0.27	0.26	0.26	0.27

Source: Dataquest (June 1995)

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Table 3-3
Asia/Pacific Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	6.54	6.98	9.13	10.55	12.06	13.38	14.69	16.66	17.16
Total IC	5.20	5.69	7.73	9.01	10.39	11.60	12.88	14.75	15.27
Bipolar Digital	0.28	0.22	0.17	0.12	0.09	0.07	0.05	0.05	0.04
MOS Digital	3.34	3.67	4.41	5.18	6.21	7.24	8.37	10.03	10.42
MOS Memory	0.97	1.03	1.24	1.46	1.74	2.08	2.43	2.90	3.08
MOS Microcomponent	1.50	1.58	1.89	2.23	2.67	3.10	3.60	4.36	4.65
MOS Logic	0.87	1.06	1.27	1.50	1.79	2.06	2.34	2.76	2.69
Analog (Monolithic + Hybrid)	1.59	1.80	3.15	3.71	4.09	4.29	4.46	4.68	4.81
Total Discrete	1.11	1.06	1.17	1.27	1.39	1.48	1.51	1.60	1.59
Total Optoelectronic	0.23	0.22	0.24	0.27	0.28	0.30	0.30	0.31	0.29

Source: Dataquest (June 1995)

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Table 3-4
Asia/Pacific Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	6.35	7.04	8.85	9.97	11.21	12.26	13.27	14.28	14.89
Total IC	4.36	5.10	6.34	7.25	8.31	9.16	10.07	11.02	11.59
Bipolar Digital	0.57	0.42	0.30	0.25	0.20	0.16	0.13	0.11	0.09
MOS Digital	2.55	3.31	4.46	5.21	6.11	6.80	7.56	8.31	8.69
MOS Memory	0.79	0.97	1.45	1.80	2.14	2.45	2.78	3.06	3.15
MOS Microcomponent	0.96	1.37	1.82	2.15	2.62	2.98	3.37	3.78	4.09
MOS Logic	0.79	0.97	1.19	1.26	1.35	1.36	1.41	1.46	1.46
Analog (Monolithic + Hybrid)	1.25	1.37	1.58	1.79	2.00	2.20	2.37	2.61	2.81
Total Discrete	1.70	1.67	2.16	2.33	2.48	2.67	2.75	2.84	2.88
Total Optoelectronic	0.28	0.27	0.35	0.39	0.42	0.44	0.44	0.42	0.41

Source: Dataquest (June 1995)

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Table 3-5
Asia/Pacific Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	9.84	10.84	12.08	13.41	14.30	14.97	15.50	16.60	17.41
Total IC	6.80	7.50	8.57	9.90	10.8	11.44	12.19	13.39	14.27
Bipolar Digital	0.24	0.21	0.23	0.20	0.16	0.13	0.10	0.09	0.07
MOS Digital	3.05	3.32	3.84	4.50	5.11	5.63	6.22	6.93	7.38
MOS Memory	0.93	0.99	1.14	1.35	1.52	1.63	1.82	1.94	1.99
MOS Microcomponent	1.48	1.70	2.01	2.39	2.75	3.07	3.38	3.84	4.10
MOS Logic	0.65	0.63	0.69	0.76	0.83	0.92	1.02	1.16	1.29
Analog (Monolithic + Hybrid)	3.50	3.98	4.51	5.20	5.53	5.68	5.87	6.37	6.82
Total Discrete	2.78	3.01	3.00	2.98	2.94	2.97	2.78	2.69	2.63
Total Optoelectronic	0.27	0.33	0.51	0.54	0.56	0.56	0.53	0.52	0.52

Source: Dataquest (June 1995)

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Table 3-6
Asia/Pacific Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	3.52	3.68	4.06	4.43	4.67	5.11	5.59	6.22	6.48
Total IC	2.91	3.00	3.31	3.61	3.81	4.16	4.57	5.10	5.35
Bipolar Digital	0.40	0.35	0.38	0.40	0.36	0.31	0.25	0.18	0.15
MOS Digital	1.77	1.91	2.14	2.37	2.57	2.91	3.29	3.79	4.07
MOS Memory	0.51	0.54	0.60	0.70	0.75	0.88	1.01	1.12	1.18
MOS Microcomponent	0.61	0.71	0.81	0.90	1.01	1.16	1.34	1.63	1.79
MOS Logic	0.64	0.66	0.73	0.76	0.81	0.87	0.94	1.04	1.10
Analog (Monolithic + Hybrid)	0.74	0.73	0.79	0.85	0.88	0.95	1.03	1.13	1.13
Total Discrete	0.54	0.52	0.56	0.60	0.62	0.66	0.70	0.74	0.72
Total Optoelectronic	0.08	0.17	0.19	0.21	0.24	0.29	0.33	0.39	0.42

Source: Dataquest (June 1995)

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Table 3-7
Asia/Pacific Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	10.40	11.43	11.96	12.16	12.43	12.84	13.31	13.86	13.95
Total IC	6.97	7.93	8.30	8.44	8.66	8.97	9.37	9.78	9.92
Bipolar Digital	0.38	0.34	0.26	0.17	0.06	0.04	0.02	0.02	0.01
MOS Digital	4.94	5.65	5.98	6.18	6.47	6.74	7.09	7.44	7.53
MOS Memory	1.08	1.27	1.31	1.35	1.43	1.48	1.57	1.61	1.59
MOS Microcomponent	2.73	3.16	3.40	3.57	3.72	3.91	4.16	4.43	4.55
MOS Logic	1.13	1.22	1.27	1.26	1.32	1.34	1.35	1.40	1.38
Analog (Monolithic + Hybrid)	1.65	1.94	2.06	2.09	2.13	2.19	2.26	2.33	2.38
Total Discrete	2.92	2.87	2.95	2.97	2.93	2.92	2.91	2.90	2.79
Total Optoelectronic	0.52	0.63	0.71	0.75	0.84	0.95	1.03	1.18	1.25

Source: Dataquest (June 1995)

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Section 4—Asia/Pacific Semiconductor Consumption by Application Markets, Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
Asia/Pacific Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronics Equipment	84,747	96,873	114,523	134,654	155,414	176,397	201,009	231,195	267,585
Data Processing	31,502	36,420	44,140	53,881	63,967	72,565	82,959	96,334	113,502
Computers	12,956	15,496	19,639	24,784	30,287	35,678	42,492	52,070	65,087
Data Storage	6,715	7,499	9,555	12,135	15,059	16,716	18,387	20,024	21,826
Input/Output	7,508	8,624	9,506	10,647	11,711	12,953	14,507	16,277	18,230
Dedicated System	3,686	4,037	4,365	4,889	5,280	5,708	6,136	6,626	7,163
Other Data Processing	637	764	1,075	1,426	1,629	1,511	1,436	1,337	1,195
Communications	11,480	13,353	15,570	17,604	19,914	22,681	25,992	29,934	34,588
Premise Telecommunications	3,914	4,463	5,286	5,989	6,899	8,017	9,204	10,584	12,204
Public Telecommunications	2,705	3,308	3,912	4,655	5,307	6,071	6,945	8,001	9,201
Mobile Communications	1,146	1,402	1,601	1,844	2,130	2,552	3,121	3,876	4,861
Broadcast and Studio	489	596	797	974	1,180	1,335	1,541	1,820	2,173
Other Communications	3,226	3,584	3,974	4,141	4,398	4,705	5,181	5,652	6,150
Industrial	3,530	4,022	4,621	5,132	5,706	6,404	7,273	8,355	9,619
Security and Energy Management	1,041	1,139	1,379	1,562	1,751	1,991	2,264	2,583	2,953
Manufacturing Systems/Instruments	1,062	1,204	1,324	1,418	1,533	1,702	1,908	2,198	2,539
Medical Equipment	822	959	1,094	1,206	1,333	1,480	1,647	1,843	2,066
Other Industrial	605	720	824	946	1,088	1,230	1,453	1,731	2,061
Consumer	32,204	36,469	42,835	49,897	56,753	64,533	73,200	83,332	94,658
Audio	8,558	10,061	11,570	13,535	15,652	18,162	21,008	24,235	27,684
Video	12,949	14,617	16,956	19,677	22,154	24,839	27,749	30,989	34,576
Personal Electronics	5,490	6,139	7,059	8,192	9,365	10,752	12,437	14,591	17,298
Appliances	3,531	3,813	4,508	5,366	6,189	7,113	8,061	9,234	10,462
Other Consumer	1,676	1,839	2,743	3,127	3,393	3,668	3,945	4,283	4,637
Military/Civil Aerospace	3,907	4,239	4,680	5,218	5,855	6,633	7,569	8,644	9,923
Transportation	2,124	2,371	2,676	2,922	3,220	3,581	4,018	4,596	5,295

Source: Dataquest (June 1995)

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Table 4-2
Asia/Pacific Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	14.3	18.2	17.6	15.4	13.5	14.0	15.0	15.7	14.7
Data Processing	15.6	21.2	22.1	18.7	13.4	14.3	16.1	17.8	16.1
Computers	19.6	26.7	26.2	22.2	17.8	19.1	22.5	25.0	21.3
Data Storage	11.7	27.4	27.0	24.1	11.0	10.0	8.9	9.0	12.5
Input/Output	14.9	10.2	12.0	10.0	10.6	12.0	12.2	12.0	11.4
Dedicated System	9.5	8.1	12.0	8.0	8.1	7.5	8.0	8.1	7.9
Other Data Processing	19.9	40.8	32.6	14.3	-7.2	-5.0	-6.9	-10.6	-3.5
Communications	16.3	16.6	13.1	13.1	13.9	14.6	15.2	15.5	14.5
Premise Telecommunications	14.0	18.4	13.3	15.2	16.2	14.8	15.0	15.3	15.3
Public Telecommunications	22.3	18.3	19.0	14.0	14.4	14.4	15.2	15.0	14.6
Mobile Communications	22.3	14.2	15.2	15.5	19.8	22.3	24.2	25.4	21.4
Broadcast and Studio	21.9	33.7	22.2	21.1	13.2	15.4	18.1	19.4	17.4
Other Communications	11.1	10.9	4.2	6.2	7.0	10.1	9.1	8.8	8.2
Industrial	13.9	14.9	11.1	11.2	12.2	13.6	14.9	15.1	13.4
Security and Energy Management	9.4	21.1	13.3	12.1	13.7	13.7	14.1	14.3	13.6
Manufacturing Systems/Instruments	13.4	10.0	7.1	8.1	11.0	12.1	15.2	15.5	12.3
Medical Equipment	16.7	14.1	10.2	10.6	11.0	11.3	11.9	12.1	11.4
Other Industrial	19.0	14.4	14.8	15.0	13.1	18.1	19.1	19.1	16.9
Consumer	13.2	17.5	16.5	13.7	13.7	13.4	13.8	13.6	13.7
Audio	17.6	15.0	17.0	15.6	16.0	15.7	15.4	14.2	15.4
Video	12.9	16.0	16.1	12.6	12.1	11.7	11.7	11.6	11.9
Personal Electronics	11.8	15.0	16.1	14.3	14.8	15.7	17.3	18.6	16.1
Appliances	8.0	18.2	19.1	15.3	14.9	13.3	14.5	13.3	14.3
Other Consumer	9.7	49.2	14.0	8.5	8.1	7.6	8.6	8.3	8.2
Military/Civil Aerospace	8.5	10.4	11.5	12.2	13.3	14.1	14.2	14.8	13.7
Transportation	11.6	12.9	9.2	10.2	11.2	12.2	14.4	15.2	12.6

Source: Dataquest (June 1995)

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Table 4-3
Asia/Pacific Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	9,191	12,034	17,486	22,812	28,525	33,879	39,481	47,923	58,543
Data Processing	4,688	6,437	9,969	13,164	16,693	19,598	22,390	26,737	33,312
Computers	2,389	3,766	6,562	9,040	11,703	13,435	15,401	18,598	23,395
Data Storage	892	1,006	1,296	1,550	1,910	2,322	2,565	2,912	3,445
Input/Output	780	890	1,048	1,296	1,632	2,128	2,549	3,111	3,957
Dedicated System	303	383	535	662	841	1,078	1,280	1,551	1,958
Other Data Processing	325	392	528	615	608	635	596	564	557
Communications	751	932	1,422	1,858	2,402	3,035	3,819	4,986	5,934
Premise Telecommunications	327	392	579	713	878	1,042	1,223	1,465	1,584
Public Telecommunications	141	176	271	344	415	485	561	657	694
Mobile Communications	60	76	130	228	346	518	760	1,154	1,562
Broadcast and Studio	24	31	71	129	235	361	527	803	1,104
Other Communications	200	258	371	443	529	629	748	906	990
Industrial	224	283	409	512	640	785	965	1,193	1,432
Security and Energy Management	49	60	92	128	169	219	288	386	532
Manufacturing Systems/Instruments	88	115	179	224	274	328	396	493	531
Medical Equipment	48	57	71	85	99	117	140	173	218
Other Industrial	39	50	66	75	98	122	142	140	151
Consumer	3,170	3,955	5,176	6,692	8,117	9,663	11,348	13,832	16,484
Audio	841	1,056	1,438	1,959	2,443	3,002	3,692	4,618	5,643
Video	1,135	1,452	1,813	2,231	2,628	3,015	3,414	4,084	4,774
Personal Electronics	509	618	837	1,108	1,332	1,553	1,756	2,081	2,410
Appliances	373	468	618	839	1,080	1,383	1,686	2,110	2,579
Other Consumer	311	362	470	555	633	710	801	940	1,078
Military/Civil Aerospace	138	156	190	231	273	339	423	538	643
Transportation	221	271	320	355	400	460	535	637	739

Source: Dataquest (June 1995)

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Table 4-4
Asia/Pacific Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	30.9	45.3	30.5	25.0	18.8	16.5	21.4	22.2	20.7
Data Processing	37.3	54.9	32.0	26.8	17.4	14.3	19.4	24.6	20.4
Computers	57.6	74.3	37.8	29.4	14.8	14.6	20.8	25.8	20.9
Data Storage	12.8	28.9	19.6	23.2	21.6	10.5	13.5	18.3	17.3
Input/Output	14.2	17.7	23.7	26.0	30.4	19.8	22.1	27.2	25.0
Dedicated System	26.5	39.6	23.8	27.0	28.2	18.8	21.2	26.3	24.2
Other Data Processing	20.7	34.6	16.6	-1.2	4.4	-6.1	-5.3	-1.3	-2.0
Communications	24.1	52.6	30.6	29.3	26.3	25.8	30.6	19.0	26.1
Premise Telecommunications	19.9	47.9	23.1	23.1	18.6	17.4	19.8	8.1	17.3
Public Telecommunications	24.8	54.0	27.1	20.6	16.9	15.7	17.1	5.5	15.1
Mobile Communications	26.7	71.5	75.3	51.4	49.9	46.8	51.8	35.3	46.9
Broadcast and Studio	29.2	128.7	82.6	81.6	53.7	45.9	52.5	37.5	53.5
Other Communications	29.0	44.0	19.4	19.4	18.9	18.9	21.2	9.3	17.5
Industrial	26.3	44.5	25.1	25.0	22.8	22.8	23.7	20.0	22.8
Security and Energy Management	22.9	53.2	38.7	32.2	29.4	31.6	34.2	37.6	33.0
Manufacturing Systems/Instruments	31.1	55.5	24.7	22.7	19.4	20.8	24.7	7.5	18.9
Medical Equipment	19.2	24.4	19.4	16.0	18.3	19.8	23.7	26.4	20.8
Other Industrial	28.7	31.9	13.7	29.8	25.4	15.7	-0.8	7.8	15.0
Consumer	24.8	30.9	29.3	21.3	19.0	17.4	21.9	19.2	19.8
Audio	25.5	36.2	36.2	24.7	22.8	23.0	25.1	22.2	23.6
Video	27.9	24.9	23.0	17.8	14.7	13.2	19.6	16.9	16.4
Personal Electronics	21.4	35.4	32.4	20.2	16.6	13.1	18.5	15.8	16.8
Appliances	25.4	32.1	35.7	28.8	28.0	21.9	25.2	22.3	25.2
Other Consumer	16.3	29.8	18.1	14.1	12.2	12.7	17.4	14.7	14.2
Military/Civil Aerospace	13.5	21.8	21.6	18.2	23.9	24.9	27.1	19.6	22.7
Transportation	22.6	18.1	11.1	12.6	14.9	16.3	19.0	16.0	15.8

Source: Dataquest (June 1995)

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Table 4-5
Asia/Pacific Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.092	0.080	0.065	0.059	0.054	0.052	0.051	0.048	0.046
Data Processing	0.067	0.057	0.044	0.041	0.038	0.037	0.037	0.036	0.034
Computers	0.054	0.041	0.030	0.027	0.026	0.027	0.028	0.028	0.028
Data Storage	0.075	0.075	0.074	0.078	0.079	0.072	0.072	0.069	0.063
Input/Output	0.096	0.097	0.091	0.082	0.072	0.061	0.057	0.052	0.046
Dedicated System	0.122	0.105	0.082	0.074	0.063	0.053	0.048	0.043	0.037
Other Data Processing	0.020	0.019	0.020	0.023	0.027	0.024	0.024	0.024	0.021
Communications	0.153	0.143	0.109	0.095	0.083	0.075	0.068	0.060	0.058
Premise Telecommunications	0.120	0.114	0.091	0.084	0.079	0.077	0.075	0.072	0.077
Public Telecommunications	0.192	0.188	0.145	0.135	0.128	0.125	0.124	0.122	0.133
Mobile Communications	0.191	0.185	0.123	0.081	0.062	0.049	0.041	0.034	0.031
Broadcast and Studio	0.204	0.192	0.113	0.075	0.050	0.037	0.029	0.023	0.020
Other Communications	0.162	0.139	0.107	0.093	0.083	0.075	0.069	0.062	0.062
Industrial	0.158	0.142	0.113	0.100	0.089	0.082	0.075	0.070	0.067
Security and Energy Management	0.212	0.189	0.150	0.122	0.104	0.091	0.079	0.067	0.056
Manufacturing Systems/Instruments	0.121	0.104	0.074	0.063	0.056	0.052	0.048	0.045	0.048
Medical Equipment	0.171	0.168	0.154	0.142	0.135	0.127	0.118	0.107	0.095
Other Industrial	0.155	0.143	0.125	0.126	0.111	0.101	0.103	0.123	0.136
Consumer	0.102	0.092	0.083	0.075	0.070	0.067	0.065	0.060	0.057
Audio	0.102	0.095	0.080	0.069	0.064	0.061	0.057	0.052	0.049
Video	0.114	0.101	0.094	0.088	0.084	0.082	0.081	0.076	0.072
Personal Electronics	0.108	0.099	0.084	0.074	0.070	0.069	0.071	0.070	0.072
Appliances	0.095	0.081	0.073	0.064	0.057	0.051	0.048	0.044	0.041
Other Consumer	0.054	0.051	0.058	0.056	0.054	0.052	0.049	0.046	0.043
Military/Civil Aerospace	0.284	0.272	0.246	0.226	0.214	0.196	0.179	0.161	0.154
Transportation	0.096	0.087	0.084	0.082	0.080	0.078	0.075	0.072	0.072

Source: Dataquest (June 1995)

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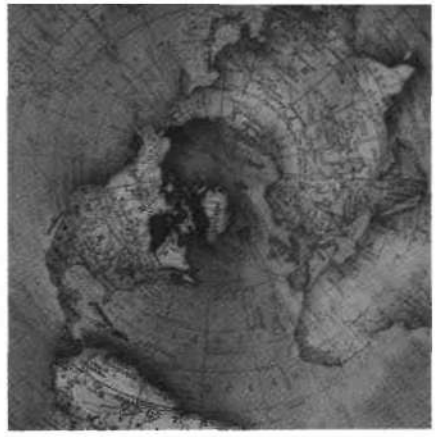
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Taiwanese Semiconductor Consumption by Application Market

Market Statistics

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Taiwanese Semiconductor Consumption by Application Market



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Note: All tables show estimated data.

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Chapter 1
Taiwanese Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.
- Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate three or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications

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equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

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Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed-circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) electronics.

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  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Taiwan, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Taiwanese operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market—Database Tables

Section 1—Taiwanese Semiconductor Consumption by Application Market, History and Forecast

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Table 1-1
Taiwanese Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	11,585	12,717	15,003	17,779	21,089	24,557	28,788	34,283	40,703
Total Semiconductor	2,449	2,819	3,793	4,378	5,083	5,631	6,787	8,324	9,839
Total IC	2,078	2,404	3,329	3,870	4,519	5,002	6,078	7,509	8,940
Bipolar Digital	103	98	91	79	64	53	48	48	44
MOS Digital	1,527	1,799	2,664	3,139	3,688	4,141	5,091	6,336	7,617
MOS Memory	620	763	1,211	1,459	1,747	1,860	2,263	2,815	3,365
MOS Microcomponent	534	610	952	1,149	1,383	1,634	1,991	2,421	2,898
MOS Logic	373	426	501	531	558	647	837	1,100	1,354
Analog (Monolithic + Hybrid)	448	507	574	652	767	808	939	1,125	1,279
Total Discrete	306	335	375	405	446	493	556	629	684
Total Optoelectronic	65	80	89	103	118	136	153	186	215

Source: Dataquest (June 1995)

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Table 1-2
Taiwanese Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	6,151	6,590	7,776	9,185	10,838	12,464	14,583	17,208	20,305
Total Semiconductor	1,487	1,734	2,529	2,863	3,303	3,619	4,462	5,444	6,430
Total IC	1,411	1,642	2,417	2,748	3,171	3,478	4,299	5,263	6,226
Bipolar Digital	57	57	53	48	40	33	31	31	30
MOS Digital	1,204	1,410	2,174	2,498	2,898	3,194	3,958	4,870	5,780
MOS Memory	471	584	986	1,166	1,386	1,435	1,754	2,160	2,542
MOS Microcomponent	438	493	801	941	1,127	1,325	1,632	1,958	2,323
MOS Logic	295	333	387	391	385	434	572	752	915
Analog (Monolithic + Hybrid)	150	175	190	202	233	251	310	362	416
Total Discrete	54	67	86	89	105	113	132	145	166
Total Optoelectronic	22	25	26	26	27	28	31	36	38

Source: Dataquest (June 1995)

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Table 1-3
Taiwanese Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	1,981	2,419	3,144	3,922	4,902	6,078	7,294	9,118	11,306
Total Semiconductor	197	244	339	428	543	657	770	1,015	1,285
Total IC	165	204	290	370	477	585	687	911	1,162
Bipolar Digital	12	9	8	7	5	4	3	3	3
MOS Digital	111	141	204	269	351	440	522	696	895
MOS Memory	45	56	84	117	157	189	223	293	376
MOS Microcomponent	41	53	76	97	120	153	173	233	296
MOS Logic	25	32	44	55	74	98	126	170	223
Analog (Monolithic + Hybrid)	42	54	78	94	121	141	162	212	264
Total Discrete	21	25	31	39	43	45	53	67	79
Total Optoelectronic	11	15	18	19	23	27	30	37	44

Source: Dataquest (June 1995)

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Table 1-4
Taiwanese Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	160	197	236	287	339	390	460	547	656
Total Semiconductor	20	22	25	31	38	47	57	72	88
Total IC	16	18	20	26	32	38	47	60	77
Bipolar Digital	9	8	8	6	4	3	2	2	1
MOS Digital	5	7	8	15	21	27	38	51	70
MOS Memory	2	2	3	6	8	11	16	21	28
MOS Microcomponent	2	3	3	6	8	10	14	18	25
MOS Logic	1	2	2	3	5	6	8	12	17
Analog (Monolithic + Hybrid)	2	3	4	5	7	8	7	7	6
Total Discrete	3	3	4	4	4	7	7	7	6
Total Optoelectronic	1	1	1	1	2	2	3	5	5

Source: Dataquest (June 1995)

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Table 1-5
Taiwanese Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	2,916	3,084	3,386	3,854	4,394	4,921	5,659	6,508	7,419
Total Semiconductor	699	769	847	995	1,131	1,231	1,413	1,698	1,927
Total IC	450	500	560	677	786	840	977	1,198	1,385
Bipolar Digital	16	15	14	11	10	10	9	9	8
MOS Digital	184	215	249	321	378	432	519	658	799
MOS Memory	95	113	128	158	182	208	252	321	394
MOS Microcomponent	45	52	62	92	114	130	153	192	230
MOS Logic	44	50	59	71	82	94	114	145	175
Analog (Monolithic + Hybrid)	250	270	297	345	398	398	449	531	578
Total Discrete	220	232	245	263	282	315	351	396	418
Total Optoelectronic	29	37	42	55	63	76	85	104	124

Source: Dataquest (June 1995)

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Table 1-6
Taiwanese Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	232	264	291	336	390	437	498	573	642
Total Semiconductor	24	24	26	30	34	38	42	46	51
Total IC	21	21	23	26	28	32	36	40	45
Bipolar Digital	6	6	6	5	4	2	2	2	1
MOS Digital	13	13	15	19	21	26	29	32	37
MOS Memory	4	4	5	6	7	9	9	10	12
MOS Microcomponent	5	5	6	8	9	10	12	13	15
MOS Logic	4	4	4	5	5	7	8	9	10
Analog (Monolithic + Hybrid)	2	2	2	2	3	4	5	6	7
Total Discrete	3	3	3	4	5	5	5	5	5
Total Optoelectronic	0	0	0	0	1	1	1	1	1

Source: Dataquest (June 1995)

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Table 1-7
Taiwanese Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	145	163	170	195	226	267	294	329	375
Total Semiconductor	22	26	27	31	34	39	43	49	58
Total IC	15	19	19	23	25	29	32	37	45
Bipolar Digital	3	3	2	2	1	1	1	1	1
MOS Digital	10	13	14	17	19	22	25	29	36
MOS Memory	3	4	5	6	7	8	9	10	13
MOS Microcomponent	3	4	4	5	5	6	7	7	9
MOS Logic	4	5	5	6	7	8	9	12	14
Analog (Monolithic + Hybrid)	2	3	3	4	5	6	6	7	8
Total Discrete	5	5	6	6	7	8	8	9	10
Total Optoelectronic	2	2	2	2	2	2	3	3	3

Source: Dataquest (June 1995)

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Section 2—Taiwanese Semiconductor Consumption by Application Market, Annual Growth Rates

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Table 2-1
Taiwanese Semiconductor Consumption—Total Electronics (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	9.77	17.98	18.50	18.62	16.44	17.23	19.09	18.73	18.02
Total Semiconductor	15.11	34.55	15.42	16.10	10.78	20.53	22.65	18.20	17.58
Total IC	15.69	38.48	16.25	16.77	10.69	21.51	23.54	19.06	18.23
Bipolar Digital	-4.85	-7.14	-13.19	-18.99	-17.19	-9.43	0	-8.33	-11.05
MOS Digital	17.81	48.08	17.83	17.49	12.28	22.94	24.45	20.22	19.40
MOS Memory	23.06	58.72	20.48	19.74	6.47	21.67	24.39	19.54	18.19
MOS Microcomponent	14.23	56.07	20.69	20.37	18.15	21.85	21.60	19.70	20.32
MOS Logic	14.21	17.61	5.99	5.08	15.95	29.37	31.42	23.09	20.59
Analog (Monolithic + Hybrid)	13.17	13.21	13.59	17.64	5.35	16.21	19.81	13.69	14.43
Total Discrete	9.48	11.94	8.00	10.12	10.54	12.78	13.13	8.74	11.05
Total Optoelectronic	23.08	11.25	15.73	14.56	15.25	12.50	21.57	15.59	15.86

Source: Dataquest (June 1995)

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Table 2-2
Taiwanese Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	7.14	18.00	18.12	18.00	15.00	17.00	18.00	18.00	17.19
Total Semiconductor	16.61	45.85	13.21	15.37	9.57	23.29	22.01	18.11	17.56
Total IC	16.37	47.20	13.69	15.39	9.68	23.61	22.42	18.30	17.77
Bipolar Digital	0	-7.02	-9.43	-16.67	-17.50	-6.06	0	-3.23	-8.97
MOS Digital	17.11	54.18	14.90	16.01	10.21	23.92	23.04	18.69	18.27
MOS Memory	23.99	68.84	18.26	18.87	3.54	22.23	23.15	17.69	16.87
MOS Microcomponent	12.56	62.47	17.48	19.77	17.57	23.17	19.98	18.64	19.81
MOS Logic	12.88	16.22	1.03	-1.53	12.73	31.80	31.47	21.68	18.54
Analog (Monolithic + Hybrid)	16.67	8.57	6.32	15.35	7.73	23.51	16.77	14.92	15.54
Total Discrete	24.07	28.36	3.49	17.98	7.62	16.81	9.85	14.48	13.28
Total Optoelectronic	13.64	4.00	0	3.85	3.70	10.71	16.13	5.56	7.89

Source: Dataquest (June 1995)

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Table 2-3
Taiwanese Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	22.11	29.97	24.75	24.99	23.99	20.01	25.01	24.00	23.58
Total Semiconductor	23.86	38.93	26.25	26.87	20.99	17.20	31.82	26.60	24.59
Total IC	23.64	42.16	27.59	28.92	22.64	17.44	32.61	27.55	25.72
Bipolar Digital	-25.00	-11.11	-12.50	-28.57	-20.00	-25.00	0	0	-15.59
MOS Digital	27.03	44.68	31.86	30.48	25.36	18.64	33.33	28.59	27.18
MOS Memory	24.44	50.00	39.29	34.19	20.38	17.99	31.39	28.33	26.30
MOS Microcomponent	29.27	43.40	27.63	23.71	27.50	13.07	34.68	27.04	25.00
MOS Logic	28.00	37.50	25.00	34.55	32.43	28.57	34.92	31.18	32.31
Analog (Monolithic + Hybrid)	28.57	44.44	20.51	28.72	16.53	14.89	30.86	24.53	22.94
Total Discrete	19.05	24.00	25.81	10.26	4.65	17.78	26.42	17.91	15.16
Total Optoelectronic	36.36	20.00	5.56	21.05	17.39	11.11	23.33	18.92	18.29

Source: Dataquest (June 1995)

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Table 2-4
Taiwanese Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	23.13	19.80	21.61	18.12	15.04	17.95	18.91	19.93	17.98
Total Semiconductor	10.00	13.64	24.00	22.58	23.68	21.28	26.32	22.22	23.20
Total IC	12.50	11.11	30.00	23.08	18.75	23.68	27.66	28.33	24.25
Bipolar Digital	-11.11	0	-25.00	-33.33	-25.00	-33.33	0	-50.00	-30.12
MOS Digital	40.00	14.29	87.50	40.00	28.57	40.74	34.21	37.25	36.08
MOS Memory	0	50.00	100.00	33.33	37.50	45.45	31.25	33.33	36.08
MOS Microcomponent	50.00	0	100.00	33.33	25.00	40.00	28.57	38.89	33.03
MOS Logic	100.00	0	50.00	66.67	20.00	33.33	50.00	41.67	41.47
Analog (Monolithic + Hybrid)	50.00	33.33	25.00	40.00	14.29	-12.50	0	-14.29	3.71
Total Discrete	0	33.33	0	0	75.00	0	0	-14.29	8.45
Total Optoelectronic	0	0	0	100.00	0	50.00	66.67	0	37.97

Source: Dataquest (June 1995)

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Table 2-5
Taiwanese Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	5.76	9.79	13.82	14.01	11.99	15.00	15.00	14.00	14.00
Total Semiconductor	10.01	10.14	17.47	13.67	8.84	14.78	20.17	13.49	14.13
Total IC	11.11	12.00	20.89	16.10	6.87	16.31	22.62	15.61	15.39
Bipolar Digital	-6.25	-6.67	-21.43	-9.09	0	-10.00	0	-11.11	-6.17
MOS Digital	16.85	15.81	28.92	17.76	14.29	20.14	26.78	21.43	20.01
MOS Memory	18.95	13.27	23.44	15.19	14.29	21.15	27.38	22.74	20.05
MOS Microcomponent	15.56	19.23	48.39	23.91	14.04	17.69	25.49	19.79	20.11
MOS Logic	13.64	18.00	20.34	15.49	14.63	21.28	27.19	20.69	19.77
Analog (Monolithic + Hybrid)	8.00	10.00	16.16	15.36	0	12.81	18.26	8.85	10.87
Total Discrete	5.45	5.60	7.35	7.22	11.70	11.43	12.82	5.56	9.71
Total Optoelectronic	27.59	13.51	30.95	14.55	20.63	11.84	22.35	19.23	17.66

Source: Dataquest (June 1995)

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Table 2-6
Taiwanese Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	13.79	10.23	15.46	16.07	12.05	13.96	15.06	12.04	13.83
Total Semiconductor	0	8.33	15.38	13.33	11.76	10.53	9.52	10.87	11.20
Total IC	0	9.52	13.04	7.69	14.29	12.50	11.11	12.50	11.60
Bipolar Digital	0	0	-16.67	-20.00	-50.00	0	0	-50.00	-27.52
MOS Digital	0	15.38	26.67	10.53	23.81	11.54	10.34	15.63	14.26
MOS Memory	0	25.00	20.00	16.67	28.57	0	11.11	20.00	14.87
MOS Microcomponent	0	20.00	33.33	12.50	11.11	20.00	8.33	15.38	13.40
MOS Logic	0	0	25.00	0	40.00	14.29	12.50	11.11	14.87
Analog (Monolithic + Hybrid)	0	0	0	50.00	33.33	25.00	20.00	16.67	28.47
Total Discrete	0	0	33.33	25.00	0	0	0	0	4.56
Total Optoelectronic	0	0	0	0	0	0	0	0	0

Source: Dataquest (June 1995)

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Table 2-7
Taiwanese Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	12.41	4.29	14.71	15.90	18.14	10.11	11.90	13.98	13.97
Total Semiconductor	**18.18**	**3.85**	**14.81**	**9.68**	**14.71**	**10.26**	**13.95**	**18.37**	**13.35**
Total IC	26.67	0	21.05	8.70	16.00	10.34	15.63	21.62	14.37
Bipolar Digital	**0**	**-33.33**	**0**	**-50.00**	**0**	**0**	**0**	**0**	**-12.94**
MOS Digital	**30.00**	**7.69**	**21.43**	**11.76**	**15.79**	**13.64**	**16.00**	**24.14**	**16.19**
MOS Memory	33.33	25.00	20.00	16.67	14.29	12.50	11.11	30.00	16.72
MOS Microcomponent	**33.33**	**0**	**25.00**	**0**	**20.00**	**16.67**	**0**	**28.57**	**12.47**
MOS Logic	25.00	0	20.00	16.67	14.29	12.50	33.33	16.67	18.47
Analog (Monolithic + Hybrid)	**50.00**	**0**	**33.33**	**25.00**	**20.00**	**0**	**16.67**	**14.29**	**14.87**
Total Discrete	**0**	**20.00**	**0**	**16.67**	**14.29**	**0**	**12.50**	**11.11**	**10.76**
Total Optoelectronic	0	0	0	0	0	50.00	0	0	8.45

Source: Dataquest (June 1995)

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Section 3—Taiwanese Semiconductor Consumption by Application Market, Input/Output Ratios

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Table 3-1
Taiwanese Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	21.14	22.17	25.28	24.62	24.10	22.93	23.58	24.28	24.17
Total IC	17.94	18.90	22.19	21.77	21.43	20.37	21.11	21.90	21.96
Bipolar Digital	0.89	0.77	0.61	0.44	0.30	0.22	0.17	0.14	0.11
MOS Digital	13.18	14.15	17.76	17.66	17.49	16.86	17.68	18.48	18.71
MOS Memory	5.35	6.00	8.07	8.21	8.28	7.57	7.86	8.21	8.27
MOS Microcomponent	4.61	4.80	6.35	6.46	6.56	6.65	6.92	7.06	7.12
MOS Logic	3.22	3.35	3.34	2.99	2.65	2.63	2.91	3.21	3.33
Analog (Monolithic + Hybrid)	3.87	3.99	3.83	3.67	3.64	3.29	3.26	3.28	3.14
Total Discrete	2.64	2.63	2.50	2.28	2.11	2.01	1.93	1.83	1.68
Total Optoelectronic	0.56	0.63	0.59	0.58	0.56	0.55	0.53	0.54	0.53

Source: Dataquest (June 1995)

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Table 3-2
Taiwanese Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	24.17	26.31	32.52	31.17	30.48	29.04	30.60	31.64	31.67
Total IC	22.94	24.92	31.08	29.92	29.26	27.90	29.48	30.58	30.66
Bipolar Digital	0.93	0.86	0.68	0.52	0.37	0.26	0.21	0.18	0.15
MOS Digital	19.57	21.40	27.96	27.20	26.74	25.63	27.14	28.30	28.47
MOS Memory	7.66	8.86	12.68	12.69	12.79	11.51	12.03	12.55	12.52
MOS Microcomponent	7.12	7.48	10.30	10.24	10.40	10.63	11.19	11.38	11.44
MOS Logic	4.80	5.05	4.98	4.26	3.55	3.48	3.92	4.37	4.51
Analog (Monolithic + Hybrid)	2.44	2.66	2.44	2.20	2.15	2.01	2.13	2.10	2.05
Total Discrete	0.88	1.02	1.11	0.97	0.97	0.91	0.91	0.84	0.82
Total Optoelectronic	0.36	0.38	0.33	0.28	0.25	0.22	0.21	0.21	0.19

Source: Dataquest (June 1995)

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Table 3-3
Taiwanese Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	9.94	10.09	10.78	10.91	11.08	10.81	10.56	11.13	11.37
Total IC	8.33	8.43	9.22	9.43	9.73	9.62	9.42	9.99	10.28
Bipolar Digital	0.61	0.37	0.25	0.18	0.10	0.07	0.04	0.03	0.03
MOS Digital	5.60	5.83	6.49	6.86	7.16	7.24	7.16	7.63	7.92
MOS Memory	2.27	2.32	2.67	2.98	3.20	3.11	3.06	3.21	3.33
MOS Microcomponent	2.07	2.19	2.42	2.47	2.45	2.52	2.37	2.56	2.62
MOS Logic	1.26	1.32	1.40	1.40	1.51	1.61	1.73	1.86	1.97
Analog (Monolithic + Hybrid)	2.12	2.23	2.48	2.40	2.47	2.32	2.22	2.33	2.34
Total Discrete	1.06	1.03	0.99	0.99	0.88	0.74	0.73	0.73	0.70
Total Optoelectronic	0.56	0.62	0.57	0.48	0.47	0.44	0.41	0.41	0.39

Source: Dataquest (June 1995)

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Table 3-4
Taiwanese Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	12.50	11.17	10.59	10.80	11.21	12.05	12.39	13.16	13.41
Total IC	10.00	9.14	8.47	9.06	9.44	9.74	10.22	10.97	11.74
Bipolar Digital	5.63	4.06	3.39	2.09	1.18	0.77	0.43	0.37	0.15
MOS Digital	3.13	3.55	3.39	5.23	6.19	6.92	8.26	9.32	10.67
MOS Memory	1.25	1.02	1.27	2.09	2.36	2.82	3.48	3.84	4.27
MOS Microcomponent	1.25	1.52	1.27	2.09	2.36	2.56	3.04	3.29	3.81
MOS Logic	0.63	1.02	0.85	1.05	1.47	1.54	1.74	2.19	2.59
Analog (Monolithic + Hybrid)	1.25	1.52	1.69	1.74	2.06	2.05	1.52	1.28	0.91
Total Discrete	1.88	1.52	1.69	1.39	1.18	1.79	1.52	1.28	0.91
Total Optoelectronic	0.63	0.51	0.42	0.35	0.59	0.51	0.65	0.91	0.76

Source: Dataquest (June 1995)

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Table 3-5
Taiwanese Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	23.97	24.94	25.01	25.82	25.74	25.02	24.97	26.09	25.97
Total IC	15.43	16.21	16.54	17.57	17.89	17.07	17.26	18.41	18.67
Bipolar Digital	0.55	0.49	0.41	0.29	0.23	0.20	0.16	0.14	0.11
MOS Digital	6.31	6.97	7.35	8.33	8.60	8.78	9.17	10.11	10.77
MOS Memory	3.26	3.66	3.78	4.10	4.14	4.23	4.45	4.93	5.31
MOS Microcomponent	1.54	1.69	1.83	2.39	2.59	2.64	2.70	2.95	3.10
MOS Logic	1.51	1.62	1.74	1.84	1.87	1.91	2.01	2.23	2.36
Analog (Monolithic + Hybrid)	8.57	8.75	8.77	8.95	9.06	8.09	7.93	8.16	7.79
Total Discrete	7.54	7.52	7.24	6.82	6.42	6.40	6.20	6.08	5.63
Total Optoelectronic	0.99	1.20	1.24	1.43	1.43	1.54	1.50	1.60	1.67

Source: Dataquest (June 1995)

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Table 3-6
Taiwanese Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	10.34	9.09	8.93	8.93	8.72	8.70	8.43	8.03	7.94
Total IC	9.05	7.95	7.90	7.74	7.18	7.32	7.23	6.98	7.01
Bipolar Digital	2.59	2.27	2.06	1.49	1.03	0.46	0.40	0.35	0.16
MOS Digital	5.60	4.92	5.15	5.65	5.38	5.95	5.82	5.58	5.76
MOS Memory	1.72	1.52	1.72	1.79	1.79	2.06	1.81	1.75	1.87
MOS Microcomponent	2.16	1.89	2.06	2.38	2.31	2.29	2.41	2.27	2.34
MOS Logic	1.72	1.52	1.37	1.49	1.28	1.60	1.61	1.57	1.56
Analog (Monolithic + Hybrid)	0.86	0.76	0.69	0.60	0.77	0.92	1.00	1.05	1.09
Total Discrete	1.29	1.14	1.03	1.19	1.28	1.14	1.00	0.87	0.78
Total Optoelectronic	0	0	0	0	0.26	0.23	0.20	0.17	0.16

Source: Dataquest (June 1995)

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Table 3-7
Taiwanese Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	15.17	15.95	15.88	15.90	15.04	14.61	14.63	14.89	15.47
Total IC	10.34	11.66	11.18	11.79	11.06	10.86	10.88	11.25	12.00
Bipolar Digital	2.07	1.84	1.18	1.03	0.44	0.37	0.34	0.30	0.27
MOS Digital	6.90	7.98	8.24	8.72	8.41	8.24	8.50	8.81	9.60
MOS Memory	2.07	2.45	2.94	3.08	3.10	3.00	3.06	3.04	3.47
MOS Microcomponent	2.07	2.45	2.35	2.56	2.21	2.25	2.38	2.13	2.40
MOS Logic	2.76	3.07	2.94	3.08	3.10	3.00	3.06	3.65	3.73
Analog (Monolithic + Hybrid)	1.38	1.84	1.76	2.05	2.21	2.25	2.04	2.13	2.13
Total Discrete	3.45	3.07	3.53	3.08	3.10	3.00	2.72	2.74	2.67
Total Optoelectronic	1.38	1.23	1.18	1.03	0.88	0.75	1.02	0.91	0.80

Source: Dataquest (June 1995)

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Section 4—Taiwanese Semiconductor Consumption by Application Market, Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
Taiwanese Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Equipment	11,585	12,717	15,003	17,779	21,089	24,557	28,788	34,283	40,703
Data Processing	6,151	6,590	7,776	9,185	10,838	12,464	14,583	17,208	20,305
Computers	2,795	3,013	3,573	4,256	5,088	5,898	6,973	8,288	9,852
Data Storage	344	395	513	659	860	1,069	1,398	1,755	2,166
Input/Output	2,313	2,403	2,735	3,099	3,456	3,800	4,248	4,833	5,485
Dedicated System	421	466	562	678	802	964	1,124	1,332	1,604
Other Data Processing	278	313	393	493	632	733	840	1,000	1,198
Communications	1,981	2,419	3,144	3,922	4,902	6,078	7,294	9,118	11,306
Premise Telecommunications	853	1,036	1,346	1,653	2,033	2,519	2,998	3,718	4,610
Public Telecommunications	270	348	468	605	774	1,068	1,335	1,735	2,256
Mobile Communications	99	138	212	318	463	648	875	1,225	1,654
Broadcast and Studio	121	175	258	370	531	473	662	960	1,363
Other Communications	638	722	860	976	1,101	1,370	1,424	1,480	1,423
Industrial	160	197	236	287	339	390	460	547	656
Security and Energy Management	52	66	79	96	115	131	156	187	224
Manufacturing Systems/Instruments	45	55	68	85	103	118	142	172	210
Medical Equipment	32	36	39	44	49	55	72	83	95
Other Industrial	31	40	50	62	72	86	90	105	127
Consumer	2,916	3,084	3,386	3,854	4,394	4,921	5,659	6,508	7,419
Audio	1,066	1,125	1,214	1,357	1,520	1,687	1,906	2,173	2,455
Video	697	771	898	1,084	1,312	1,524	1,829	2,195	2,590
Personal Electronics	401	417	449	502	562	615	695	778	879
Appliances	427	458	509	586	674	768	860	963	1,076
Other Consumer	325	313	316	325	326	327	369	399	419
Military/Civil Aerospace	232	264	291	336	390	437	498	573	642
Transportation	145	163	170	195	226	267	294	329	375

Source: Dataquest (June 1995)

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Table 4-2
Taiwanese Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Equipment	9.8	18.0	18.5	18.6	16.4	17.2	19.1	18.7	18.0
Data Processing	7.1	18.0	18.1	18.0	15.0	17.0	18.0	18.0	17.2
Computers	7.8	18.6	19.1	19.5	15.9	18.2	18.9	18.9	18.3
Data Storage	14.8	29.9	28.5	30.5	24.3	30.8	25.5	23.4	26.9
Input/Output	3.9	13.8	13.3	11.5	10.0	11.8	13.8	13.5	12.1
Dedicated System	10.7	20.6	20.6	18.3	20.2	16.6	18.5	20.4	18.8
Other Data Processing	12.6	25.6	25.4	28.2	16.0	14.6	19.0	19.8	19.4
Communications	22.1	30.0	24.7	25.0	24.0	20.0	25.0	24.0	23.6
Premise Telecommunications	21.5	29.9	22.8	23.0	23.9	19.0	24.0	24.0	22.8
Public Telecommunications	28.9	34.5	29.3	27.9	38.0	25.0	30.0	30.0	30.1
Mobile Communications	39.4	53.6	50.0	45.6	40.0	35.0	40.0	35.0	39.1
Broadcast and Studio	44.6	47.4	43.4	43.5	-10.9	40.0	45.0	42.0	29.8
Other Communications	13.2	19.1	13.5	12.8	24.4	3.9	3.9	-3.9	7.8
Industrial	23.1	19.8	21.6	18.1	15.0	17.9	18.9	19.9	18.0
Security and Energy Management	26.9	19.7	21.5	19.8	13.9	19.1	19.9	19.8	18.5
Manufacturing Systems/Instruments	22.2	23.6	25.0	21.2	14.6	20.3	21.1	22.1	19.8
Medical Equipment	12.5	8.3	12.8	11.4	12.2	30.9	15.3	14.5	16.6
Other Industrial	29.0	25.0	24.0	16.1	19.4	4.7	16.7	21.0	15.4
Consumer	5.8	9.8	13.8	14.0	12.0	15.0	15.0	14.0	14.0
Audio	5.5	7.9	11.8	12.0	11.0	13.0	14.0	13.0	12.6
Video	10.6	16.5	20.7	21.0	16.2	20.0	20.0	18.0	19.0
Personal Electronics	4.0	7.7	11.8	12.0	9.4	13.0	11.9	13.0	11.9
Appliances	7.3	11.1	15.1	15.0	13.9	12.0	12.0	11.7	12.9
Other Consumer	-3.7	1.0	2.8	0.3	0.3	12.8	8.1	5.0	5.2
Military/Civil Aerospace	13.8	10.2	15.5	16.1	12.1	14.0	15.1	12.0	13.8
Transportation	12.4	4.3	14.7	15.9	18.1	10.1	11.9	14.0	14.0

Source: Dataquest (June 1995)

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Table 4-3
Taiwanese Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	2,451	2,819	3,793	4,378	5,083	5,631	6,787	8,324	9,839
Data Processing	1,487	1,734	2,529	2,863	3,303	3,619	4,462	5,444	6,430
Computers	970	1,120	1,690	1,851	2,146	2,306	2,880	3,522	4,206
Data Storage	63	81	94	107	114	128	169	219	275
Input/Output	351	406	520	604	643	695	816	938	1,092
Dedicated System	35	44	97	128	172	222	282	380	494
Other Data Processing	68	83	128	173	228	268	315	385	363
Communications	197	244	339	428	543	657	770	1,015	1,285
Premise Telecommunications	87	96	148	174	209	239	252	330	383
Public Telecommunications	21	28	38	54	66	84	100	125	167
Mobile Communications	13	20	33	52	84	123	171	249	339
Broadcast and Studio	16	23	36	52	74	71	105	156	245
Other Communications	60	77	84	96	110	140	142	155	151
Industrial	20	22	25	31	38	47	57	72	88
Security and Energy Management	8	8	9	11	14	17	21	27	33
Manufacturing Systems/Instruments	5	6	7	9	11	13	16	21	26
Medical Equipment	3	3	4	4	5	6	8	10	11
Other Industrial	4	5	5	7	8	11	12	14	18
Consumer	699	769	847	995	1,131	1,231	1,413	1,698	1,927
Audio	234	255	278	312	326	343	376	424	448
Video	192	214	247	309	380	416	485	615	730
Personal Electronics	121	127	139	157	183	206	240	272	316
Appliances	87	101	107	126	147	169	194	257	291
Other Consumer	65	72	76	91	95	97	118	130	142
Military/Civil Aerospace	24	24	26	30	34	38	42	46	51
Transportation	24	26	27	31	34	39	43	49	58

Source: Dataquest (June 1995)

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Table 4-4
Taiwanese Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	15.0	34.6	15.4	16.1	10.8	20.5	22.6	18.2	17.6
Data Processing	16.6	45.8	13.2	15.4	9.6	23.3	22.0	18.1	17.6
Computers	15.5	50.9	9.5	15.9	7.5	24.9	22.3	19.4	17.8
Data Storage	28.6	16.0	13.8	6.5	12.3	32.0	29.6	25.6	20.8
Input/Output	15.7	28.1	16.2	6.5	8.1	17.4	15.0	16.4	12.6
Dedicated System	25.7	120.5	32.0	34.4	29.1	27.0	34.8	30.0	31.0
Other Data Processing	22.1	54.2	35.2	31.8	17.5	17.5	22.2	-5.7	16.0
Communications	23.9	38.9	26.3	26.9	21.0	17.2	31.8	26.6	24.6
Premise Telecommunications	10.3	54.2	17.6	20.1	14.4	5.4	31.0	16.1	17.1
Public Telecommunications	33.3	35.7	42.1	22.2	27.3	19.0	25.0	33.6	25.3
Mobile Communications	53.8	65.0	57.6	61.5	46.4	39.0	45.6	36.1	45.5
Broadcast and Studio	43.8	56.5	44.4	42.3	-4.1	47.9	48.6	57.1	36.3
Other Communications	28.3	9.1	14.3	14.6	27.3	1.4	9.2	-2.6	9.5
Industrial	10.0	13.6	24.0	22.6	23.7	21.3	26.3	22.2	23.2
Security and Energy Management	0	12.5	22.2	27.3	21.4	23.5	28.6	22.2	24.6
Manufacturing Systems/Instruments	20.0	16.7	28.6	22.2	18.2	23.1	31.3	23.8	23.6
Medical Equipment	0	33.3	0	25.0	20.0	33.3	25.0	10.0	22.4
Other Industrial	25.0	0	40.0	14.3	37.5	9.1	16.7	28.6	20.8
Consumer	10.0	10.1	17.5	13.7	8.8	14.8	20.2	13.5	14.1
Audio	9.0	9.0	12.2	4.5	5.2	9.6	12.8	5.7	7.5
Video	11.5	15.4	25.1	23.0	9.5	16.6	26.8	18.7	18.8
Personal Electronics	5.0	9.4	12.9	16.6	12.6	16.5	13.3	16.2	15.0
Appliances	16.1	5.9	17.8	16.7	15.0	14.8	32.5	13.2	18.2
Other Consumer	10.8	5.6	19.7	4.4	2.1	21.6	10.2	9.2	9.3
Military/Civil Aerospace	0	8.3	15.4	13.3	11.8	10.5	9.5	10.9	11.2
Transportation	8.3	3.8	14.8	9.7	14.7	10.3	14.0	18.4	13.3

Source: Dataquest (June 1995)

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Table 4-5
Taiwanese Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.212	0.222	0.253	0.246	0.241	0.229	0.236	0.243	0.242
Data Processing	0.242	0.263	0.325	0.312	0.305	0.290	0.306	0.316	0.317
Computers	0.347	0.372	0.473	0.435	0.422	0.391	0.413	0.425	0.427
Data Storage	0.183	0.205	0.183	0.162	0.133	0.120	0.121	0.125	0.127
Input/Output	0.152	0.169	0.190	0.195	0.186	0.183	0.192	0.194	0.199
Dedicated System	0.083	0.094	0.173	0.189	0.214	0.230	0.251	0.285	0.308
Other Data Processing	0.245	0.265	0.326	0.351	0.361	0.366	0.375	0.385	0.303
Communications	0.099	0.101	0.108	0.109	0.111	0.108	0.106	0.111	0.114
Premise Telecommunications	0.102	0.093	0.110	0.105	0.103	0.095	0.084	0.089	0.083
Public Telecommunications	0.078	0.080	0.081	0.089	0.085	0.079	0.075	0.072	0.074
Mobile Communications	0.131	0.145	0.156	0.164	0.181	0.190	0.195	0.203	0.205
Broadcast and Studio	0.132	0.131	0.140	0.141	0.139	0.150	0.159	0.163	0.180
Other Communications	0.094	0.107	0.098	0.098	0.100	0.102	0.100	0.105	0.106
Industrial	0.125	0.112	0.106	0.108	0.112	0.121	0.124	0.132	0.134
Security and Energy Management	0.154	0.121	0.114	0.115	0.122	0.130	0.135	0.144	0.147
Manufacturing Systems/Instruments	0.111	0.109	0.103	0.106	0.107	0.110	0.113	0.122	0.124
Medical Equipment	0.094	0.083	0.103	0.091	0.102	0.109	0.111	0.120	0.116
Other Industrial	0.129	0.125	0.100	0.113	0.111	0.128	0.133	0.133	0.142
Consumer	0.240	0.249	0.250	0.258	0.257	0.250	0.250	0.261	0.260
Audio	0.220	0.227	0.229	0.230	0.214	0.203	0.197	0.195	0.182
Video	0.275	0.278	0.275	0.285	0.290	0.273	0.265	0.280	0.282
Personal Electronics	0.302	0.305	0.310	0.313	0.326	0.335	0.345	0.350	0.359
Appliances	0.204	0.221	0.210	0.215	0.218	0.220	0.226	0.267	0.270
Other Consumer	0.200	0.230	0.241	0.280	0.291	0.297	0.320	0.326	0.339
Military/Civil Aerospace	0.103	0.091	0.089	0.089	0.087	0.087	0.084	0.080	0.079
Transportation	0.166	0.160	0.159	0.159	0.150	0.146	0.146	0.149	0.155

Source: Dataquest (June 1995)

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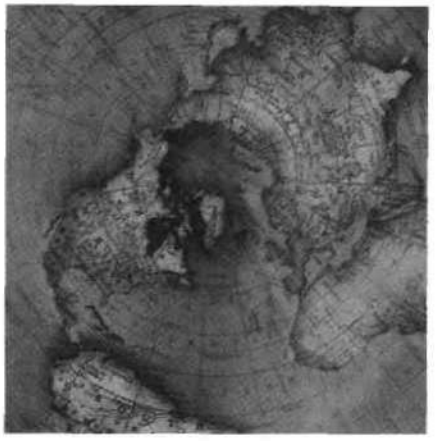
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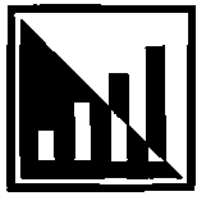
Dataquest

Singaporean Semiconductor Consumption by Application Market

Market Statistics

Program: Semiconductor Application Markets Asia/Pacific
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Note: All tables show estimated data.

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Chapter 1
Singaporean Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1991-1994 historical data
- 1995-1999 forecast data

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for the intermarket comparisons and aggregation. In general, Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in the month of January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.
- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic

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goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecommunications
  - Public telecommunications
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

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Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/output devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise telecommunications equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX

[1] Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

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telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.

- Public telecommunications equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile communications equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and studio equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other telecommunications equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/energy management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing systems/instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other industrial equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.

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- Personal electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/civil aerospace[2]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, power-train sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.

[2]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U. S. defense and civil (aerospace) electronics.

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- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).
  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).
- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singaporean operation (which is factory revenue) and the European distributor or final user.

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Chapter 2
Application Market—Database Tables

Section 1—Singaporean Semiconductor Consumption by Application Market, History and Forecast

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Table 1-1
Singaporean Semiconductor Consumption—Total Electronics (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	9,931	13,042	16,312	19,951	23,370	26,859	30,049	34,026	39,227
Total Semiconductor	1,142	1,471	2,178	3,339	4,018	4,834	5,505	6,787	8,572
Total IC	944	1,233	1,874	2,903	3,498	4,261	4,866	6,050	7,664
Bipolar Digital	52	45	40	38	32	27	23	20	18
MOS Digital	648	881	1,439	2,304	2,786	3,419	3,912	4,934	6,319
MOS Memory	264	341	615	916	1,110	1,320	1,512	1,900	2,505
MOS Microcomponent	221	326	491	808	985	1,220	1,390	1,754	2,122
MOS Logic	164	215	332	580	692	878	1,010	1,280	1,692
Analog (Monolithic + Hybrid)	244	307	395	561	680	815	931	1,096	1,327
Total Discrete	172	207	263	379	454	498	552	633	779
Total Optoelectronic	26	31	41	57	67	75	87	104	129

Source: Dataquest (May 1995)

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Table 1-2
Singaporean Semiconductor Consumption—Data Processing (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Data Processing	6,770	9,140	11,823	14,746	17,533	20,410	23,010	26,340	30,795
Total Semiconductor	692	898	1,458	2,302	2,770	3,390	3,893	4,922	6,369
Total IC	623	810	1,333	2,108	2,548	3,132	3,600	4,564	5,929
Bipolar Digital	45	40	36	34	28	24	20	18	16
MOS Digital	487	655	1,137	1,833	2,220	2,749	3,160	4,020	5,233
MOS Memory	204	265	507	745	925	1115	1280	1600	2133
MOS Microcomponent	157	225	360	606	725	909	1045	1340	1640
MOS Logic	126	165	270	482	570	725	835	1080	1460
Analog (Monolithic + Hybrid)	91	115	160	241	300	359	420	526	680
Total Discrete	55	69	99	158	180	212	240	296	360
Total Optoelectronic	14	19	26	36	42	46	53	62	80

Source: Dataquest (May 1995)

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Table 1-3
Singaporean Semiconductor Consumption—Communications (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Communications	394	598	954	1,059	1,140	1,249	1,355	1,497	1,692
Total Semiconductor	55	61	85	194	233	281	315	383	472
Total IC	50	56	79	180	218	266	298	362	446
Bipolar Digital	2	1	1	1	1	1	1	1	0
MOS Digital	36	40	55	122	148	176	194	238	298
MOS Memory	14	17	25	60	72	84	92	110	135
MOS Microcomponent	11	12	16	32	41	49	53	66	82
MOS Logic	10	11	14	30	35	43	49	62	81
Analog (Monolithic + Hybrid)	13	15	23	57	69	89	103	123	148
Total Discrete	4	4	5	12	13	12	14	16	19
Total Optoelectronic	1	1	1	2	3	3	3	5	7

Source: Dataquest (May 1995)

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Table 1-4
Singaporean Semiconductor Consumption—Industrial (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Industrial	224	210	225	273	309	345	385	432	487
Total Semiconductor	24	27	32	44	56	71	83	103	127
Total IC	18	21	25	35	45	58	68	85	105
Bipolar Digital	1	1	1	1	1	1	1	1	0
MOS Digital	13	16	19	28	38	50	59	72	90
MOS Memory	3	3	4	5	6	8	9	12	16
MOS Microcomponent	5	7	9	15	21	29	35	42	52
MOS Logic	5	5	6	9	11	13	15	18	22
Analog (Monolithic + Hybrid)	4	4	5	6	6	7	9	12	15
Total Discrete	5	5	5	7	8	9	11	14	17
Total Optoelectronic	1	1	1	2	3	3	4	5	6

Source: Dataquest (May 1995)

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Table 1-5
Singaporean Semiconductor Consumption—Consumer (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Consumer	2,216	2,703	2,868	3,370	3,832	4,248	4,641	5,041	5,472
Total Semiconductor	337	444	553	736	881	998	1,106	1,248	1,441
Total IC	229	315	401	534	632	740	825	949	1,070
Bipolar Digital	2	2	1	1	1	1	1	1	1
MOS Digital	95	147	201	286	339	394	442	533	610
MOS Memory	39	52	75	100	99	105	121	165	207
MOS Microcomponent	40	72	95	140	180	211	232	275	308
MOS Logic	16	23	31	46	60	78	89	93	95
Analog (Monolithic + Hybrid)	131	167	199	247	292	345	382	415	459
Total Discrete	100	120	142	188	234	241	260	275	345
Total Optoelectronic	8	8	10	13	15	17	21	24	26

Source: Dataquest (May 1995)

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Table 1-6
Singaporean Semiconductor Consumption—Military/Civil Aerospace (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Military/Civil Aerospace	68	85	112	124	139	157	173	191	211
Total Semiconductor	2	3	3	4	4	5	6	7	8
Total IC	2	2	2	3	3	4	4	5	6
Bipolar Digital	0	0	0	0	0	0	0	0	0
MOS Digital	1	1	2	2	2	3	3	3	4
MOS Memory	0	0	0	1	1	1	1	1	1
MOS Microcomponent	0	0	0	1	1	1	1	1	1
MOS Logic	0	1	1	1	1	1	1	1	2
Analog (Monolithic + Hybrid)	1	1	1	1	1	1	1	2	2
Total Discrete	0	0	1	1	1	1	1	1	2
Total Optoelectronic	0	0	0	0	0	0	0	0	0

Source: Dataquest (May 1995)

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Table 1-7
Singaporean Semiconductor Consumption—Transportation (Millions of U.S. Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transportation	259	307	330	379	417	450	485	525	570
Total Semiconductor	32	39	47	59	74	89	103	125	155
Total IC	22	28	33	42	51	61	71	87	108
Bipolar Digital	1	1	1	0	0	0	0	0	0
MOS Digital	17	22	26	32	39	47	54	67	85
MOS Memory	3	3	4	6	7	8	9	11	14
MOS Microcomponent	7	10	12	14	17	21	24	30	39
MOS Logic	6	9	10	12	15	18	21	26	32
Analog (Monolithic + Hybrid)	4	6	7	10	12	14	16	19	23
Total Discrete	8	9	11	14	19	23	26	31	37
Total Optoelectronic	2	2	2	3	4	5	6	8	10

Source: Dataquest (May 1995)

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Section 2—Singaporean Semiconductor Consumption by Application Market, Annual Growth Rates

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Table 2-1
Singaporean Semiconductor Consumption—Total Electronics (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	31.3	25.1	22.3	17.1	14.9	11.9	13.2	15.3	14.5
Total Semiconductor	28.8	48.1	53.3	20.3	20.3	13.9	23.3	26.3	20.8
Total IC	30.6	51.9	54.9	20.5	21.8	14.2	24.3	26.7	21.4
Bipolar Digital	-12.7	-10.6	-5.0	-17.5	-14.3	-16.0	-11.0	-11.2	-14.0
MOS Digital	35.9	63.3	60.1	20.9	22.7	14.4	26.1	28.1	22.4
MOS Memory	29.1	80.6	48.9	21.1	19.0	14.5	25.6	31.9	22.3
MOS Microcomponent	47.8	50.7	64.4	21.9	23.9	13.9	26.2	21.0	21.3
MOS Logic	30.9	54.8	74.5	19.3	26.9	15.0	26.7	32.1	23.9
Analog (Monolithic + Hybrid)	25.8	28.5	42.2	21.3	19.8	14.2	17.8	21.0	18.8
Total Discrete	20.1	27.3	44.3	19.6	9.7	10.9	14.6	23.1	15.5
Total Optoelectronic	18.3	32.7	37.8	17.7	12.5	16.7	18.6	24.5	17.9

Source: Dataquest (May 1995)

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Table 2-2
Singaporean Semiconductor Consumption—Data Processing (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	35.0	29.4	24.7	18.9	16.4	12.7	14.5	16.9	15.9
Total Semiconductor	29.6	62.4	57.9	20.3	22.4	14.8	26.4	29.4	22.6
Total IC	30.0	64.5	58.1	20.9	22.9	14.9	26.8	29.9	23.0
Bipolar Digital	-11.1	-10.0	-5.6	-17.6	-14.3	-16.7	-10.0	-11.1	-14.0
MOS Digital	34.6	73.5	61.2	21.1	23.8	15.0	27.2	30.2	23.3
MOS Memory	29.6	91.7	46.9	24.2	20.5	14.8	25.0	33.3	23.4
MOS Microcomponent	44.0	59.7	68.3	19.6	25.4	15.0	28.2	22.4	22.0
MOS Logic	31.0	63.2	78.5	18.3	27.2	15.2	29.3	35.2	24.8
Analog (Monolithic + Hybrid)	26.0	39.1	50.6	24.5	19.7	17.0	25.2	29.3	23.1
Total Discrete	25.3	44.2	59.6	13.9	17.8	13.2	23.3	21.6	17.9
Total Optoelectronic	28.5	40.5	38.5	16.7	9.5	15.2	17.0	29.0	17.3

Source: Dataquest (May 1995)

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Table 2-3
Singaporean Semiconductor Consumption—Communications (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communications	51.8	59.5	11.0	7.6	9.6	8.5	10.5	13.0	9.8
Total Semiconductor	11.7	38.4	129.0	20.2	20.3	12.3	21.4	23.4	19.4
Total IC	12.6	39.6	129.1	21.0	21.9	12.0	21.4	23.5	19.9
Bipolar Digital	-13.3	-15.4	0	-18.2	-22.2	0	-28.6	-20.0	-18.3
MOS Digital	12.7	36.3	123.9	21.3	18.9	10.2	22.7	25.2	19.6
MOS Memory	19.7	47.1	140.0	20.0	16.7	9.5	19.6	22.7	17.6
MOS Microcomponent	5.3	29.2	106.5	28.1	19.5	8.2	24.5	24.2	20.7
MOS Logic	11.1	27.3	114.3	16.7	22.9	14.0	26.5	30.6	22.0
Analog (Monolithic + Hybrid)	15.4	53.3	147.8	21.1	29.0	15.7	19.4	20.3	21.0
Total Discrete	2.6	25.0	140.0	8.3	-7.7	16.7	14.3	16.3	9.2
Total Optoelectronic	0.6	23.2	72.7	25.0	20.0	13.3	47.1	40.0	28.5

Source: Dataquest (May 1995)

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Table 2-4
Singaporean Semiconductor Consumption—Industrial (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	-6.3	7.1	21.3	13.2	11.7	11.6	12.2	12.7	12.3
Total Semiconductor	11.7	18.9	39.5	26.0	27.0	17.7	23.6	23.9	23.6
Total IC	14.5	18.0	41.9	28.3	28.3	18.0	23.7	24.1	24.4
Bipolar Digital	-22.4	-10.2	-0.2	-22.3	-13.8	-13.0	-16.7	-10.0	-15.3
MOS Digital	21.1	18.0	49.5	33.8	31.8	18.2	22.1	23.8	25.8
MOS Memory	6.3	11.8	26.3	29.2	24.2	19.5	33.7	26.0	26.4
MOS Microcomponent	35.2	23.3	64.4	41.9	40.0	19.0	20.0	23.8	28.6
MOS Logic	14.9	14.8	41.9	22.7	20.4	15.4	20.0	22.2	20.1
Analog (Monolithic + Hybrid)	5.6	26.3	20.8	10.3	12.5	19.4	37.2	27.1	20.9
Total Discrete	2.2	17.4	25.9	13.2	20.8	18.3	22.7	22.2	19.4
Total Optoelectronic	1.1	47.4	50.0	28.6	22.2	12.1	24.3	26.1	22.5

Source: Dataquest (May 1995)

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Table 2-5
Singaporean Semiconductor Consumption—Consumer (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	22.0	6.1	17.5	13.7	10.9	9.3	8.6	8.5	10.2
Total Semiconductor	31.8	24.8	33.0	19.8	13.3	10.8	12.8	15.5	14.4
Total IC	37.9	27.3	33.1	18.3	17.1	11.5	15.0	12.7	14.9
Bipolar Digital	-25.1	-17.6	0	-10.3	-11.5	-17.4	-12.6	-10.8	-12.6
MOS Digital	54.4	36.8	42.3	18.5	16.2	12.2	20.6	14.4	16.4
MOS Memory	33.0	44.6	33.3	-1.0	6.1	15.2	36.4	25.5	15.7
MOS Microcomponent	79.0	32.7	47.4	28.6	17.2	10.0	18.5	12.0	17.1
MOS Logic	45.0	32.0	48.4	30.4	30.0	14.1	4.5	2.2	15.6
Analog (Monolithic + Hybrid)	27.0	19.3	24.1	18.2	18.2	10.7	8.6	10.6	13.2
Total Discrete	19.7	18.5	32.4	24.5	3.0	7.9	5.8	25.5	12.9
Total Optoelectronic	7.8	20.5	34.0	11.9	13.3	23.5	14.3	8.3	14.2

Source: Dataquest (May 1995)

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Table 2-6
Singaporean Semiconductor Consumption—Military/Civil Aerospace (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	24.3	31.8	10.7	12.1	12.9	10.2	10.4	10.5	11.2
Total Semiconductor	6.6	21.8	13.7	17.4	18.1	12.3	20.8	22.3	18.1
Total IC	4.3	20.4	15.5	15.1	14.5	11.4	18.4	21.5	16.1
Bipolar Digital	-43.8	-33.8	0.7	-21.4	-13.6	-12.6	-22.9	-6.3	-15.6
MOS Digital	15.2	32.4	19.0	16.9	14.9	11.8	19.4	20.9	16.8
MOS Memory	13.5	12.5	20.0	20.4	18.5	15.6	21.3	22.2	19.6
MOS Microcomponent	15.4	58.2	19.9	10.9	9.8	9.0	17.8	22.1	13.8
MOS Logic	16.4	33.3	17.6	18.8	15.8	10.9	18.9	19.3	16.7
Analog (Monolithic + Hybrid)	16.4	15.6	10.8	17.1	16.7	12.5	19.0	24.0	17.8
Total Discrete	16.1	21.4	5.9	29.6	35.7	15.8	30.0	25.2	27.1
Total Optoelectronic	19.9	53.7	10.6	17.6	15.0	13.0	19.2	22.6	17.5

Source: Dataquest (May 1995)

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Table 2-7
Singaporean Semiconductor Consumption—Transportation (Percentage Growth Rate)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	18.5	7.5	14.8	10.0	7.9	7.8	8.2	8.6	8.5
Total Semiconductor	22.6	19.4	26.9	24.5	20.8	15.0	22.1	23.4	21.1
Total IC	30.0	19.3	26.8	20.9	19.8	14.9	22.6	24.6	20.5
Bipolar Digital	-31.3	-9.1	-2.0	-12.2	-9.3	-7.7	-16.7	-6.7	-10.6
MOS Digital	31.6	19.4	24.9	19.8	21.1	15.3	24.0	25.7	21.1
MOS Memory	13.3	17.6	42.5	19.3	17.6	15.0	21.7	20.5	18.8
MOS Microcomponent	34.3	21.1	25.2	18.1	23.5	14.3	25.0	30.0	22.1
MOS Logic	37.2	18.3	17.8	22.0	20.0	16.7	23.8	23.1	21.1
Analog (Monolithic + Hybrid)	35.1	21.6	35.7	26.3	16.7	14.3	18.8	21.1	19.3
Total Discrete	8.4	22.2	28.2	31.2	21.6	15.6	19.2	19.4	21.3
Total Optoelectronic	2.4	9.3	23.4	44.8	28.6	13.0	27.9	26.9	27.8

Source: Dataquest (May 1995)

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Section 3—Singaporean Semiconductor Consumption by Application Market, Input/Output Ratios

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Table 3-1
Singaporean Semiconductor Consumption—Total Electronics (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.115	0.113	0.134	0.167	0.172	0.180	0.183	0.199	0.219
Total IC	0.095	0.095	0.115	0.146	0.150	0.159	0.162	0.178	0.195
Bipolar Digital	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0
MOS Digital	0.065	0.068	0.088	0.115	0.119	0.127	0.130	0.145	0.161
MOS Memory	0.027	0.026	0.038	0.046	0.047	0.049	0.050	0.056	0.064
MOS Microcomponent	0.022	0.025	0.030	0.040	0.042	0.045	0.046	0.052	0.054
MOS Logic	0.017	0.016	0.020	0.029	0.030	0.033	0.034	0.038	0.043
Analog (Monolithic + Hybrid)	0.025	0.024	0.024	0.028	0.029	0.030	0.031	0.032	0.034
Total Discrete	0.017	0.016	0.016	0.019	0.019	0.019	0.018	0.019	0.020
Total Optoelectronic	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Source: Dataquest (May 1995)

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Table 3-2
Singaporean Semiconductor Consumption—Data Processing (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.102	0.098	0.123	0.156	0.158	0.166	0.169	0.187	0.207
Total IC	0.092	0.089	0.113	0.143	0.145	0.153	0.156	0.173	0.193
Bipolar Digital	0.007	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001
MOS Digital	0.072	0.072	0.096	0.124	0.127	0.135	0.137	0.153	0.170
MOS Memory	0.030	0.029	0.043	0.051	0.053	0.055	0.056	0.061	0.069
MOS Microcomponent	0.023	0.025	0.030	0.041	0.041	0.045	0.045	0.051	0.053
MOS Logic	0.019	0.018	0.023	0.033	0.033	0.036	0.036	0.041	0.047
Analog (Monolithic + Hybrid)	0.013	0.013	0.014	0.016	0.017	0.018	0.018	0.020	0.022
Total Discrete	0.008	0.008	0.008	0.011	0.010	0.010	0.010	0.011	0.012
Total Optoelectronic	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003

Source: Dataquest (May 1995)

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Table 3-3
Singaporean Semiconductor Consumption—Communications (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.139	0.102	0.089	0.183	0.205	0.225	0.233	0.256	0.279
Total IC	0.127	0.094	0.082	0.170	0.191	0.213	0.220	0.241	0.264
Bipolar Digital	0.004	0.002	0.001	0.001	0.001	0.001	0.001	0	0
MOS Digital	0.090	0.067	0.057	0.115	0.130	0.141	0.143	0.159	0.176
MOS Memory	0.036	0.028	0.026	0.057	0.063	0.067	0.068	0.073	0.080
MOS Microcomponent	0.029	0.020	0.016	0.030	0.036	0.039	0.039	0.044	0.048
MOS Logic	0.025	0.018	0.015	0.028	0.031	0.034	0.036	0.041	0.048
Analog (Monolithic + Hybrid)	0.033	0.025	0.024	0.054	0.061	0.071	0.076	0.082	0.087
Total Discrete	0.010	0.007	0.005	0.011	0.011	0.010	0.010	0.011	0.011
Total Optoelectronic	0.002	0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.004

Source: Dataquest (May 1995)

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Table 3-4
Singaporean Semiconductor Consumption—Industrial (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.106	0.127	0.141	0.162	0.180	0.205	0.216	0.238	0.261
Total IC	0.082	0.100	0.110	0.129	0.146	0.168	0.178	0.196	0.216
Bipolar Digital	0.007	0.005	0.005	0.004	0.003	0.002	0.002	0.001	0.001
MOS Digital	0.059	0.077	0.084	0.104	0.123	0.145	0.154	0.167	0.184
MOS Memory	0.014	0.016	0.017	0.018	0.020	0.022	0.024	0.028	0.032
MOS Microcomponent	0.024	0.035	0.040	0.054	0.068	0.085	0.091	0.097	0.107
MOS Logic	0.021	0.026	0.028	0.032	0.035	0.038	0.039	0.042	0.045
Analog (Monolithic + Hybrid)	0.016	0.018	0.021	0.021	0.021	0.021	0.022	0.027	0.031
Total Discrete	0.020	0.022	0.024	0.025	0.025	0.027	0.029	0.031	0.034
Total Optoelectronic	0.004	0.005	0.006	0.008	0.009	0.010	0.010	0.011	0.012

Source: Dataquest (May 1995)

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Table 3-5
Singaporean Semiconductor Consumption—Consumer (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.152	0.164	0.193	0.218	0.230	0.235	0.238	0.248	0.263
Total IC	0.103	0.117	0.140	0.159	0.165	0.174	0.178	0.188	0.195
Bipolar Digital	0.001	0.001	0.001	0	0	0	0	0	0
MOS Digital	0.043	0.054	0.070	0.085	0.088	0.093	0.095	0.106	0.111
MOS Memory	0.018	0.019	0.026	0.030	0.026	0.025	0.026	0.033	0.038
MOS Microcomponent	0.018	0.026	0.033	0.042	0.047	0.050	0.050	0.055	0.056
MOS Logic	0.007	0.009	0.011	0.014	0.016	0.018	0.019	0.018	0.017
Analog (Monolithic + Hybrid)	0.059	0.062	0.069	0.073	0.076	0.081	0.082	0.082	0.084
Total Discrete	0.045	0.044	0.050	0.056	0.061	0.057	0.056	0.055	0.063
Total Optoelectronic	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.005

Source: Dataquest (May 1995)

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Table 3-6
Singaporean Semiconductor Consumption—Military/Civil Aerospace (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.035	0.030	0.028	0.029	0.030	0.031	0.032	0.035	0.039
Total IC	0.029	0.024	0.022	0.023	0.024	0.024	0.024	0.026	0.029
Bipolar Digital	0.005	0.002	0.001	0.001	0.001	0.001	0	0	0
MOS Digital	0.015	0.014	0.014	0.015	0.016	0.016	0.016	0.018	0.019
MOS Memory	0.005	0.005	0.004	0.004	0.005	0.005	0.005	0.006	0.006
MOS Microcomponent	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005
MOS Logic	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008
Analog (Monolithic + Hybrid)	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.008	0.009
Total Discrete	0.005	0.005	0.005	0.004	0.005	0.006	0.006	0.007	0.008
Total Optoelectronic	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002

Source: Dataquest (May 1995)

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Table 3-7
Singaporean Semiconductor Consumption—Transportation (Input/Output Ratio)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.123	0.128	0.142	0.157	0.177	0.198	0.212	0.239	0.271
Total IC	0.083	0.091	0.101	0.112	0.123	0.136	0.145	0.165	0.189
Bipolar Digital	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0
MOS Digital	0.064	0.071	0.079	0.085	0.093	0.104	0.112	0.128	0.148
MOS Memory	0.012	0.011	0.012	0.015	0.016	0.018	0.019	0.021	0.024
MOS Microcomponent	0.027	0.031	0.035	0.038	0.041	0.047	0.049	0.057	0.068
MOS Logic	0.025	0.029	0.032	0.032	0.036	0.040	0.043	0.050	0.056
Analog (Monolithic + Hybrid)	0.016	0.019	0.021	0.025	0.029	0.031	0.033	0.036	0.040
Total Discrete	0.032	0.029	0.033	0.037	0.044	0.050	0.054	0.059	0.065
Total Optoelectronic	0.008	0.007	0.007	0.008	0.010	0.012	0.013	0.015	0.017

Source: Dataquest (May 1995)

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Section 4—Singaporean Semiconductor Consumption by Application Market, Detailed Equipment Categories, History and Forecast (Factory Revenue)

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Table 4-1
Singaporean Electronic Production Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Electronic Equipment	9,931	13,043	16,311	19,951	23,370	26,859	30,049	34,026	39,227
Data Processing	6,770	9,140	11,823	14,746	17,533	20,410	23,010	26,340	30,795
Computers	1,572	1,228	2,231	2,993	3,649	4,320	5,040	6,000	7,400
Data Storage	4,210	6,246	7,433	9,553	11,400	13,400	15,100	17,100	19,800
Input/Output	411	689	1,074	1,050	1,210	1,340	1,460	1,600	1,760
Dedicated System	453	750	795	803	874	940	1,010	1,090	1,175
Other Data Processing	124	228	289	347	400	410	400	550	660
Communications	394	598	954	1,059	1,140	1,249	1,355	1,497	1,692
Premise Telecommunications	128	380	832	968	1,043	1,143	1,240	1,371	1,550
Public Telecommunications	1	1	5	2	3	4	5	5	6
Mobile Communications	228	186	71	58	59	63	68	74	82
Broadcast and Studio	16	13	27	14	16	18	20	23	27
Other Communications	21	18	19	17	19	21	22	24	27
Industrial	224	210	225	273	309	345	385	432	487
Security and Energy Management	36	40	42	55	62	70	79	90	103
Manufacturing Systems/Instruments	86	80	86	89	96	106	117	129	143
Medical Equipment	3	1	3	8	11	12	13	14	15
Other Industrial	99	89	94	121	140	157	176	199	226
Consumer	2,216	2,703	2,868	3,370	3,832	4,248	4,641	5,041	5,472
Audio	781	1,076	1,112	1,306	1,551	1,747	1,947	2,101	2,261
Video	1,092	1,168	1,275	1,514	1,658	1,806	1,934	2,100	2,300
Personal Electronics	9	11	6	7	7	6	4	6	8
Appliances	322	432	457	523	595	665	730	805	870
Other Consumer	12	16	18	20	22	24	26	29	33
Military/Civil Aerospace	68	85	112	124	139	157	173	191	211
Transportation	259	307	330	379	417	450	485	525	570

Source: Dataquest (May 1995)

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Table 4-2
Singaporean Electronic Production Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Equipment	31.3	25.1	22.3	17.1	14.9	11.9	13.2	15.3	14.5
Data Processing	35.0	29.3	24.7	18.9	16.4	12.7	14.5	16.9	15.9
Computers	-21.9	81.7	34.2	21.9	18.4	16.7	19.0	23.3	19.8
Data Storage	48.3	19.0	28.5	19.3	17.5	12.7	13.2	15.8	15.7
Input/Output	67.6	56.0	-2.2	15.2	10.7	9.0	9.6	10.0	10.9
Dedicated System	65.7	6.0	1.0	8.8	7.6	7.4	7.9	7.8	7.9
Other Data Processing	83.4	27.0	19.9	15.3	2.5	-2.4	37.5	20.0	13.7
Communications	51.8	59.5	11.0	7.6	9.6	8.4	10.5	13.0	9.8
Premise Telecommunications	196.9	118.9	16.3	7.7	9.6	8.5	10.6	13.1	9.9
Public Telecommunications	0	400.0	-60.0	50.0	33.3	12.5	11.1	20.0	24.6
Mobile Communications	-18.4	-61.8	-18.3	1.7	6.8	7.9	8.8	10.8	7.2
Broadcast and Studio	-18.8	107.7	-48.1	14.3	12.5	11.1	15.0	17.4	14.0
Other Communications	-14.3	5.6	-10.5	11.8	10.5	4.8	9.1	12.5	9.7
Industrial	-6.3	7.1	21.3	13.2	11.7	11.6	12.2	12.7	12.3
Security and Energy Management	11.1	5.0	31.0	12.7	12.9	12.9	13.9	14.4	13.4
Manufacturing Systems/Instruments	-7.0	7.5	3.5	7.9	10.4	10.4	10.3	10.9	9.9
Medical Equipment	-66.7	200.0	166.7	37.5	9.1	8.3	7.7	7.1	13.4
Other Industrial	-10.1	5.6	28.7	15.7	12.1	12.1	13.1	13.6	13.3
Consumer	22.0	6.1	17.5	13.7	10.9	9.3	8.6	8.5	10.2
Audio	37.8	3.3	17.4	18.7	12.6	11.5	7.9	7.6	11.6
Video	7.0	9.2	18.7	9.5	8.9	7.1	8.6	9.5	8.7
Personal Electronics	22.2	-45.5	20.0	-9.7	-1.5	-32.8	41.9	31.1	2.1
Appliances	34.2	5.8	14.4	13.8	11.8	9.8	10.3	8.1	10.7
Other Consumer	33.3	9.4	14.3	10.0	9.1	8.3	11.5	13.8	10.5
Military/Civil Aerospace	25.0	31.8	10.7	12.1	12.9	10.2	10.4	10.5	11.2
Transportation	18.5	7.5	14.8	10.0	7.9	7.8	8.2	8.6	8.5

Source: Dataquest (May 1995)

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Table 4-3
Singaporean Semiconductor Consumption by Application (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	1,143	1,471	2,178	3,339	4,018	4,833	5,505	6,788	8,572
Data Processing	692	897	1,458	2,303	2,770	3,390	3,893	4,922	6,369
Computers	270	225	500	1,025	1,194	1,400	1,700	2,166	3,027
Data Storage	370	572	790	1,043	1,226	1,500	1,649	2,138	2,633
Input/Output	32	58	94	120	150	180	200	230	270
Dedicated System	4	8	14	25	60	160	190	237	290
Other Data Processing	16	34	60	90	140	150	154	151	149
Communications	55	61	85	194	233	281	315	383	472
Premise Telecommunications	25	38	69	176	212	256	287	350	432
Public Telecommunications	0	0	2	1	1	2	2	2	3
Mobile Communications	25	18	7	10	11	12	13	15	17
Broadcast and Studio	2	2	4	3	4	5	6	7	9
Other Communications	3	3	3	4	5	6	7	9	11
Industrial	24	27	32	44	56	71	83	103	127
Security and Energy Management	3	4	7	10	11	13	16	21	27
Manufacturing Systems/Instruments	8	11	12	16	24	33	39	50	63
Medical Equipment	0	0	0	1	1	2	2	2	2
Other Industrial	13	12	13	17	20	23	26	30	35
Consumer	337	444	553	736	881	998	1,106	1,248	1,441
Audio	80	124	150	233	320	380	420	470	520
Video	228	274	320	405	446	488	545	620	742
Personal Electronics	2	3	2	3	3	3	2	3	3
Appliances	25	40	76	89	105	119	130	145	165
Other Consumer	2	3	5	6	7	8	9	10	11
Military/Civil Aerospace	2	3	3	4	4	5	6	7	8
Transportation	32	39	47	59	74	89	103	125	155

Source: Dataquest (May 1995)

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Table 4-4
Singaporean Semiconductor Consumption Growth Rates (Percent)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	28.7	48.1	53.3	20.4	20.3	13.9	23.3	26.3	20.8
Data Processing	29.6	62.5	58.0	20.3	22.4	14.8	26.4	29.4	22.6
Computers	-16.7	122.2	105.0	16.5	17.3	21.4	27.4	39.8	24.2
Data Storage	54.6	38.1	32.0	17.5	22.3	9.9	29.7	23.2	20.3
Input/Output	81.3	62.1	27.7	25.0	20.0	11.1	15.0	17.4	17.6
Dedicated System	100.0	75.0	78.6	140.0	166.7	18.8	24.7	22.4	63.3
Other Data Processing	112.5	76.5	50.0	55.6	7.1	2.7	-1.9	-1.3	10.6
Communications	11.1	38.0	129.0	20.3	20.4	12.2	21.7	23.1	19.5
Premise Telecommunications	52.0	81.6	155.1	20.5	20.8	12.1	22.0	23.4	19.7
Public Telecommunications	50.0	433.3	-56.3	42.9	50.0	6.7	25.0	25.0	29.0
Mobile Communications	-28.0	-61.1	42.9	10.0	9.1	8.3	15.4	13.3	11.2
Broadcast and Studio	0	100.0	-25.0	33.3	25.0	20.0	16.7	28.6	24.6
Other Communications	0	0	33.3	25.0	20.0	16.7	28.6	22.2	22.4
Industrial	12.3	18.8	35.8	28.9	25.8	17.3	24.4	23.5	23.9
Security and Energy Management	33.3	75.0	42.9	10.0	18.2	23.1	31.3	28.6	22.0
Manufacturing Systems/Instruments	37.5	9.1	33.3	50.0	37.5	18.2	28.2	26.0	31.5
Medical Equipment	-60.0	400.0	500.0	100.0	41.7	11.8	10.5	9.5	30.8
Other Industrial	-7.7	8.3	30.8	17.6	15.0	13.0	15.4	16.7	15.5
Consumer	31.8	24.6	33.0	19.7	13.3	10.8	12.8	15.5	14.4
Audio	55.0	21.0	55.3	37.3	18.8	10.5	11.9	10.6	17.4
Video	20.2	16.8	26.6	10.1	9.4	11.7	13.8	19.7	12.9
Personal Electronics	50.0	-26.7	36.4	0	0	-33.3	45.0	3.4	0
Appliances	60.0	90.0	17.1	18.0	13.3	9.2	11.5	13.8	13.1
Other Consumer	50.0	66.7	20.0	16.7	14.3	12.5	11.1	10.0	12.9
Military/Civil Aerospace	6.3	23.1	14.6	16.7	16.7	12.2	21.8	22.8	18.0
Transportation	21.9	20.5	25.5	25.4	20.3	15.7	21.4	24.0	21.3

Source: Dataquest (May 1995)

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Table 4-5
Singaporean Semiconductor Consumption I/O Ratios (Percent)

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	0.115	0.113	0.134	0.167	0.172	0.180	0.183	0.199	0.219
Data Processing	0.102	0.098	0.123	0.156	0.158	0.166	0.169	0.187	0.207
Computers	0.172	0.183	0.224	0.342	0.327	0.324	0.337	0.361	0.409
Data Storage	0.088	0.092	0.106	0.109	0.108	0.112	0.109	0.125	0.133
Input/Output	0.078	0.084	0.088	0.114	0.124	0.134	0.137	0.144	0.153
Dedicated System	0.009	0.011	0.018	0.031	0.069	0.170	0.188	0.217	0.247
Other Data Processing	0.129	0.149	0.207	0.259	0.350	0.366	0.385	0.275	0.226
Communications	0.140	0.103	0.089	0.183	0.204	0.225	0.232	0.256	0.279
Premise Telecommunications	0.195	0.100	0.083	0.182	0.203	0.224	0.231	0.255	0.279
Public Telecommunications	0.200	0.300	0.320	0.350	0.333	0.375	0.356	0.400	0.417
Mobile Communications	0.110	0.097	0.099	0.172	0.186	0.190	0.191	0.203	0.207
Broadcast and Studio	0.125	0.154	0.148	0.214	0.250	0.278	0.300	0.304	0.333
Other Communications	0.143	0.167	0.158	0.235	0.263	0.286	0.318	0.375	0.407
Industrial	0.107	0.129	0.143	0.160	0.182	0.205	0.215	0.239	0.261
Security and Energy Management	0.083	0.100	0.167	0.182	0.177	0.186	0.203	0.233	0.262
Manufacturing Systems/Instruments	0.093	0.138	0.140	0.180	0.250	0.311	0.333	0.388	0.441
Medical Equipment	0.017	0.020	0.033	0.075	0.109	0.142	0.146	0.150	0.153
Other Industrial	0.131	0.135	0.138	0.140	0.143	0.146	0.148	0.151	0.155
Consumer	0.152	0.164	0.193	0.218	0.230	0.235	0.238	0.248	0.263
Audio	0.102	0.115	0.135	0.178	0.206	0.218	0.216	0.224	0.230
Video	0.209	0.235	0.251	0.268	0.269	0.270	0.282	0.295	0.323
Personal Electronics	0.222	0.273	0.367	0.417	0.462	0.469	0.465	0.475	0.375
Appliances	0.078	0.093	0.166	0.170	0.176	0.179	0.178	0.180	0.190
Other Consumer	0.167	0.188	0.286	0.300	0.318	0.333	0.346	0.345	0.333
Military/Civil Aerospace	0.035	0.030	0.028	0.029	0.030	0.031	0.032	0.035	0.039
Transportation	0.124	0.127	0.142	0.156	0.177	0.198	0.212	0.238	0.272

Source: Dataquest (May 1995)

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Analysis

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Singapore's Semiconductor Consumption Outlook

Abstract: *Dataquest has delivered the 1994 Singaporean electronics equipment production history and forecast. This article proceeds with our estimates of the Singaporean semiconductor consumption by application market and by device, which include our usual history and five-year forecast.*
By Eddy Tan (Singapore)

Overview

We understated historical production numbers in communications and data processing in our previous newsletter on Singaporean electronic equipment production (see the Market Forecasts document dated April 10, 1995, SAMM-AP-MF-9502). We now increase the Singaporean total equipment production by $200 million to $13 billion for 1992, and by $1.4 billion to $16.3 billion for 1993. The increase is a consequence of adding production revenue from telephonic/telegraphic radio receivers, telephone sets, and pagers/cellular telephones, PCs, and input devices. Our corresponding market statistics book will furnish updated estimates and revise our forecast.

This article proceeds with Singaporean semiconductor consumption segmented by application and by device, based on our revised history and forecast estimates.

Data Processing Rules Again

Singapore's focus on data processing has resulted in healthy growth in the country's overall electronics equipment manufacturing, since revenue from the computing industry commanded 74 percent of last year's total equipment output. Using our revised 1993 historical estimates, our 1994

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estimates showed that the data processing industry grew by 25 percent to $14.7 billion. Much of the growth was driven by the key sectors: data storage and computers. Data storage, which occupies 65 percent of the data processing pie, grew by 28.5 percent to $9.6 billion in 1994 and is expected to increase at a compound annual growth rate (CAGR) of 15.7 percent to $20 billion in 1999. In comparison, computers, which take up 20 percent of data processing, grew by 34 percent to $3 billion in 1994. We forecast computers to grow by a CAGR of 19.8 percent to $7.4 billion by 1999.

Our optimism is based on the assumption that the world's major PC manufacturers, such as Compaq, Apple, and Hewlett-Packard, are expanding their Singaporean capacities to meet increasing local demand for computing power in the region. Both Apple and Compaq are targeting output increases by 50 to 70 percent. Although these two giant manufacturers are also leaning toward portable PCs, their future products will integrate multimedia functions such as audio effects, data communication, and videoconferencing. Riding on the regional PC market boom, HP too expects healthy growth in its printer manufacturing, in addition to its own computer business.

Dataquest also assumes that Singapore will continue to defend its forte as the world's largest disk drive manufacturer. Much of the support naturally will continue to come from the Singaporean government, which has been championing the country's key sector for the last decade. Future capacities will be buoyed by recent arrival of IBM's first Singaporean gigabyte-capacity disk drive facility, and by capacity expansion from among other disk drive players such as Seagate, Micropolis, and Integral Peripherals. Future trends must include higher-capacity storage devices to support faster speeds and more sophisticated computing equipment. Manufacturing of storage devices also will see improved yields because of application of magneto-resistive technology.

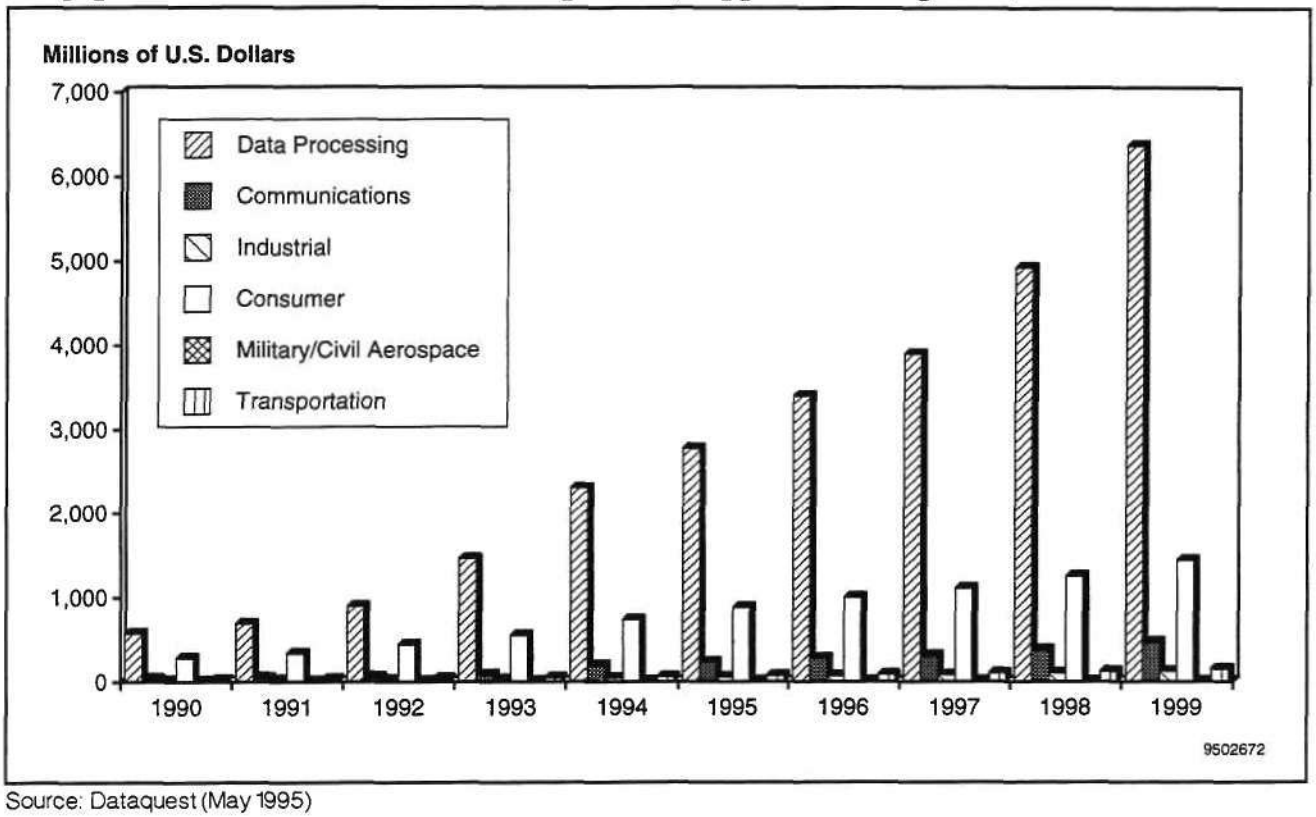
Opportunities for Semiconductor Vendors in Data Processing

The rapid rise in data processing spells good news for semiconductor vendors, particularly those supplying MOS digital semiconductors to the computing industry. We project Singapore's total semiconductor consumption, largely driven by data processing, to increase from $3.3 billion in 1994 to $8.6 billion in 1999, for a CAGR of 20.8 percent. Figures 1 and 2 show how data processing devours most of Singapore's total semiconductors. Data processing consumption of semiconductors will surge from $2.3 billion in 1994 to $6.4 billion in 1999, for a CAGR of 23 percent. As a result, the data processing application market will increase to 74 percent by 1999 from 1994's share of 69 percent.

Table 1 (graphically represented by Figures 3 and 4) provides details of total consumption growth for all equipment segmented by device from 1990 through 1999. Memory consumption for all equipment will nearly triple from $916 million in 1994 to $2.5 billion in 1999, for a CAGR of 22 percent. Logic, microcomponents, and analog will exhibit comparable CAGRs of 24 percent, 21 percent, and 19 percent, respectively. We expect memory to occupy 29 percent of the 1999 total semiconductor consumption pie worth $8.6 billion, followed by microcomponents (25 percent), logic (20 percent), and analog (15 percent). Singapore's future total semiconductor consumption will be an important function of memories, microcomponents, logic, and analogs.

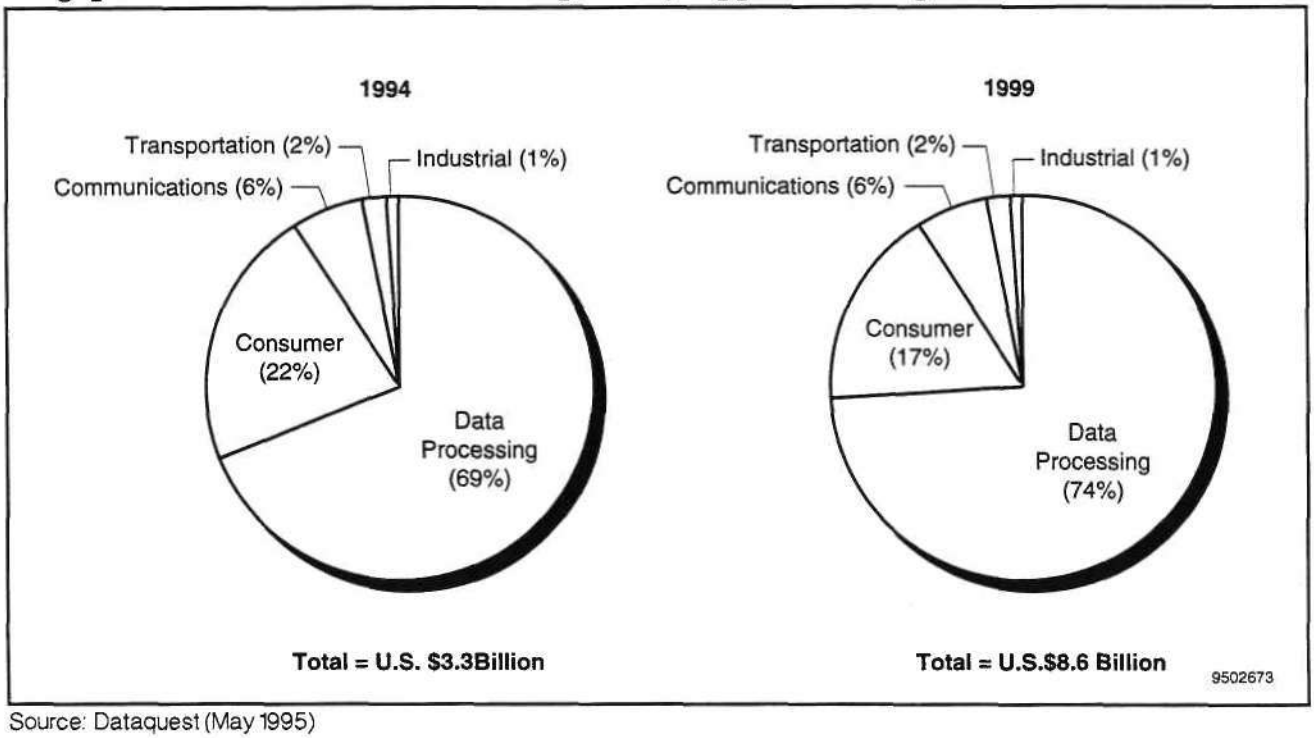
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Figure 1
Singaporean Semiconductor Consumption by Application Segment, 1990 to 1999



Source: Dataquest (May 1995)

Figure 2
Singaporean Semiconductor Consumption by Application Segment, 1990 and 1999



Source: Dataquest (May 1995)

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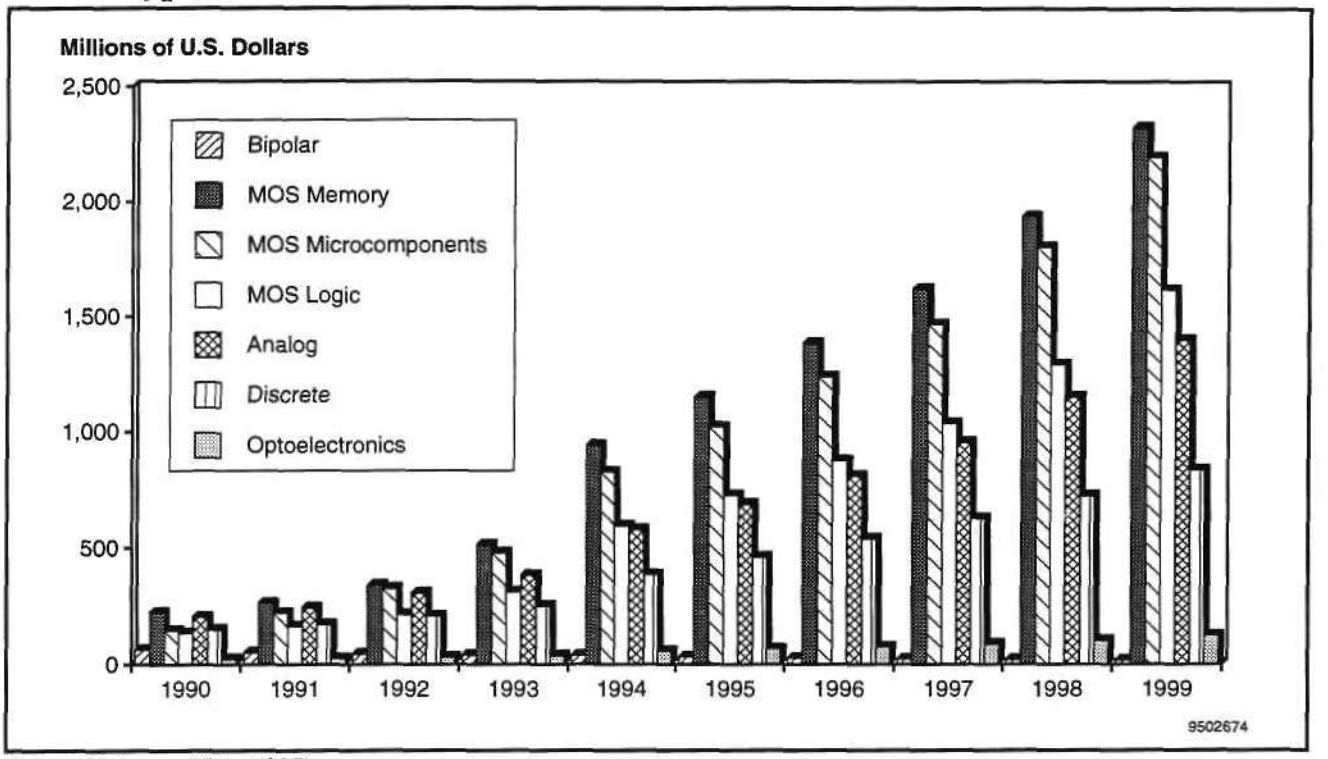
Table 1
Singaporean Semiconductor Consumption History and Forecast
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	946	1,142	1,471	2,178	3,339	4,018	4,834	5,505	6,787	8,572	20.8
Total IC	773	944	1,233	1,874	2,903	3,498	4,261	4,866	6,050	7,664	21.4
Bipolar	63	51	45	40	38	32	27	2,2	20	18	-14.0
MOS Digital	505	648	881	1,438	2,304	2,787	3,418	3,912	4,934	6,319	22.4
MOS Memory	225	264	341	615	916	1,110	1,320	1,512	1,900	2,505	22.3
MOS Microcomponent	146	221	326	491	808	985	1,220	1,390	1,754	2,122	21.3
MOS Logic	135	164	215	332	580	692	878	1,010	1,280	1,692	23.9
Analog	205	244	307	395	561	680	815	931	1,096	1,327	18.8
Discrete	151	172	207	263	379	454	498	552	633	779	15.5
Optoelectronic	23	26	31	41	57	67	75	87	104	129	17.9

Source: Dataquest (May 1995)

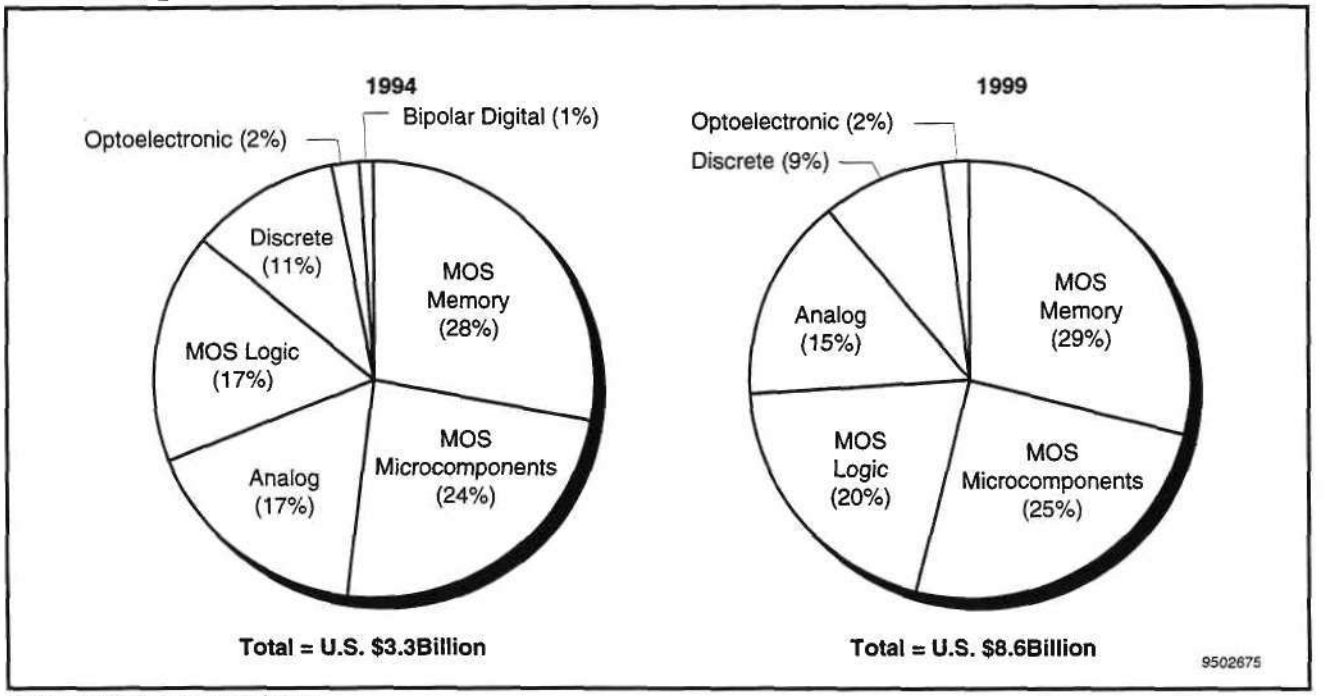
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Figure 3
Singaporean Semiconductor Consumption History and Forecast by Device Type, 1990 to 1999



Source: Dataquest (May 1995)

Figure 4
Singaporean Semiconductor Consumption History and Forecast by Device Type, 1990 and 1999



Source: Dataquest (May 1995)

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Opportunities from Other Applications

Consumer electronics, the second-largest equipment industry in Singapore, is expected to grow at a CAGR of 10 percent from $3.4 billion in 1994 to $5.4 billion in 1999. Because Singapore faces a manpower shortage, limited land, and a strong currency, several audio manufacturers such as Sanyo channel their labor-intensive audio operations to neighboring countries. Other consumer players are diversifying into other applications: Aiwa has started producing PC components and peripherals, while Kenwood is turning to design and manufacture of telecommunications equipment. Such a strategy is suited to Singapore's ability to support the manufacture of high value-added components and/or design of new consumer products. The rising value of the yen should lead to more higher-value-added consumer manufacturing opportunities for Singapore. The leading consumer sectors, both audio and video equipment, contributed 39 percent and 45 percent, respectively, to consumer production revenue in 1994. We expect total semiconductor application in the consumer sector to double from $734 million to $1.4 billion by 1999, or to 17 percent of total consumption by application by 1999. The result will, nevertheless, sustain demand for analogs and discretes. Increasing digitalization of high-end consumer products with incorporation of features such as CD and video players also will drive application of 1Mb and 4Mb DRAM, microprocessors, and microcontrollers.

Singapore is located within the Asia/Pacific region of high growth opportunities for communication, but it only has a significantly small manufacturing base for communications products. This sector in Singapore is only expected to consume $472 million worth of semiconductors in 1999. Other semiconductor consumption will come from transportation ($199 million), industrial ($127 million), and military/civil aerospace ($8 million) in 1999.

Dataquest Perspective

Singapore's data processing industry, which determines the country's overall electronic equipment health, is expected to register positive growth for the next five years. Dataquest anticipates gradual slowdown until 1997, after which the industry is expected to accelerate, in line with the overall trends in the region. Hard disk drives, computers, printers, and other peripherals' high growth will continue to place unquenchable demand for memories, particularly DRAM and high-speed SRAM, and for microprocessors. Allocation issues still will be a limiting factor in equipment production growth, which in turn affect semiconductor consumption and sustain healthy component pricing.

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Forecasts

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Singapore's Electronics Equipment Production Outlook

Abstract: *This article presents the final 1994 estimates of Singapore's electronics equipment production, with a five-year forecast from 1995 through 1999. We also highlight Singapore's key trends in the equipment sectors. Singapore's equipment manufacturing will continue to focus on data processing, with growing emphasis on equipment design of improved products. The country also will continue to sustain its reign as the world's largest storage device manufacturer.*

By Eddy Tan

Overview

Singapore's electronics equipment manufacturing has displayed healthy growth rates since 1989 when we began tracking its production. Total equipment output almost doubled in the four years following 1989. Dataquest estimated that Singapore's electronics equipment production in 1994 grew at an annual rate of 33.1 percent to $20.0 billion and with a compound annual growth rate (CAGR) of 21.3 percent from 1989 to 1994 (see Table 1). The 1994 figures were led by data processing, which represented a hefty 73.9 percent of the total. As expected, the storage sector was the star performer, commanding 46.2 percent of Singapore's total electronics equipment. Output of data processing soared to 35 percent in 1992, with the storage sector spiraling to an all-time high annual growth rate of 50 percent (see Table 2). Rigid disk drives grew at an annual 27.9 percent to $9.2 billion in 1994, or a CAGR of 25.5 percent from 1989. Nearly 70 percent of Singapore manufactured drives were shipped to the United States and the Netherlands in 1993 and 1994.

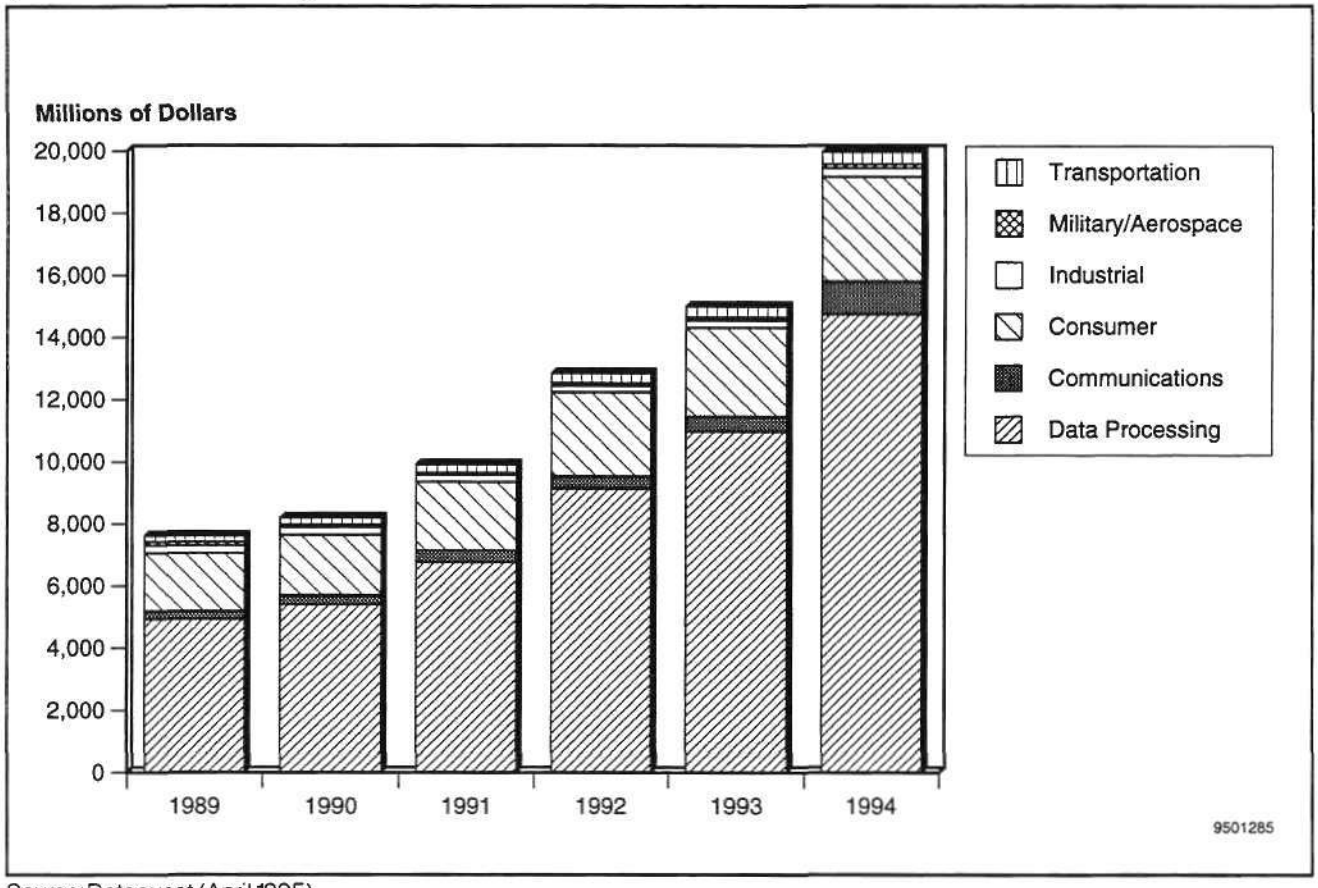
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The island's success can be attributed to the three-decade aggressive effort by the Singaporean government to promote the country as an excellent base for manufacturing data processing, particularly disk drives. Its involvement in nurturing Singapore's manufacturing is obvious—for example, through investments in joint-venture companies and in critical and high-cost projects. High manufacturing costs and limitations in manpower and land are quickly compensated by consolidation of facilities, active productivity drives, and automation. An added incentive to the manufacturers is that Singapore's excellent infrastructure, communications, and transportation systems are unparalleled in Southeast Asia. Many electronics manufacturers—such as Toshiba and Compaq—locate their headquarters in Singapore to function as the region's center for logistics and engineering support, procurement, distribution, marketing, and design.

Figures 1 and 2 and Tables 1 through 6 provide details on Singapore's electronics equipment production.

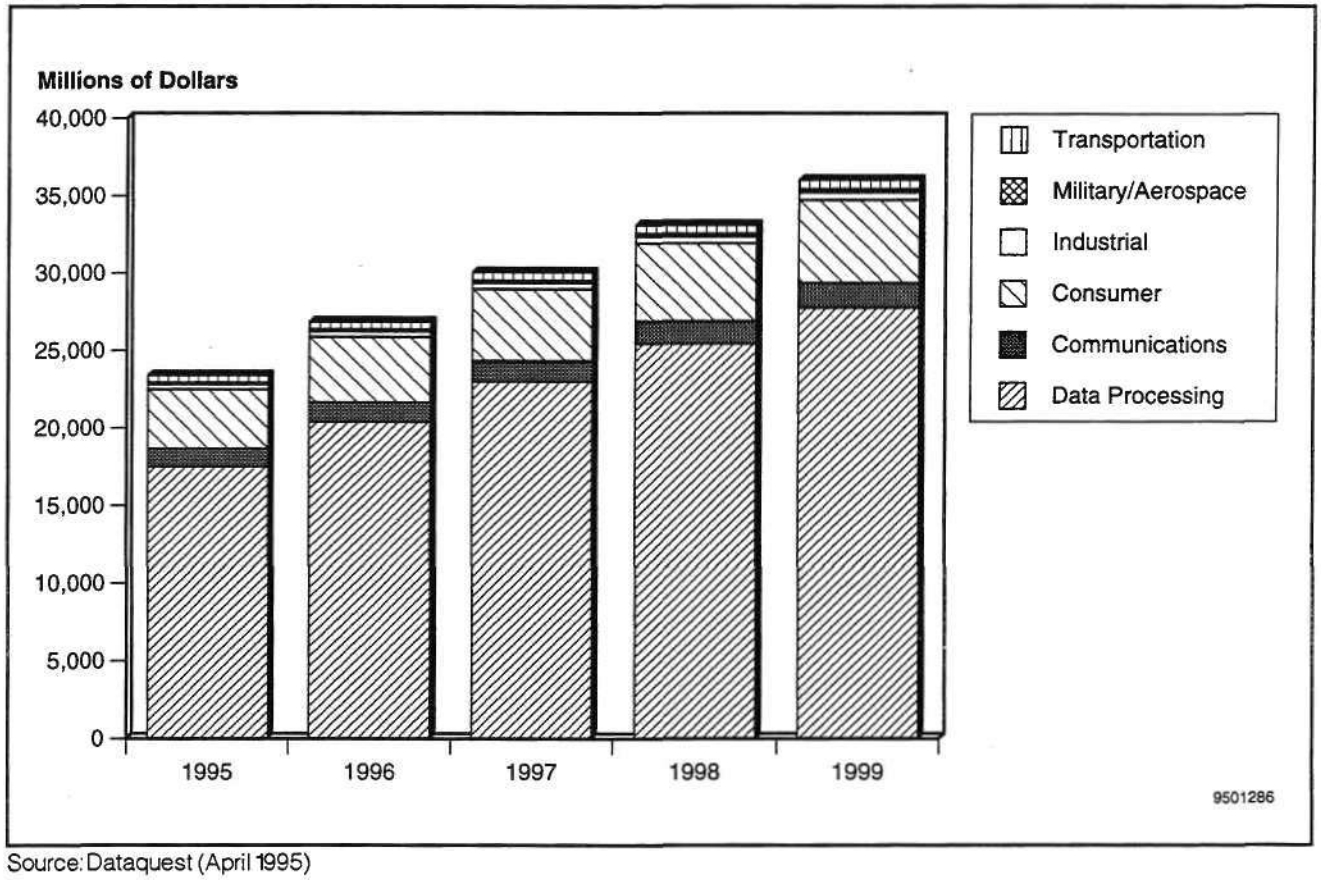
Figure 1
Singaporean Electronics Equipment Production History by Application (Millions of Dollars)



Source: Dataquest (April 1995)

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Figure 2
Singaporean Electronics Equipment Production Forecast by Application (Millions of Dollars)



Source: Dataquest (April 1995)

Table 1
Singaporean Electronics Equipment Production History by Application (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Data Processing	4,928	5,406	6,770	9,140	10,977	14,746	24.5
Communications	262	298	373	400	476	1,059	32.2
Consumer	1,874	1,943	2,216	2,703	2,868	3,370	12.5
Industrial	246	252	224	210	225	273	2.1
Military/Aerospace	114	97	68	85	112	124	1.7
Transportation	179	189	259	307	330	379	16.2
Total	7,603	8,185	9,910	12,845	14,988	19,951	21.3

Source: Dataquest (April 1995)

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Table 2
Singaporean Rigid Disk Drive Production History

	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Millions of U.S. Dollars	2,958	3,300	4,034	6,060	7,211	9,224	25.5
Annual Growth Percentage	8.6	11.6	22.2	50.2	19.0	27.9	

Source: Dataquest (April 1995)

Table 3
Singaporean Electronics Equipment Production Forecast by Application (Millions of Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Data Processing	14,746	17,533	20,410	23,010	25,470	27,785	13.5
Communications	1,059	1,132	1,236	1,354	1,476	1,606	8.7
Consumer	3,370	3,832	4,248	4,641	4,997	5,356	9.7
Industrial	273	309	345	385	432	487	12.3
Military/Aerospace	124	139	157	173	191	211	11.2
Transportation	379	417	450	485	525	570	8.5
Total	19,951	23,362	26,846	30,048	33,091	36,015	12.5

Source: Dataquest (April 1995)

Table 4
Singaporean Electronics Equipment Production History by Application (Annual Growth Percentage)

	1990	1991	1992	1993	1994
Data Processing	9.7	25.2	35.0	20.1	34.3
Communications	13.7	25.2	7.2	19.0	122.5
Consumer	3.7	14.1	22.0	6.1	17.5
Industrial	2.4	-11.1	-6.3	7.1	21.3
Military/Aerospace	-14.9	-29.9	25.0	31.8	10.7
Transportation	5.6	37.0	18.5	7.5	14.8
Total	7.7	21.1	29.6	16.7	33.1

Source: Dataquest (April 1995)

Table 5
Singaporean Electronics Equipment Production Forecast by Application (Annual Growth Percentage)

	1995	1996	1997	1998	1999
Data Processing	18.9	16.4	12.7	10.7	9.1
Communications	6.9	9.2	9.5	9.0	8.8
Consumer	13.7	10.9	9.3	7.7	7.2
Industrial	13.2	11.7	11.6	12.2	12.7
Military/Aerospace	12.1	12.9	10.2	10.4	10.5
Transportation	10.0	7.9	7.8	8.2	8.6
Total	17.1	14.9	11.9	10.1	8.8

Source: Dataquest (April 1995)

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Table 6
Singaporean Rigid Disk Drive Production Forecast

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Millions of U.S. Dollars	9,224	10,900	12,795	14,366	15,806	17,052	13.1
Annual Growth Percentage	27.9	18.2	17.4	12.3	10.0	7.9	

Source: Dataquest (April 1995)

Malaysia Is Catching Up

Malaysia's proximity to Singapore has enabled it to enjoy the success wave from its southern neighbor. Malaysia has been an important market, trading partner, supplier of manpower, and recipient of overflowing manufacturing projects to Singapore. Over the years, several consumer equipment manufacturers have shifted their production from Singapore to Malaysia, the latter of which has relatively more land and human resources. The labor situation in Malaysia has begun to tighten over the years because of rapid economic expansion. At any rate, production shifts to Malaysia fit in well with the country's plans to focus on equipment manufacturing such as consumer and industrial equipment, and not to depend entirely on the semiconductor sector. As a host to some of the world's major IC assembly houses (see the Semiconductor Asia/Pacific *Dataquest Perspective* dated November 7, 1994, SEMI-AP-DP-9406) and consumer equipment manufacturers, Malaysia is enhancing its disk drive industry and is bound to attract other PC manufacturers besides Dell. We will publish a focus report on Malaysia to highlight its prowess in the semiconductor and electronics equipment industries.

Figures 3 and 4 provide details on Singapore's electronics equipment production from 1989 to 1999.

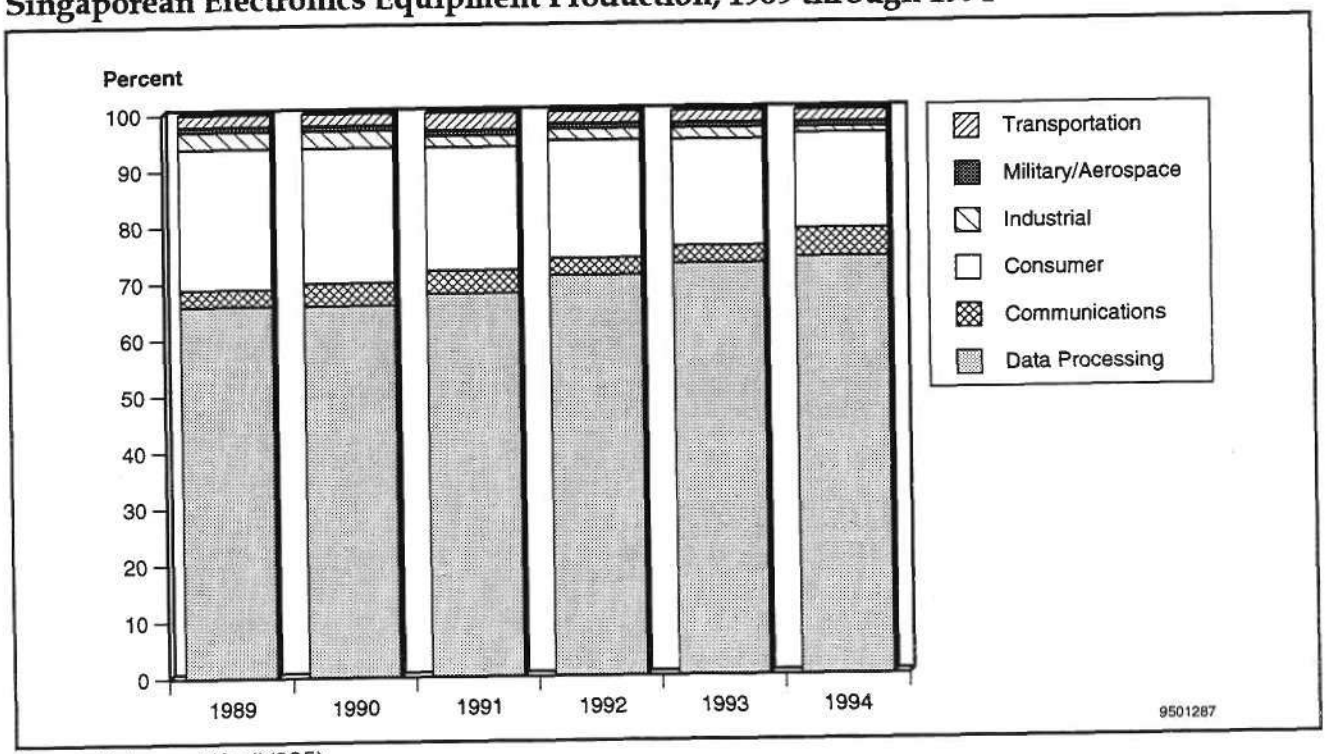
Outlook through 1999: Electronics Equipment Production Forecast

We project Singapore to ramp up its electronics equipment output to $36.0 billion in 1999, at a CAGR of 12.5 percent from 1994. Data processing will be the key driver, with a CAGR of 13.5 percent. Data processing will represent 77.1 percent of the total electronics equipment output by the end of the century, thus maintaining its reign as the leading sector since 1989. Rigid disk drives are expected to grow to $10.9 billion this year, given the entry of IBM and expansion of other giants in Singapore that are leaning toward gigabyte, magneto-resistive-type products. We project that Singapore's rigid disk drive output will grow at a CAGR of 13.1 percent to $17.1 billion from 1994 to 1999, or maintain its share of total Singaporean electronics equipment output at exceeding 45 percent.

While the outlook is positive for the whole data processing sector, Singapore will undoubtedly see further flights of labor-intensive and matured electronics equipment manufacturing to its neighboring countries. Citing uncompetitive manufacturing costs as the major culprit, Singapore has lost several audio manufacturing facilities to Malaysia. Even low-end data processing products will be relegated to the region, to be substituted with newer models with high capacity and enhanced features. We expect moderate growth for the other sectors such as communications and military/aerospace equipment. In place of manufactured products with high

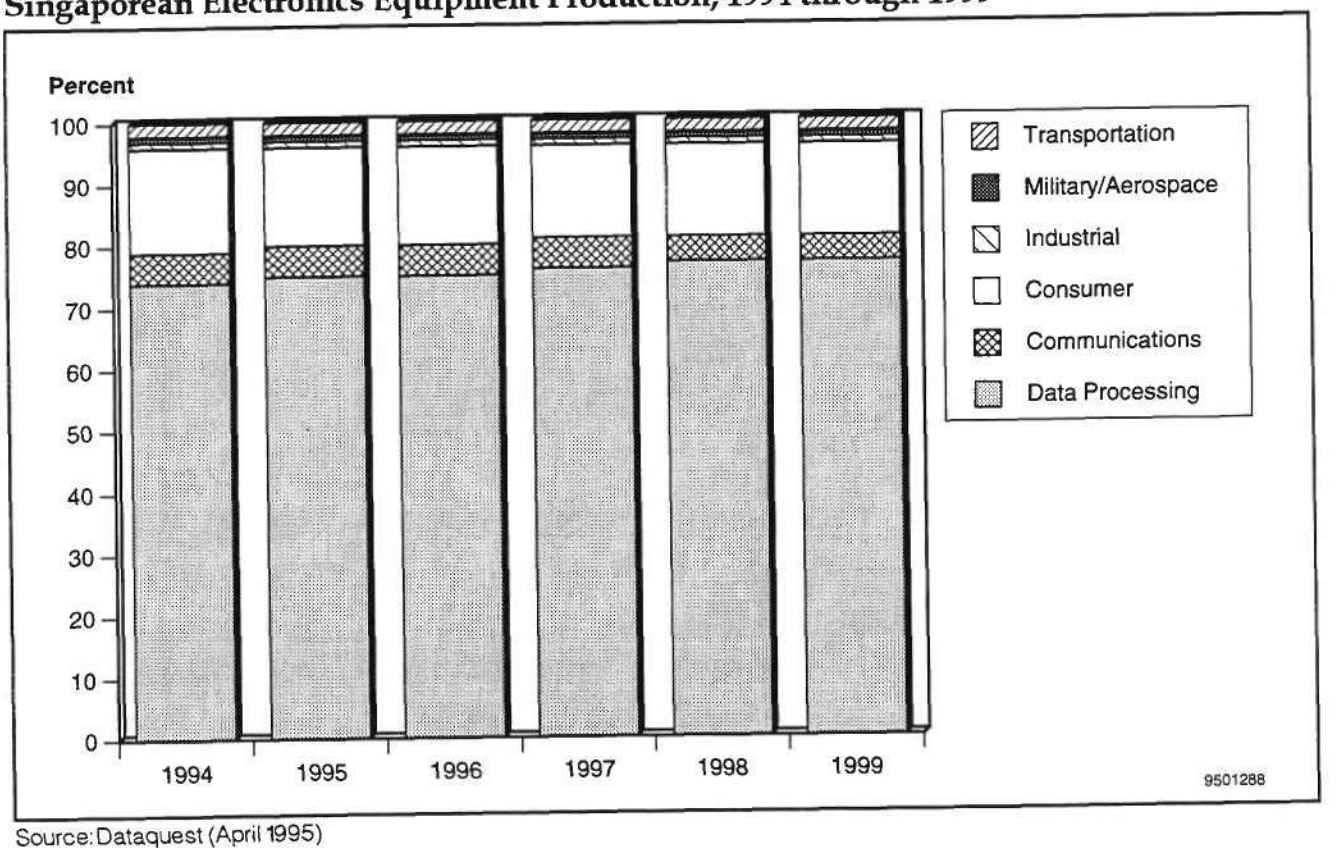
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Figure 3
Singaporean Electronics Equipment Production, 1989 through 1994



Source: Dataquest (April 1995)

Figure 4
Singaporean Electronics Equipment Production, 1994 through 1999



Source: Dataquest (April 1995)

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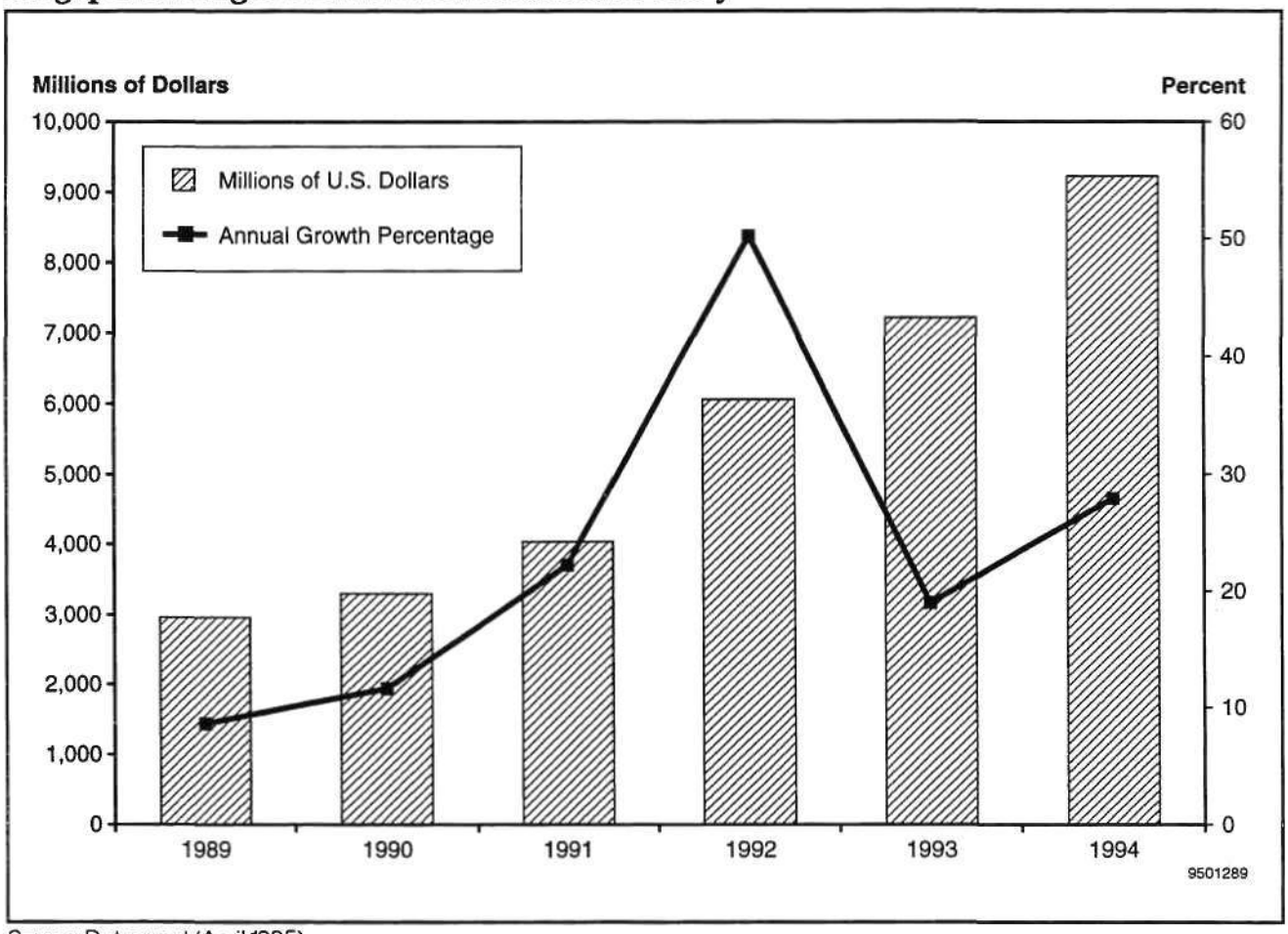
labor content, Singaporean electronics manufacturers are gearing toward higher-end products and critical components.

Figure 5 provides details on Singapore's rigid disk drive production.

Dataquest Perspective

Dataquest is optimistic that Singapore will continue to expand its electronics industry, particularly PCs and disk drives, given the increasing worldwide demand and rising acceptance of multimedia-related products and peripherals. Manufacturers of Singapore's top electronics sectors, disk drive and PCs, over the last year have announced investments in new headquarters, factories, and production lines. Simultaneously, Singapore continues to enhance its vertical integration of semiconductor and electronics manufacturing through expansion of wafer fabs, IC design, assembly, and test, and software development. Provision of tax incentives and research grants continues to become an important incentive for manufacturers to move toward more knowledge-intensive activities.

Figure 5
Singaporean Rigid Disk Drive Production History



Source: Dataquest (April 1995)

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Analysis

Taiwanese Electronic Equipment Production Outlook: The PC Reigns, but Communication Surges

Abstract: *This article presents the final Taiwanese electronics equipment production history and a five-year forecast from 1995 through 1999. We also analyze the major trends in the major equipment sectors. This island has been playing a much more important role in the electronics equipment production in the past few years, especially in data processing sectors. According to Taiwan's final 1994 export statistics, electronics was the largest exporting sector and is slated to become the major propulsion behind future economic growth.*

By Ben F.P. Lee (Taiwan)

Overview

Taiwanese electronic equipment factory revenue growth accelerated to 18.6 percent in 1994, following 17.7 percent expansion to U.S.$15 billion in 1993. Data processing electronic equipment still occupies more than half of total production among the six categories of electronic equipment production (see Figure 1). Communications and consumer electronic equipment are about equal, and each represents about 22 percent of the total. These are the three major sectors of Taiwanese electronic equipment production, and they account for 95 percent of all production.

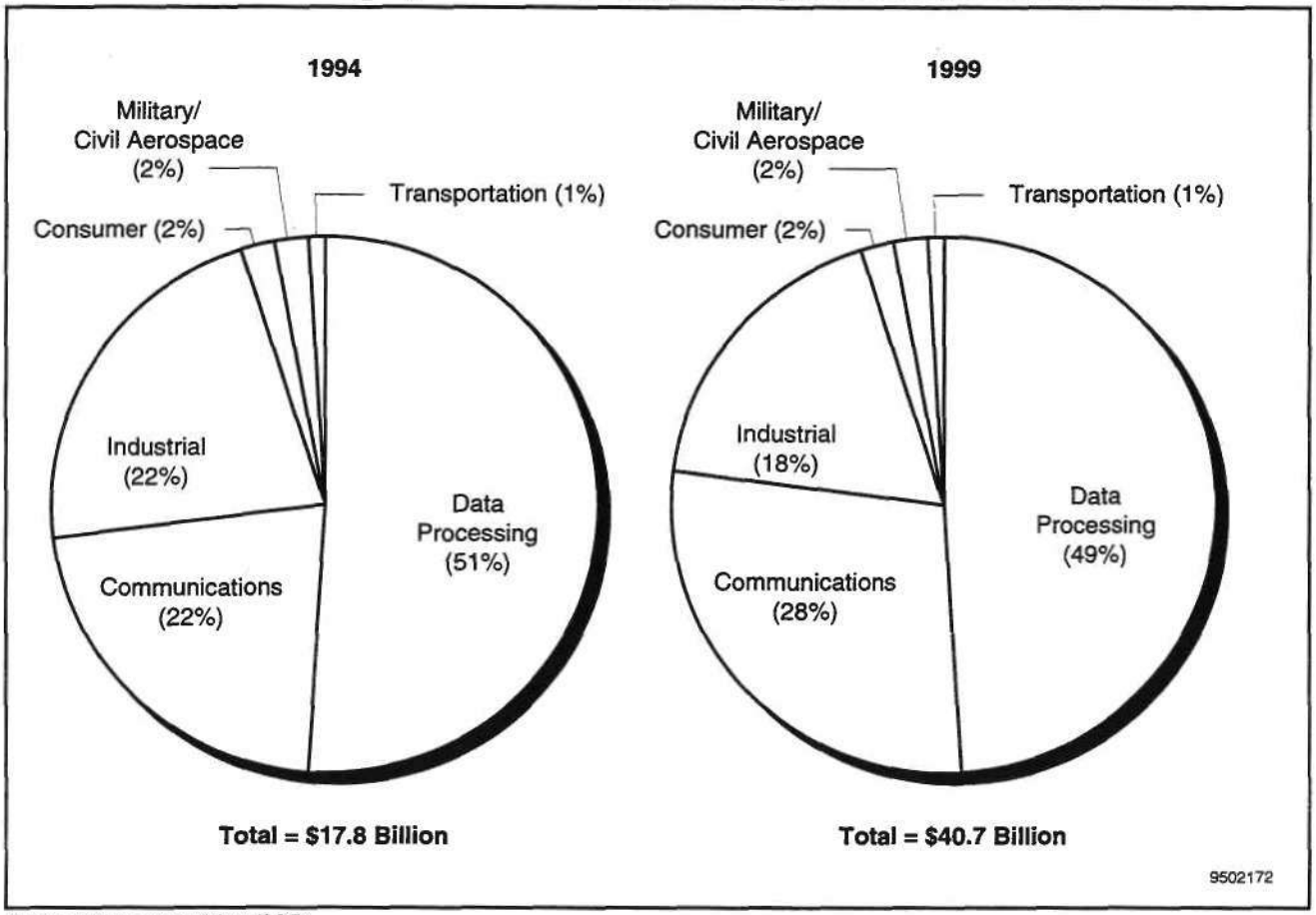
Dataquest forecasts that the electronic equipment production will sustain its current high growth of 18.6 percent in 1995, to $21 billion in revenue. We expect the communications sector to have the highest growth, with a 25 percent increase over 1994. The data processing sector could surpass the $10 billion mark this year, thereby sustaining its steady expansion.

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Figure 1
Taiwanese Electronic Equipment Production, Factory, Revenue, 1994 and 1999



Source: Dataquest (May 1995)

Dataquest believes that these three sectors will be the drivers of Taiwan's semiconductor markets during the next five years. In addition to long-term trends and forecast assumptions, this article focuses on immediate issues affecting growth in each sector in 1995.

Electronic Equipment Production Forecast

Dataquest's long-term electronic equipment production forecast by sector projects data processing to sustain the lion's share of production in Taiwan during the next five years (see Table 1 and Figure 2). We expect a compound annual growth rate (CAGR) of about 17.2 percent, which is slightly slower than the industry average of 18.0 percent. The main reason for this growth is the high growth in communications production, which we expect to have a 23.6 percent CAGR during the same period. Communication's share on a revenue basis will increase from 22 percent in 1994 to 28 percent in 1999. Communication will grow faster than any other sectors from 1995 to 1999. Its CAGR growth rate will be up to 23.6 percent for the next five years.

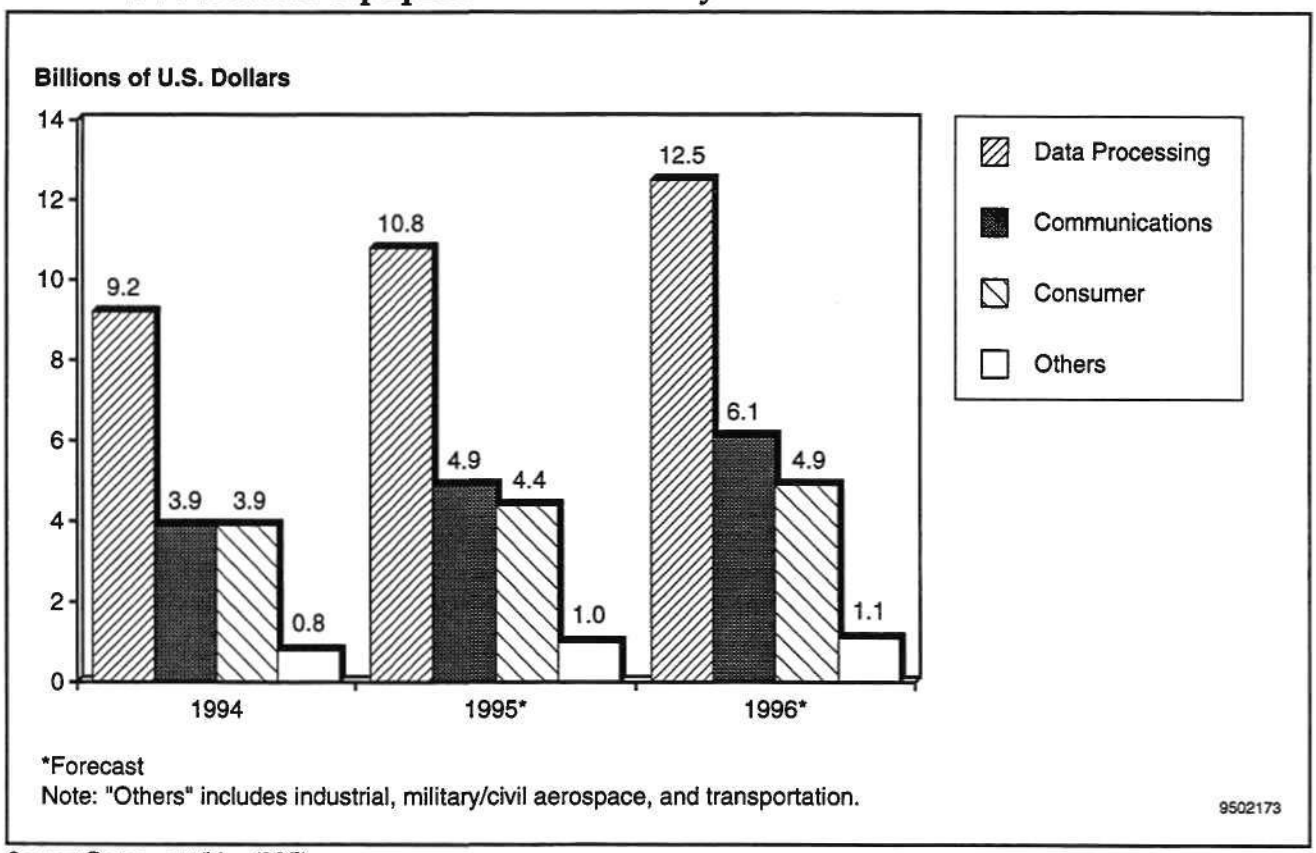
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Table 1
Taiwanese Electronic Equipment Production by Sector, Factory Revenue, 1994 to 1999 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994 to 1999
Data Processing	9,185	10,838	12,464	14,583	17,208	20,305	17.2
Communications	3,922	4,902	6,078	7,294	9,118	11,306	23.6
Consumer Electronics	3,854	4,394	4,921	5,659	6,508	7,419	14.0
Others	818	955	1,094	1,252	1,449	1,673	15.4
Total Equipment	17,779	21,089	24,557	28,788	34,283	40,703	18.0

Source: Dataquest (May 1995)

Figure 2
Taiwanese Electronic Equipment Production by Sector



Source: Dataquest (May 1995)

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Consumer electronics will continue to be the slowest-growing sector because of its production shift to China and Southeast Asia. However, certain products, such as color televisions, are still showing substantial growth.

Table 2 lists the high-volume electronic equipment products of Taiwan. These products represented 62 percent of Taiwan's total electronic equipment production output in 1994, so we have highlighted them. Monitors and personal computers alone account for 40 percent of total production.

Table 2
Taiwan's High-Volume Electronic Equipment Products, 1993 to 1994 (Millions of U.S. Dollars)

	1993	1994	1994 Percentage Share	1994 Percentage Growth	1994 Units (K)
Data Processing					
Personal Computer	3,646	4,094	35.7	12.3	5,591
Monitor	2,889	3,034	28.3	5.0	16,225
Motherboard	1,020	1,055	10.0	3.4	10,650
Graphic Cards	350	385	3.4	10.0	5,392
Image Scanner	258	257	2.5	-0.4	1,350
Calculator	147	130	1.4	-11.6	9,532
Keyboard	142	106	1.4	-25.4	9,200
Communication					
Total Radio/Broadcast	740	399	7.2	-46.1	8,810
LAN Card	260	299	2.5	15.0	8,530
Telephone	248	488	2.4	96.8	4,157
Modem	208	348	2.0	67.3	5,985
Facsimile	117	142	1.1	21.4	518
Consumer Electronics					
Color Television	200	257	2.0	28.5	1,861
Total	10,225	10,994	100.0	7.5	

Source: Dataquest (May 1995)

Data Processing—The Most Important Sector in Taiwan

After 15 years of development, the Taiwanese data processing sector became the most prosperous and promising sector in the Taiwanese economy in 1994. Data processing accounts for about 50 percent of total Taiwanese electronic equipment production. Three niche markets – PCs, monitors, and motherboards – dominate this sector, accounting for 90 percent of total data processing production. Table 3 summarizes the detailed statistics in the standard Dataquest applications groupings.

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Table 3
Taiwanese Data Processing Electronic Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Computers	4,256	5,088	19.5	18.3
Data Storage	659	860	30.5	26.9
Input/Output	3,099	3,456	11.5	12.1
Dedicated System	678	802	18.3	18.8
Other Data Processing	493	632	28.2	19.4
Total Data Processing	9,185	10,838	18.0	17.2

Source: Dataquest (May 1995)

Success factors for this sector in Taiwan include the following:

- Very qualified PC design and manufacturing skill: The main force behind Taiwan's computer industry growth now and in the future is its very high educational level and plentiful supply of engineers. The large number of engineers returning from graduate school or with industry employment is proving to be an increasingly critical weapon for Taiwanese manufacturers.
- A highly efficient and interdependent production system: One characteristic of Taiwanese industry is that there are many medium-size and small enterprises that are very flexible and quick to develop, manufacture, and market their products. Most companies within this unique production system (from top to bottom) can operate at an efficiency rate higher than that in most regions in the world. Furthermore, companies use close relationships to accomplish development of new products both in the trial-run and mass-production stages within a relatively shorter time frame. This is very helpful in making the companies competitive, especially in regard to shortening the life cycle of PC products.
- A very diverse and low-priced purchasing environment: As Taiwan has become a very important manufacturing base for the worldwide PC industry, all the component suppliers in the world have focused their selling on the Taiwanese market. Therefore, the PC manufacturers in Taiwan can get the best and most competitive prices through batch orders. Costs for PCs then can be reduced, making them more competitive in the market.

Although all these key success factors have contributed to the prosperity of the PC industry in Taiwan, there are some possible threats and downward pressures to the current high level of growth in Taiwan:

- Serious shortages of key components: There are serious shortages of key components that have lasted for more than one year, especially DRAMs. We do not expect these shortages to improve in 1995 and for most of 1996. Adding to the problem is that, since the beginning of 1995, shortages have spread to other areas, such as SRAMs, printed circuit boards, CRTs, LCDs, and even hard disk drives. This has seriously inhibited the delivery time of final product and stimulated price hikes across many key components.

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- Taiwanese NT dollar depreciation against the Japanese yen: The Japanese yen has appreciated more than 20 percent against the U.S. dollar since the beginning of this year, while the NT dollar has only appreciated less than 4 percent within the same period. That means about 17 percent depreciation of the NT dollar against the Japanese yen since the beginning of this year. Because various key components of this industry, such as DRAM, LCD, and CRT, are coming from Japan, appreciation of the yen will further increase the cost of PC production and inhibit Taiwan's global competitiveness.
- Factories moving offshore: PC companies have being moving their low-end assembly lines to Southeast Asia and China since about 1991, in search of lower production costs because of price erosion. Local companies have focused their attention on high-end product such as multimedia PCs, notebooks, high-resolution color monitors, and high-end peripherals. However, this could be seen as a positive factor because companies can gain market share in these rapidly developing markets and upgrade their local production to higher-value-added products.

Our analysis has shown that the Taiwanese government's role is increasingly limited in influencing these market forces. Similarly, the increase in local semiconductor supply will take one to two years to start to impact the local supply constraints. Although the industry is still growing within the international environment, it is also expanding rapidly in Asia/Pacific. This will be a counterbalance to the factors described. Therefore, Dataquest's overall forecast of 18.0 percent growth in 1995 is slightly slower than the 18.1 percent growth of 1994. Although this appears to be good news, this high level of growth is attributed substantially to higher production costs and currency appreciation.

Communications—The Most Potential Sector in Taiwan

Although revenue from data processing is generated from a few key products, the communications sector exhibits greater diversity. As Table 2 showed, the five largest product areas comprise about 40 percent of total communications equipment production.

Revenue in this sector in the past few years mainly was created by the CPE, fax, modem, and network card industries. Wireless communication will be the most promising industry for the sector. Taiwan is positioning itself to become an important global player in various communications sectors, including wireless. Dataquest forecasts this sector to grow the fastest among these six sectors in the next five years. The CAGR forecast is 23.6 percent, which is an increase in revenue from U.S.$3.9 billion in 1994 to $11.3 billion in 1999 (see Table 4).

Consumer Electronics—The Basic but Transforming Sector in Taiwan

The consumer electronics industry began more than 35 years ago in Taiwan. Asia/Pacific has become a major market for Taiwanese appliances, color televisions, video games, and electronic dictionaries. Although Taiwanese consumer electronic brands are not known globally, they are very popular in Taiwan and are increasingly common in China and Southeast Asia.

Table 5 provides the consumer electronic equipment forecast for Taiwan.

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Table 4
Taiwanese Communications Electronic Equipment Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Premise Telecom	1,653	2,033	23.0	22.8
Public Telecom	605	774	27.9	30.1
Mobile Communications	318	463	45.6	39.1
Broadcast and Studio	370	531	43.5	29.8
Other Communications	976	1,101	12.8	7.8
Total Communication	3,922	4,902	25.0	23.6

Source: Dataquest (May 1995)

Table 5
Taiwanese Consumer Electronic Equipment Production Forecast, Factory Revenue (Millions of U.S. Dollars)

	1994	1995	1994-1995 Growth (%)	1994-1999 CAGR (%)
Audio	1,357	1,520	12.0	12.6
Video	1,084	1,312	21.0	19.0
Personal Electronics	502	562	12.0	11.9
Appliances	586	674	15.0	12.9
Other Consumer	325	326	0.3	5.2
Total Consumer	3,854	4,394	14.0	14.0

Source: Dataquest (May 1995)

Dataquest Perspective

Dataquest believes that Taiwan will successfully increase its global position during the next five years primarily because of its competitiveness in the data processing and communications sectors. We believe that PCs and monitors will not wane as the most dominant industries in Taiwan. As Taiwan creates its own component supplier base, it can increase second-source supplies of key components, such as the much-coveted DRAMs.

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Market Forecasts

1995 Regional Outlook—Asia/Pacific Electronics

Abstract: *Asia/Pacific has seen strong economic growth and rapid development of its electronics industries over the last decade. Growth was led by the Four Tigers—Hong Kong, Singapore, South Korea, and Taiwan—followed by Indonesia, Malaysia, and Thailand. Dataquest believes that this region will continue to post healthy growth rates over the next few years as China and India come into the picture to provide both manufacturing muscle and consumer spending. The race is heating up for Asians to acquire luxury electronic goods and the "good life" that they believe their Western counterparts have been enjoying. This article presents an overview of the regional electronic equipment industry.*
By Eddy Tan, Reid Rasmussen, Noi Kwanjai, and Ben Lee (Singapore)

Overview

Table 1 shows the performance of selected Asian countries, based on estimated gross domestic product (GDP) and inflation rates for 1994, and projections for 1995. Asia/Pacific will continue to see strong economic growth, with investment coming from Japan, the United States, and Europe, and increasingly from Asia itself. As the richer Asian nations achieve higher per-capita income, their costs of manufacturing become uncompetitive for volume production. Companies in Hong Kong, South Korea, and Taiwan are joining their Japanese counterparts in investing in Southeast Asia and China. In terms of dollar value, the Taiwanese were the fourth-largest investor in Malaysia last year. Land-scarce Singapore has implemented its "globalization with a regional focus" concept by offering local and foreign investors the opportunity to coinvest in the region. Following the successful implementation of the Batam Island Industrial Park in Indonesia, Singapore has started developing other parks in China and India.

This article will highlight the development of several key industries in the region.

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Table 1
Estimated and Projected GDP and Inflation Figures in Asia/Pacific, 1994 and 1995 (Percent)

	1994 GDP	1995 GDP	1994 Inflation	1995 Inflation
Australia*	5.1	4.4	NA	NA
China	11.8	9.0 to 9.5	21.7	17.5 to 18.0
Hong Kong	5.8	5.5 to 6.0	8.1	8.5 to 9.0
India	6.4	5.5 to 6.0	10.4	7.5 to 8.0
Indonesia	7.1	7.5 to 8.0	8.4	8.5 to 9.0
Malaysia	8.9	8.5 to 9.0	3.9	4.0 to 4.5
Philippines	4.4	5.5 to 6.0	9.1	7.5 to 8.0
Singapore	10.3	8.0 to 8.6	3.7	3.0 to 3.5
South Korea	8.3	7.0 to 7.5	6.3	5.5 to 6.0
Taiwan	6.1	5.0 to 5.5	3.9	4.0 to 4.5
Thailand	8.4	8.0 to 8.5	4.9	4.0 to 4.5
Vietnam*	9.0	9.0	NA	NA

*Figures from Standard Chartered, Singapore
NA = Not available
Source: Asian Economic Commentary, February 1995

Disk Drives

Singapore is the world's top producer of rigid disk drives. Singapore last year generated 32.3 million units of drives worth $7.6 billion, commanding 46 percent of global output. Unit production swelled by 26 percent from 1993, when Singapore captured 40 percent of the world's output. The country's well-developed infrastructure, among other reasons, has continued to attract new investment. Adding to the growth in 1995 is the recent decision of IBM to set up a large-capacity disk drive plant in Singapore. The pioneer of magneto-resistive technology is investing $100 million to build its gigabyte-drive Singaporean manufacturing facility, which will be fully operational by April. IBM is also increasing production volume of low-end drives in Thailand while scaling down output in Fujisawa, Japan.

Dataquest expects Singapore to maintain her top ranking in the next few years for the following reasons:

- Seagate is building its $137 million, 1.2 million-square-foot complex. Called the largest electronics manufacturing facility in Singapore, the complex will increase Seagate's capacity by 25 percent after mid-1996.
- Micropolis, another gigabyte-drive leader, projects its $34 million plant—with completion expected middle of 1996—to double its present annual capacity to 1 million drives.
- Integral Peripherals, manufacturer of removable disk drives, is investing $75 million in a new manufacturing plant. It will increase its workforce fivefold to 500.
- SyQuest is investing $6.8 million to manufacture its new 1.8-inch drives and Singaporean-designed 5.25-inch cartridge.

Singapore's leading disk drive manufacturers are moving toward large-capacity drives—1GB and above. Seagate has started introducing its new gigabyte models featuring 4.1GB, 3.5-inch and 9.1GB, 5.25-inch drives.

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IBM, Seagate, and Quantum are expected to take the lead in the industry using their newfound weapon—magneto-resistive technology.

Malaysia has emerged as a medium-cost alternative. Its proximity to Singapore has allowed the country to absorb excess capacity from Singapore and elsewhere. All the disk drive manufacturers, together with Malaysia's major IC assembly and test operations, are on the island of Penang in the north of Malaysia:

- Seagate recently opened its fourth plant, at a cost of $22 million, in Perak, to manufacture drive components. Malaysia's largest disk drive manufacturer has three facilities in Penang. Seagate is also the largest disk drive manufacturer in Thailand.
- Quantum is expanding its factory to 450,000 square feet at a cost of $10 million. It assembles head gimbles and head stacks in Batam Island, Indonesia, and is considering setting up a second components plant on the Indonesian island.
- Western Digital spent $20 million converting its IC assembly operation to manufacture disk drives, as a supplement to the current 2.1 million quarterly output from Singapore. Capacity is said to be 500,000 units per quarter, and is targeted to hit 1 million units per quarter.
- Hewlett-Packard is moving its 1GB drive manufacturing from Bristol, United Kingdom, to Penang. Upon completing the fifth Malaysian building, HP Malaysia aims to produce half of the company's global output.

Personal Computers

Both Taiwan and Singapore are home to major American PC manufacturers—which are supported by local contract manufacturers—and foreign-based manufacturers, in the case of Singapore. These countries are moving away from the image of being cheap contract manufacturers to that of quality designers with a rapid design-to-manufacture cycle. Demand for PCs is rising in the region, thanks to price wars that have evolved PCs into consumer electronics items. Table 2 shows Dataquest's projections of PC consumption around the region. Although the total regional market is projected to grow at 23 percent, China is expected to experience the highest consumption growth rate, exceeding 50 percent.

Taiwan's forte lies in the manufacturing of PCs (both desktop and notebook computers), motherboards, monitors, and add-on cards. Low-end systems and components are usually relegated to Southeast Asia. Taiwan produced 2.4 million notebooks units in 1994, most under OEM contracts.

PC manufacturers in Singapore and Taiwan announced expansion plans to meet the region's rising consumption:

- Compaq, Singapore's largest PC manufacturer, recently received "Overseas Headquarters" status from the Singaporean government. It plans to double its capacity, where notebooks constitute 70 percent of the output.
- Apple is boosting capacity by 50 percent. It is freeing up space for manufacturing by moving its marketing and support services to a new $25 million building. Apple's local R&D team designed the LC 630 family—PCs with integrated TV tuners, CD-ROM drives, and video cards.

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Table 2
Asia/Pacific Total PC Consumption, Units

	1994	1995	Percentage Growth (1994 to 1995)
Korea	1,093,560	1,228,200	12
Australia	800,000	1,000,000	25
China	651,100	991,780	52
Taiwan	363,329	425,800	17
Indonesia	250,985	304,600	21
Hong Kong	219,310	261,680	19
Malaysia	199,312	228,500	15
Thailand	176,000	204,300	16
Singapore	91,310	95,100	4
Total	3,844,906	4,739,960	23

Source: Dataquest (February 1995)

- HP is building its $163 million complex to expand some of its manufacturing operations. HP Singapore is the center to design palmtop computers and mobile deskjet printers.
- Acer, Mitac, and Leo, among others, are ramping up production in Taiwan. Acer, one of the more popular brands in Southeast Asia, is assembling complete PCs in Indonesia and monitors in Malaysia. It plans to set up assembly operations in Thailand and Singapore.

Malaysia recently welcomed a major PC manufacturer. Dell will be establishing its third PC manufacturing facility in Penang, with an expected final monthly output of 100,000 units. One of the reasons Dell cited for locating in Penang is its proximity to Intel Penang.

Multimedia

Because of all the hype regarding multimedia, Singapore began producing CD-ROM in early 1994. Sound card manufacturers Creative Technology and Aztech, Wearnes and newcomer Optics Storage together churned out 1.2 million drives last year. Wearnes Singapore aspires to become a global manufacturer of CD-ROM. Aztech targets annual output of 3.5 million units in two years. It is setting up its CD-ROM drive facility in Malaysia, where the country is already a host to Sony, Likom, NEC, and Acer. These manufacturers are expected to increase their capacity to meet demand for the following reasons:

- Price erosion of CD-ROM (double-speed) drives, encouraging volume production
- Incorporation of CD-ROM drives into PCs, which offers quality image, storage capacity, and reliability. Dataquest projects that more than 50 percent of PC sales in Hong Kong and Taiwan will incorporate CD-ROM drives this year.
- Ease of interface with existing rigid disk drives' architecture.

Singapore's double-speed drive manufacturers have quickly migrated to quad-speed to maintain their profit margins and are investing research funds to design higher-speed drives.

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Foreign players are also participating in Southeast Asia's multimedia frenzy. Aiwa began producing CD-ROM key modules last year in Singapore, while Philips is expected to start manufacturing similar modules this year. Mitsubishi Chemical in Singapore plans to deliver Singapore's first recordable compact discs. The CD-ROM media industry will ride on the booming wave of multimedia. This year, four new local manufacturers—Datapulse, FAS Disc Manufacturing, Olivine, and Summit CD—will join Eastgate in manufacturing CD-ROM discs, while Malaysia is making way for a newcomer, Optical Disc.

Consumer Electronics

The consumer electronic industry in Asia/Pacific has long been dominated by the Japanese, which are still expanding their manufacturing capacity into Southeast Asia in a bid to escape the rising yen. Southeast Asia, particularly Malaysia with its "Look East" policy, has always appealed to the Japanese for its abundance of land, affordable skilled workforce, and demand for quality Japanese-brand products' attitude. Table 3 compares the manufacturing considerations in selected Asian countries.

Table 3
Investment Considerations for Five Selected Asian Countries

	Corporate Tax (%)	Labor Cost ($/Hour)	Industrial Land Cost ($/sq. m. per Year)
China	33	0.54	NA
Indonesia	30	0.28	42
Malaysia	30	1.80	97
Singapore	27	5.12	220
Thailand	30	0.71	71

NA = Not available
Source: DRI McGraw, Morgan Stanley Research, Jones Lang Wootton

Although the Japanese manufacturers are continuously thinking of relocation to beat operating costs, some companies have started setting up offshore design capabilities and manufacturing of other products:

- Kenwood, while moving its audio manufacturing to Malaysia, is transforming Singapore into its designer and manufacturer of telecommunications products.
- Audio products manufacturer Aiwa Singapore has started manufacturing fax modems, CD-ROM modules, and LAN disk arrays to support PC manufacturing in Japan. Aiwa's five plants in Malaysia manufacture 60 percent of the company's products worldwide.
- Philips Singapore is investing $26 million to double its CD-ROM drive modules output and to house its first offshore laser-optics plant.

Although Singapore is building its capabilities in manufacturing critical components such as wide-screen television panels and electron guns, most of the volume production is located in manufacturing bases with abundant labor.

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Malaysia is still a major consumer electronics equipment manufacturer. Almost all the Japanese manufacturers are represented in Malaysia, producing large volumes of stereo products, color televisions, videocassette recorders, and air conditioners, among other electronic products. Indonesia, a low-cost manufacturing base, will rise as a big consumer of electronics products, thanks to its 300 million population. Goldstar, already manufacturing air conditioners and washing machines through a joint venture with Astra, is investing $580 million in its third-largest manufacturing base in Indonesia. Thailand is the home to many independent color television manufacturers, in addition to some 10 major IC assemblers and two major disk drive manufacturers.

Dataquest Perspective

Asia/Pacific will continue to attract investments from American disk drive and PC manufacturers and Japanese consumer electronic equipment manufacturers. Asia/Pacific is also witnessing increasing levels of cross-regional cooperation led by cash-rich Asian nations. In a continuous attempt to evade rising operating costs, Japanese manufacturers such as Sony and Matsushita are using Southeast Asia as a launching pad to penetrate other opening markets, particularly India. Multinationals are also increasing their Asian operations' design responsibilities.

Dataquest is confident that Taiwan can maintain its position as the top notebook and OEM manufacturer in the region. Singapore will lead as the world's No. 1 disk drive producer, while building its multimedia capabilities. Malaysia, Thailand, and Indonesia's high GDP growth potential, abundant labor, and land will continue to offer manufacturing muscle in the consumer electronics products, particularly in the audio/video sector.

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Preliminary Market Look

Asia/Pacific 1994 January Market Share Report

Abstract: *On January 4, Dataquest released a Dataquest Alert containing our preliminary 1994 Asia/Pacific top 20 semiconductor supplier ranking. Our Alert summarized key market developments, and this newsletter further explains our numbers by providing a by-company analysis for the top 10 companies. Detailed product information will be published in March when the complete Asia/Pacific market share database is shipped to clients of our Asia/Pacific regional services.*

By Daniel Heyler (Hong Kong) and Eddy Tan (Singapore)

Asia/Pacific without Rest of World (ROW)

It should come as no surprise that we have discarded ROW from Asia/Pacific service coverage, because clients have had almost no interest in Latin America or the Middle East. In 1995 and hereafter, we will publish only Asia/Pacific and respective country information.

Although these ROW markets have in fact been growing, capturing these regions has remained difficult because they are too small to warrant separate coverage.

Dataquest is moving away from the concept of ROW as a catchall term. Instead, regional and country-level coverage are more essential to business planners. For example, eastern Europe and the Russian republics used to be included in ROW and now are tracked from our European offices. The bottom line is that we will continue to redefine regions and products to best reflect the current markets and, presumably, the needs of our clients.

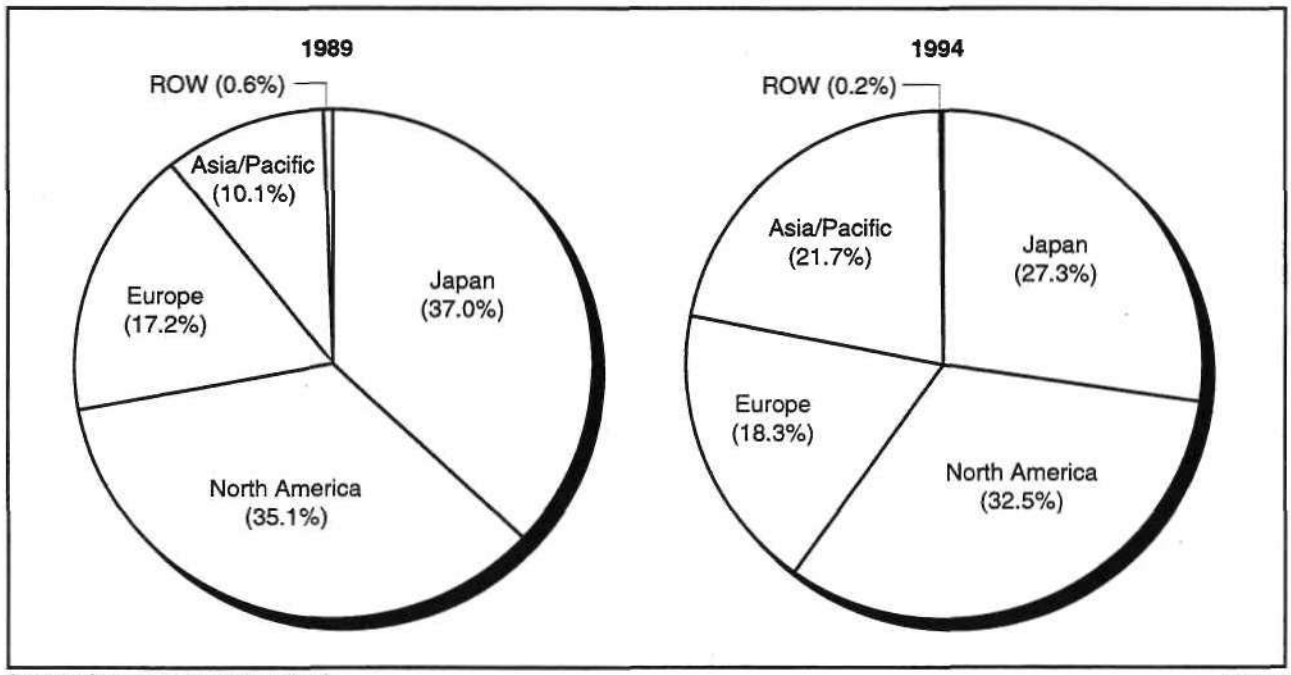
Figure 1 compares the worldwide market share survey results of 1989 and 1994. Both years show ROW as less than 1 percent of the worldwide market (numbers rounded to the nearest percentage). We have chosen to not report this as a separate region because of its small size, but the importance of Asia/Pacific warrants the exclusion of ROW.

Dataquest

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Figure 1
Worldwide Semiconductor Consumption by Region, 1989 and Preliminary 1994



Source: Dataquest (January 1995)

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Major Market Trends

The Asia/Pacific region, which was the high-growth region of the 1980s, is proving to be the market of the 1990s. Asia/Pacific had a little more than half of Japan's total semiconductor consumption in 1992 (see Figure 2). But the two are nearly equal when 1994 revenue is compared with Japan's 1993 revenue. That means that Asia/Pacific is now within one year of surpassing the Japanese market in terms of semiconductor consumption.

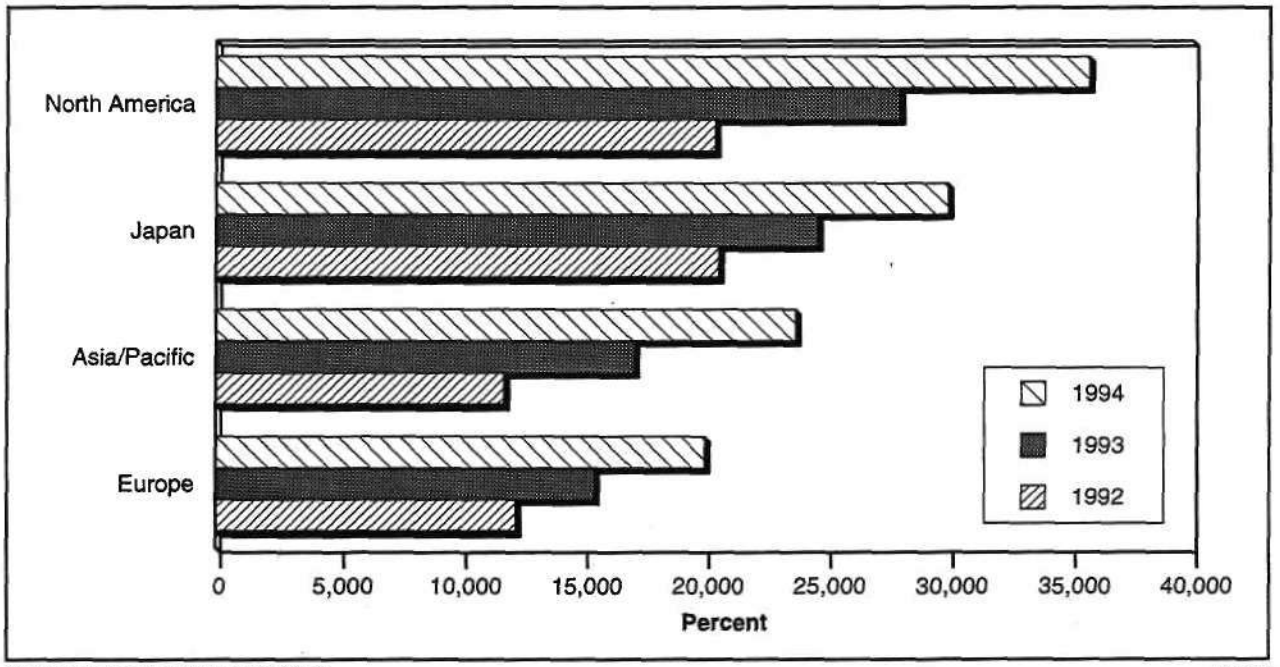
Although PCs are the most important market driver of 1994, a plethora of consumer and communications applications contributed to the region's rapid growth. This section discusses some of the key products and applications in 1994.

The relentless migration to higher-performance PCs by demanding users was catalyzed by aggressive system pricing. Although PC and disk-drive companies suffered at the bottom line (although the number of units shipped accelerated), semiconductor companies were the benefactors in the PC-oriented Asia/Pacific.

The twin evils of DRAM supply constraints and PC demand acceleration aggravated PC companies but propped prices for about two quarters beyond our previous year's forecast. Cache SRAMs were in short supply later in the year, further frustrating PC exporters. The lack of key components resulted in further consolidation of the PC industry. DRAM-dependent Taiwanese PC companies are facing the same frenzy experienced in the late 1980s, which resulted in the Texas Instruments (TI)-Acer joint venture. PowerChip, Vanguard, Nan Ya, MOSel/Vitelic, and TSMC (foundry)

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Figure 2
Worldwide Semiconductor Consumption by Region, 1992 to Preliminary 1994



Source: Dataquest (January 1995)

9500554

have jointed TI-Acer in producing DRAMs locally. Japanese companies, short of capital and weary of overbuilding, are transferring technology to Taiwanese semiconductor companies. These moves by Oki, Toshiba, Mitsubishi, and others help Japan temper Taiwan's long-standing complaints about Japan's huge DRAM imports and its trade surplus.

As we have mentioned during the past two years, microprocessor demand is increasingly driven by local consumption of PCs in Asia/Pacific. The movement to modularized PCs in both desktop and, more recently, notebook form is enabling PC companies to purchase their CPUs at the last possible moment in order to obtain the best price or volume discounts (the difference between profit and loss in the cutthroat PC industry). Furthermore, PC exporters to the United States can reduce tariff costs by 3.9 percent by shipping a motherboard without its microprocessor (0 percent tariff with a microprocessor and 3.9 percent with it). As for exports to Europe, the tariff margin is negligible, so the issue is related more to inventory costs, delivery time, and pricing.

The greatest long-term microprocessor opportunities lie in the markets beginning to consume PCs in Asia/Pacific. In particular, Pentium system demand in Korea, Taiwan, and Australia further contributed to Intel's impressive 6.6 percent market share. These countries' PC trends lagged worldwide product trends by about two quarters, but the lag time is decreasing to one quarter in 1995. Consistent with Advanced Micro Devices (AMD) and Intel is the view from PC companies that positioned their Asia/Pacific facilities to prepare for Asia/Pacific systems demand.

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But production expansion by these six DRAM producers did not alone account for a strong microprocessor market. The increased reliance on subcontract manufacturing within Asia/Pacific contributed to the high PC production and CPU consumption within the region. We have referred to this trend several times, and nowhere is it more important than in PCs, where we see increased original equipment manufacturer/original design manufacturing (OEM/ODM) activity in Taiwan.

The thirst for enhanced computing power is felt even in mainland China. By the middle of 1994, China's interest in 386-based machines began to die and the fourth quarter saw a surge in 486DX2 demand. However, official statistics in China show that sales in Indonesia and Malaysia are much higher than in China, but most companies, including Intel, admit that the "gray market" in China/Hong Kong is "very active." At the same time, we see Taiwanese motherboards being built in China with the help of Hong Kong systems integrators. Some motherboards are exported (with CPU), and others are sold within Asia/Pacific.

We expect downward growth pressure in the latter half of 1995 for microprocessors. The main reason is Intel's worldwide pricing strategy for CPUs. Although we saw $400 prices for DXs in the beginning of 1994, Pentiums will be less than $300 during the first quarter, according to Intel. Intel's goal is to make the 486 obsolete as quickly as possible. Another factor negatively affecting CPU growth is the fact that notebook computers are increasingly shipped in modular kit form and will suffer the same fate as desktops. The surge in notebook production and export in Asia/Pacific will not be directly translated into high CPU growth because some exporters will wait to buy the CPU in Europe, North America, or Japan.

Malaysia: Asia/Pacific's Fastest-Growing Market

More than 20 years of hard selling to foreign investors has earned Malaysia the reputation of amassing a significant number of major manufacturing facilities in the region. This is particularly true in the area of consumer electronic equipment, which is dominated by the Japanese. The consumer equipment industry seemed to have defied the last fourth-quarter and possible first-quarter slowdown. Production shifts from Japan, mostly in consumer electronics equipment, have been cited as the major suspect in supporting semiconductor revenue growth in Malaysia. Semiconductor components that benefited from the shift include (mostly low-end) audio and video ICs and analogs, and to some extent, microcontrollers. Some chip manufacturers are concerned about whether they can even cope with supply for 1995.

Among other Japanese manufacturers, Aiwa and Pioneer plan to move a portion of their capacity to Malaysia. In Singapore, Mitsubishi Electronics Manufacturing is relocating its car audio operation to Malaysia because of a tight labor situation and escalating manufacturing costs. The company has also cited another motive—improved access to the southeast Asian market under the Brand-to-Brand Complementation Scheme, an incentive that halves tariffs on automobile parts traded among members. Singapore is not part of that scheme.

Concerns over the expiration of Malaysia's Generalized System of (trade) Preferences (GSP) status have also been flying around. A natural reaction for equipment manufacturers is to consider greener pastures in the region. Even without the GSP extension, Malaysia will still sell well because of its

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low production costs, good supporting infrastructure, and capable and English-speaking labor. Many manufacturers are already wary of Malaysia's continuing shortage of manpower and rising production costs relative to other opening markets in the region. Matsushita, which has been a partner with Indian consumer electronics company Videocon Group, is now studying the possibility of using Malaysia as a launching pad to produce additional air-conditioning units in India.

Malaysia could expect a fairly bullish first half in 1995 and may show slowdowns in the second half. (This service will publish a Focus Report on Malaysia's emerging semiconductor market and electronic equipment industry in August 1995.)

Company Performances: Top 10 in 1994

Companies whose market share did not increase should not be dismayed, unless they are in the DRAM business -- wait until our product-level information is released in March to compare. North American companies lost market share to the three other regions, which is a reversal of 1993 trends. DRAM demand was the single most important revenue driver among the region's leading suppliers. As shown in Table 1, every major DRAM supplier in Asia/Pacific exhibited more than 40 percent growth in 1994. Hyundai was the biggest winner. Because of its aggressive surge in DRAM sales, Hyundai's total revenue increased 123 percent to $721 million, and it climbed four positions to No. 12 in the region. The top DRAM suppliers concur that their two biggest surprises were the volume of demand for 4Mb parts during the first three quarters and the unexpected surge in low-voltage, wide-bit 16Mb DRAM demand starting in the third quarter. Toshiba was able to sustain its leadership in the region, not only because of its DRAM business but also because of its substantial discrete sales.

No 1: Toshiba

Toshiba topped the Asia/Pacific semiconductor suppliers club with great success in the areas of consumers (audio/video ICs) and data processing (memory). It experienced healthy growth in the southeast Asia region as a whole. Toshiba's "vertical business" or direct marketing has worked out well, giving the semiconductor giant a good sense of local demands. Toshiba already has an ongoing joint venture with a leading Chinese manufacturer, Huajin Electronics Group, in Wuxi, China. This signals the company's optimism about another successful year and confidence in other emerging markets such as China and Vietnam.

No 2: Samsung

Singapore turns out to be an important revenue generator for Samsung, with Apple, Compaq, Digital Equipment Corporation, and Hewlett-Packard as the major accounts. Its 4Mb and 16Mb DRAM products occupied a majority of the revenue pie. The higher-capacity memory was introduced only in mid-1994. Samsung plans to aggressively market its microcontrollers, particularly ASIC (with minimal contribution compared to memories), which grew 50 percent last year. Unlike the other companies, Samsung has not felt the "boom effect" from Malaysia. We expect Samsung to deliver yet another impressive performance in 1995.

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Table 1
Preliminary 1994 Asia/Pacific Market Share Ranking, Total Semiconductor, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank	1992 Rank	Company	1992 Revenue	1993 Revenue	1994* Revenue	Percentage Change	1994 Market Share (%)	Cumulative Market Share (%)
1	1	1	Toshiba	982	1,324	1,944	47	8.2	8.2
2	2	2	Samsung	821	1,188	1,706	44	7.2	15.4
3	4	4	Intel	856	1,170	1,566	34	6.6	21.9
4	3	3	Motorola	819	1,188	1,301	10	5.5	27.4
5	6	6	Hitachi	491	747	1,106	48	4.7	32.1
6	8	8	Texas Instruments	446	696	1,095	57	4.6	36.7
7	7	7	NEC	471	713	1,063	49	4.5	41.1
8	5	5	Sanyo	436	749	994	33	4.2	45.3
9	9	9	Goldstar	312	590	847	44	3.6	48.9
10	10	10	Mitsubishi	370	529	762	44	3.2	52.1
11	11	11	Philips	424	517	761	47	3.2	55.3
12	16	16	Hyundai	248	323	721	123	3.0	58.3
13	14	14	Matsushita	236	424	589	39	2.5	60.8
14	13	13	SGS-Thomson	303	435	564	30	2.4	63.2
15	19	19	Sony	236	305	507	66	2.1	65.3
16	12	12	National Semiconductor	392	502	491	-2	2.1	67.4
17	17	17	Advanced Micro Devices	361	314	459	46	1.9	69.3
18	20	20	Fujitsu	221	270	431	60	1.8	71.1
19	18	18	Sharp	164	306	422	38	1.8	72.9
20	15	NA	IBM	NA	333	420	26	1.8	74.6
			All Others	3,155	4,472	6,029	35	25.4	100.0
			North American Companies	4,440	6,335	8,042	27	33.8	
			Japanese Companies	4,151	6,291	9,153	45	38.5	
			European Companies	1,028	1,377	1,938	41	8.2	
			Asia/Pacific Companies	2,125	3,092	4,645	50	19.5	
			Total Market	11,744	17,095	23,778	39	100.0	

*Preliminary
NA = Not available
Source: Dataquest (January 1995)

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No 3: Intel

Intel moved from a ranking of No. 4 in 1993 to No. 3 in 1994 and increased revenue by 34 percent to $1.6 billion. Microprocessor sales revenue, the lion's share of Intel Asia/Pacific business, accelerated during the second half of 1994 primarily because of increased DX2 demand and the higher average selling prices (ASPs) associated with this part. Singapore is Intel's largest microprocessor market because of major accounts such as Digital, Compaq, and HP. Other major accounts outside of Singapore include AST, AT&T, and Acer, which further accelerated their Asia/Pacific market presence. The surge in CD-ROM production and increasing use of flash caused this market to expand dramatically in 1994.

No 4: Motorola

Ranking fourth is Motorola, which met with success in the communications and consumer markets. However, Motorola's microprocessor business in Asia/Pacific suffered more than anyone's, as Apple Computer downsized its Singapore plant and shifted production back to North America. Motorola faced further semiconductor sales constraints because of production bottlenecks in its pager and mobile handset manufacturing in Asia/Pacific. The company's revenue was limited by not-too-strong sales in the data communications market. Motorola expects to perform better this year, with a projected growth rate of 30 percent (compared with the modest 10 percent rate posted in 1994).

No 5: Hitachi

Hitachi has continuously outperformed the market, and in 1994 it joined the ranks of the top five Asia/Pacific semiconductor suppliers. As for most DRAM suppliers, sustained 4Mb DRAM prices were good news, but what came as a surprise was the surge in 16Mb DRAM wide-bit, low-voltage demand, driven by notebook production. Hitachi's continued success in the DRAM business enabled its 48 percent revenue growth, but other areas proved successful as well. Singapore remains Hitachi's largest market in Asia/Pacific, but Malaysia and China showed rapid growth. Southeast Asia's Japanese consumer electronics and communications equipment markets were particularly active for Hitachi's 4-bit and 16-bit microcontrollers and there were shortages for certain products.

While a number of companies exited the diode market, Hitachi gained market share primarily because of increased activity from Japanese television and radio tuner manufacturers.

No 6: Texas Instruments

Texas Instruments was the fastest-growing company among the top 10 in Asia/Pacific. It leaped from a rank of No. 8 in 1993 to No. 6 in 1994. TI benefited from an increased supply of DRAMs from its joint ventures in Singapore (TECH) and Hsinchu (TI-Acer). The company was well positioned to service its major DRAM accounts within the region. But TI's breadth in PC products positions it ideally for Taiwan, which became the company's new Asia/Pacific headquarters (moved from Hong Kong). Furthermore, strong telecommunications demand enabled substantial growth in mixed-signal products.

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No 7: NEC

NEC has sustained its No. 7 position for the past three years. Like Sanyo, NEC saw explosive growth rates in the southeast Asian markets: 170 percent from 1992 to 1993, and 150 percent from 1993 to 1994. Hot products such as microcontrollers (more than 200 percent growth) and DRAM (more than 150 percent growth) made 1994 a memorable year for NEC. Again, consumers and data processing markets are supporting healthy sales in the region. NEC expects its revenue to grow a minimum of 130 percent in 1995.

No 8: Sanyo

After a strong 1993, Sanyo dropped three positions from No. 5 to No. 8 in the region. However, Sanyo's sales in southeast Asia grew twofold, thanks to strong demand in consumer products and production shift from Japan to the southeast Asia region. Semiconductor devices that enjoyed healthy growth included audio/video ICs. One of the top consumer manufacturers in the southeast Asia region, Sanyo expects to maintain its growth rate throughout 1995. The company expects to run into problems coping with demand.

No 9: Goldstar

Goldstar has sustained its No. 9 position in Asia/Pacific for the past three years. Sales growth matched Samsung's at 44 percent, but revenue was less than half of its Korean rival. Similar to Samsung, Goldstar focused on its large customers in North America, which enabled Hyundai to grab market share in Asia/Pacific. Hyundai jumped from a rank of No. 16 to No. 12 in 1994 because of its phenomenal revenue growth of 123 percent. If Hyundai is able to sustain this momentum in Asia/Pacific, it could surpass Goldstar and move into the top nine.

No: 10 Mitsubishi

Mitsubishi clinched the No. 10 position in Asia/Pacific because of success in controllers and gate arrays and to a lesser extent in 16Mb memories. Its Singapore market grew by 50 percent. The Taiwanese market would have experienced similar growth if not for DRAM constraints that kept the growth rate to about 20 percent. Mitsubishi's Malaysian market performed well in the areas of microcontrollers and linear ICs. Through Hong Kong, Mitsubishi plans to set up a stronger foothold in China, which the company expects to become a major market in five years. The company is upbeat concerning its overall performance for 1995, but it expects a slowdown in DRAM growth (20 percent) because of 1x16Mb constraints.

Asia/Pacific Companies Surpass Europe

As shown in Table 2, Korean DRAM manufacturers represent the largest share of Asia/Pacific's worldwide shipments. Because Dataquest does not count foundry and OEM business performed, Taiwan's total production is substantially higher than its shipments. Nevertheless, Taiwan's worldwide shipment revenue increased 38.7 percent to $1.5 billion, which represented 1.41 percent of the worldwide market. Korea semiconductor manufacturers expanded 69.7 percent to almost $8.6 billion, which represented 7.81 percent of the worldwide market. Combined Taiwanese and Korean shipments of $10.1 billion surpassed all European shipments ($9.8 billion) for the first time (see Table 3).

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Table 2
Preliminary 1994 Asia/Pacific Companies' Worldwide Market Share Ranking, Total Semiconductor, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank	1992 Rank	Company	1992 Revenue	1993 Revenue	1994* Revenue	Percentage Change	Percentage Share of World (%)
1	1	1	Samsung	1,900	3,044	4,893	60.7	4.46
2	2	2	Goldstar	642	946	1,797	90.0	1.64
3	3	3	Hyundai	556	853	1,621	90.0	1.48
4	4	4	United Microelectronics	198	309	399	29.1	0.36
5	7	6	Winbond Electronics	117	184	308	67.4	0.28
6	5	5	MOSel/Vitelic	161	223	269	20.6	0.25
7	6	7	Korean Electronic Co.	148	177	225	27.1	0.21
8	9	9	Macronix	69	144	221	53.5	0.20
9	8	8	Hualon Microelectronics Corporation	75	83	113	36.1	0.10
10	10	10	Silicon Integrated Systems	40	71	99	39.4	0.09
11	11	NM	Holtek	NM	53	70	32.1	0.06
12	12	NM	Acer Labs	NM	50	70	40.0	0.06
13	11	11	Daewoo	24	31	38	22.6	0.03
			Korean Companies	3,270	5,051	8,574	69.7	7.81
			Taiwanese Companies	660	1,117	1,549	38.7	1.41
			Asia/Pacific Companies		6,168	10,123	64.1	9.23

*Preliminary
NM = Not meaningful
Source: Dataquest (January 1995)

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Asia/Pacific companies have more than doubled their share of the worldwide semiconductor market since 1990. Japanese and European companies' shares of worldwide revenue have decreased, while North American and Asia/Pacific companies' shares have increased. Asia/Pacific has been viewed primarily as an importer of key components, but the breakneck investments in manufacturing have made it a major global supplier (see Table 4).

Table 5 contains the exchange rates for the major Asia/Pacific markets used in this 1994 market share survey.

Table 3
Preliminary 1994 Worldwide Semiconductor Market Share Estimates by Regional Supplier (Billions of U.S. Dollars)

	1993 Revenue	1993-1994 Growth (%)	1994 Revenue	1994 Market Share (%)
North American Companies	37.1	22	45.4	41.4
Japanese Companies	34.6	28	44.4	40.5
Asia/Pacific Companies	6.2	63	10.1	9.2
European Companies	7.7	27	9.8	8.9
Total Revenue	85.6	28	109.7	100

Source: Dataquest (January 1995)

Table 4
Preliminary 1994 Worldwide Semiconductor Market Share by Region (Percentage of Worldwide Revenue)

Year	North American Companies	Japanese Companies	Asia/Pacific Companies	European Companies
1990	38.6	46.3	3.9	11.2
1991	38.4	46.4	4.6	10.6
1992	41.5	42.3	6.0	10.2
1993	43.4	40.4	7.2	9.0
1994	41.4	40.5	9.2	8.9

Source: Dataquest (January 1995)

Table 5
Asia/Pacific Preliminary 1994 Average Exchange Rates by Country, Foreign Currency per U.S. Dollar

Country	Annual Average 1994	U.S. Dollar Appreciation 1994 (%)
China (Renminbi)	8.54	48.28
Hong Kong (Dollar)	7.73	-0.10
India (Rupee)	31.15	1.00
Malaysia (Ringgit)	2.50	-3.04
Singapore (Dollar)	1.53	-5.54
South Korea (Won)	802.84	0.42
Taiwan (Dollar)	26.45	1.13
Thailand (Baht)	25.36	0.19

Source: The Dun & Bradstreet Corporation

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Dataquest Perspective

The 1994 Asia/Pacific semiconductor market reached a remarkable $23.8 billion in revenue for the year and increased its share of worldwide consumption to an unprecedented 22 percent, according to Dataquest's preliminary 1994 worldwide semiconductor market share results. The market outpaced the world market, which expanded by 28 percent.

Asia/Pacific's exceptional semiconductor market performance in 1994 is attributed to the accelerated evolution of its world-class computer and peripherals industries, the rapid emergence of communications markets, and a continuous increase in foreign expansion and investments in local manufacturing, especially among the Japanese consumer electronics manufacturers.

Asia/Pacific companies benefited from the region's growth but also made gains in foreign markets, which was most evident among the Korean DRAM manufacturers. Consequently, total worldwide revenue for Asia/Pacific companies led all regions with a 63 percent growth rate and surpassed European suppliers for the first time.

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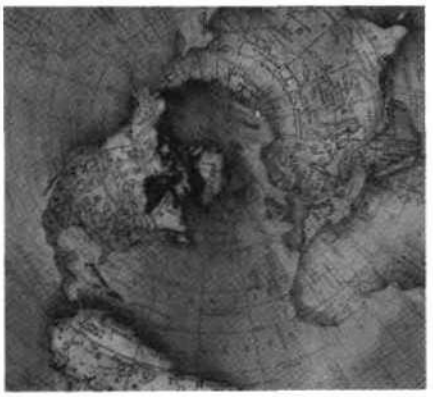
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Final 1994 Asia/Pacific Semiconductor Market Share

Market Statistics

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Final 1994 Asia/Pacific Semiconductor Market Share



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Note: All tables show estimated data.

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Chapter 1
Final 1994 Asia/Pacific Semiconductor Market Share

Introduction

This document contains detailed information on Dataquest's view of the semiconductor market. Included in this document are the following:

- 1992-1994 market share estimates
- 1993-1994 market share rankings

Analyses of market share by company provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Asian market share estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market consumption or revenue are based on the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in other Dataquest documents.

Segmentation

This section outlines the market segments that are specific to this document. Dataquest's objective is to provide data along lines of segmentation that is logical, appropriate to the industry in question, and immediately useful to clients.

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optoelectronic devices.

For market share purposes, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

Total Semiconductor (Including Hybrids)

Total Semiconductor (Excluding Hybrids)

Total Integrated Circuit (Including Hybrids)

Total Integrated Circuit (Excluding Hybrids)

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Bipolar Digital IC

Bipolar Memory

Bipolar Logic

MOS Digital IC

MOS Memory

MOS Microcomponent

MOS Logic

Monolithic Analog IC

Hybrid IC

Discrete Semiconductor

Optoelectronic Semiconductor

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. For a complete listing of all semiconductor market segments tracked by Dataquest, please refer to the Dataquest *Semiconductor Market Definitions* guide.

Product Definitions

Total Semiconductor (Total Integrated Circuit + Total Discrete + Total Optoelectronic). Defined as an active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components, such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Integrated Circuit (Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Analog IC). An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die.

Bipolar Digital IC (Bipolar Digital Memory + Bipolar Digital Microcomponent + Bipolar Digital Logic). A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

Bipolar Digital Memory. Defined as a bipolar digital semiconductor product in which binary data is stored and electronically retrieved.

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Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. Not included are products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.

Bipolar Digital Logic (Bipolar Application-Specific IC + Bipolar Digital Standard Logic + Other Bipolar Logic). Defined as a bipolar digital semiconductor product in which more than 50 percent of the die area performs logic functions. Excludes bipolar digital microcomponent ICs.

MOS Digital IC (MOS Digital Memory + MOS Digital Microcomponent + MOS Digital Logic). Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, where any portion of the die area is manufactured using metal oxide semiconductor (MOS) technology. A digital function is one in which data carrying signals vary in discrete values. Includes mixed technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

MOS Digital Memory (DRAM + SRAM + EPROM + EEPROM + Flash Memory + Mask ROM + Other MOS Digital Memory). Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS Digital Microcomponent IC (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral + Programmable Digital Signal Processor). Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit.

MOS Digital Logic IC (MOS Digital Logic Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic IC). Defined as an MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Total Analog IC (Amplifier/Comparator IC + Voltage Regulator/Reference IC + Data Converter/Switch/Multiplexer IC + Interface IC + Telecom IC + Disk Drive IC + Other Special Function IC + Linear Array/ASIC + Mixed-Signal ASIC + Total Special Consumer IC + Special Automotive IC + Smart Power IC). An analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes only monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package.

Hybrid Integrated Circuit. Defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions described in the following categories.

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Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Discrete (Transistor + Diode + Thyristor + Other Discrete). A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total Optoelectronic (LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optoelectronic). Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Merchant versus Captive Consumption. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

Regional Definitions

North America: Includes Canada, Mexico, and the United States.

Japan: Japan is the only single-country region.

Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belarus, Russian Federation, Ukraine, Georgia, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, and Turkenistan).

Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The rest of Asia/Pacific region includes Australia, Brunei, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor that sells the product to a distributor or equipment manufacturer.

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Market Share Methodology

Dataquest utilizes both primary and secondary sources to produce market statistics data. In the fourth quarter of each year, Dataquest surveys all major participants within each industry. Selected companies are resurveyed during the first quarter of the following year to verify final annual results. This primary research is supplemented with additional primary research and secondary research to verify market size, shipment totals, and pricing information. Sources of data utilized by Dataquest include the following:

- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other sources.

Notes on Market Share

In the process of conducting data collection and preparing market statistics information, Dataquest will sometimes consolidate or revise a particular company, model, series, or industry's numbers. In this section, we explain any such changes contained within this document for your reference.

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Notes to Market Share Tables

1. Analog Devices' revenue includes Precision Monolithics' revenue from 1991 forward.

2. Cirrus Logic's revenue includes Acumos and Crystal Semiconductor's revenue from 1992 forward.

3. Cypress Semiconductor acquired the logic division of Performance Semiconductor in 1993.

4. Dialog, Eurosil, Matra, Telefunken, and Siliconix are now known as TEMIC.

5. Fujitsu acquired Ross Semiconductor from Cypress Semiconductor in 1993.

6. IBM's merchant revenue was included in our Market Statistics beginning in 1993, which was the first complete year that IBM sold product on the merchant market.

7. IMP was formerly known as International Microelectronic Products.

8. Inmos' revenue is included in SGS-Thomson revenue.

9. Linfinity was formerly known as Silicon General.

10. Macronix's revenue, beginning in 1991, was moved from the North American Companies area and is now included under the Asia/Pacific Companies section.

11. Mitsubishi's revenue includes Powerex's European revenue beginning in 1993.

12. MOSel and Vitelic merged in 1992 to form MOSel/Vitelic Corporation. In 1993, MOSel/Vitelic was moved to the Asia/Pacific-Rest of World region.

13. Nittetsu Semiconductor was formerly known as NMB Semiconductor.

14. Philips' revenue includes Signetics' revenue.

15. SGS-Thomson's revenue includes TAG in 1993.

16. Quality Technologies acquired Philips' Optocoupler Division in 1992.

17. Raytheon's revenue includes that of TRW's LSI Division from 1992 forward.

18. Thomson Semiconductors Specific (TCS) was formed through the merger of Thomson Composants Microndes (TCM) and Thomson Composants Militaires et Spatiaux (TMS).

19. Unitrode's revenue includes that of Microsemi's Semiconductor Products Division from 1992 forward.

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20. Vertex's (formerly known as Integrated CMOS Systems) revenue is included in Toshiba revenue from 1991 forward.

21. Xilinx acquired Plus Logic in 1992.

22. The following companies were added to Worldwide market share tables starting in 1994, and may result in higher 1994 market growth rates in certain product areas:

- Integrated Silicon Solution Inc.
- Ramtron
- Quick Logic
- International CMOS Technology

23. In 1994, three-fourths of Intel's PLD Division's revenue was included in Intel's revenue, and the last quarter's revenue was included in Altera's revenue to accurately reflect the sale of the PLD Division.

24. Telcom was formerly known as Teledyne Semiconductor.

25. National Semiconductor, SGS-Thomson, and Siemens' revenue for 1993 was re-evaluated and restated.

26. Tektronix's revenue is now included with Maxim's revenue.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1992 through 1994.

Table 1
Exchange Rates

	1992	1993	1994
Japan (Yen/U.S.$)	126.45	111.20	101.81
France (Franc/U.S.$)	5.27	5.67	5.54
Germany (Deutsche Mark/U.S.$)	1.56	1.66	1.62
United Kingdom (U.S.$/Pound Sterling)	1.77	1.50	1.53

Source: Dataquest (March 1995)

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Section 1: Final 1994 Asia/Pacific Semiconductor Market Share

Table 1-1
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	11,744	17,121	22,583	100.0	100.0	100.0
North American Companies	4,440	6,356	7,903	37.8	37.1	35.0
ACC Microelectronics	19	28	35	0.2	0.2	0.2
Actel	3	5	6	0	0	0
Adaptec	24	41	36	0.2	0.2	0.2
Advanced Micro Devices	361	314	445	3.1	1.8	2.0
Allegro MicroSystems	19	19	21	0.2	0.1	0.1
Alliance Semiconductor	0	23	35	0	0.1	0.2
Altera	6	9	13	0.1	0.1	0.1
Analog Devices	35	76	102	0.3	0.4	0.5
Appian Technologyology	2	1	1	0	0	0
Applied Micro Circuits Corporation	0	0	4	0	0	0
AT&T	15	43	148	0.1	0.3	0.7
Atmel	23	39	59	0.2	0.2	0.3
Brooktree	7	8	15	0.1	0	0.1
Burr-Brown	5	5	6	0	0	0
California Micro Devices	2	7	4	0	0	0
Catalyst	4	5	10	0	0	0
Cherry Semiconductor	6	6	7	0.1	0	0
Chips & Technologies	58	44	46	0.5	0.3	0.2
Cirrus Logic	94	187	249	0.8	1.1	1.1
Cypress Semiconductor	10	10	23	0.1	0.1	0.1
Cyrix	21	25	40	0.2	0.1	0.2
Dallas Semiconductor	16	11	47	0.1	0.1	0.2
DSP Semiconductor	0	0	15	0	0	0.1
ETEQ Microsystems	12	12	1	0.1	0.1	0
Exar	16	19	18	0.1	0.1	0.1
General Instrument	71	82	88	0.6	0.5	0.4
Gennum	2	2	2	0	0	0
Gould AMI	5	6	19	0	0	0.1
Harris	59	75	61	0.5	0.4	0.3
Hewlett-Packard	39	45	65	0.3	0.3	0.3
IBM	NA	333	330	0	1.9	1.5
IMI	0	0	1	0	0	0

(Continued)

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Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Integrated Circuit Systems	10	12	41	0.1	0.1	0.2
Integrated Device Technology	19	30	20	0.2	0.2	0.1
Integrated Information Technology	8	10	8	0.1	0.1	0
Integrated Silicon Solution	NA	NA	26	0	0	0.1
Intel	856	1,170	1,560	7.3	6.8	6.9
IMP	3	2	4	0	0	0
International CMOS Technology	NA	NA	1	0	0	0
International Rectifier	38	41	58	0.3	0.2	0.3
ITT	19	22	48	0.2	0.1	0.2
Kulite	1	1	0	0	0	0
Lattice	12	19	21	0.1	0.1	0.1
Linear Technology	13	17	34	0.1	0.1	0.2
Linfinity	4	6	5	0	0	0
Logic Devices	1	1	1	0	0	0
LSI Logic	36	31	14	0.3	0.2	0.1
Maxim	14	16	21	0.1	0.1	0.1
Micrel	0	2	3	0	0	0
Micro Linear	7	10	6	0.1	0.1	0
Micro Power Systems	1	1	1	0	0	0
Microchip Technology	22	35	47	0.2	0.2	0.2
Micron Technology	67	167	245	0.6	1.0	1.1
Microsemi	2	2	4	0	0	0
Mitel	12	22	29	0.1	0.1	0.1
Motorola	819	1,188	1,284	7.0	6.9	5.7
NCR	9	11	27	0.1	0.1	0.1
National Semiconductor	392	523	471	3.3	3.1	2.1
Oak Technology	36	38	26	0.3	0.2	0.1
Optek	1	1	1	0	0	0
OPTi	64	43	53	0.5	0.3	0.2
Paradigm	0	1	2	0	0	0
Performance Semiconductor	3	1	1	0	0	0
Q Logic	NA	7	7	0	0	0
Quality Semiconductor	4	5	5	0	0	0
Quality Technologies	7	8	9	0.1	0	0
Ramtron	NA	NA	9	0	0	0
Raytheon	2	4	4	0	0	0
Rockwell	28	28	28	0.2	0.2	0.1

(Continued)

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Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
S3	10	44	24	0.1	0.3	0.1
SEEQ Technology	1	1	0	0	0	0
Semtech	0	0	1	0	0	0
Sierra Semiconductor	14	15	25	0.1	0.1	0.1
Silicon Systems	96	135	175	0.8	0.8	0.8
Sipex	1	1	1	0	0	0
Standard Microsystems	12	18	30	0.1	0.1	0.1
Supertex	1	1	2	0	0	0
Symphony Laboratories	14	53	11	0.1	0.3	0
Teccor Electronics	5	5	9	0	0	0
Telcom	NA	NA	4	0	0	0
Teledyne	5	6	0	0	0	0
Tektronix	3	3	0	0	0	0
Texas Instruments	446	696	1,058	3.8	4.1	4.7
Trident Microsystems	71	54	75	0.6	0.3	0.3
Tseng Labs	17	16	18	0.1	0.1	0.1
Unitrode	11	13	16	0.1	0.1	0.1
VLSI Technology	81	118	158	0.7	0.7	0.7
VTC	33	51	51	0.3	0.3	0.2
WaferScale Integration	3	3	3	0	0	0
Western Digital	46	68	55	0.4	0.4	0.2
Xicor	8	9	2	0.1	0.1	0
Xilinx	4	9	14	0	0.1	0.1
Zilog	38	58	75	0.3	0.3	0.3
Other North American Companies	76	24	20	0.6	0.1	0.1
Japanese Companies	4,151	6,291	8,624	35.3	36.7	38.2
Fuji Electric	46	71	107	0.4	0.4	0.5
Fujitsu	221	270	432	1.9	1.6	1.9
Hitachi	491	747	1,089	4.2	4.4	4.8
Matsushita	236	424	512	2.0	2.5	2.3
Mitsubishi	370	529	812	3.2	3.1	3.6
NEC	471	713	1,067	4.0	4.2	4.7
New JRC	29	56	69	0.2	0.3	0.3
Nittetsu Semiconductor	62	57	58	0.5	0.3	0.3
OKI	147	226	273	1.3	1.3	1.2
Ricoh	2	18	20	0	0.1	0.1

(Continued)

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Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Rohm	123	143	276	1.0	0.8	1.2
Sanken	107	140	176	0.9	0.8	0.8
Sanyo	436	749	966	3.7	4.4	4.3
Seiko Epson	14	18	24	0.1	0.1	0.1
Shindengen Electric	20	29	40	0.2	0.2	0.2
Sharp	164	306	424	1.4	1.8	1.9
Sony	166	305	284	1.4	1.8	1.3
Toko	12	23	28	0.1	0.1	0.1
Toshiba	982	1,324	1,706	8.4	7.7	7.6
Yamaha	22	63	161	0.2	0.4	0.7
Other Japanese Companies	30	80	100	0.3	0.5	0.4
European Companies	1,028	1,382	1,939	8.8	8.1	8.6
ABB-IXYS	0	0	6	0	0	0
Austria Mikro Systeme	6	6	9	0.1	0	0
EM Microelectronics Marin	5	7	3	0	0	0
Ericsson	3	0	17	0	0	0.1
Eupec	4	4	5	0	0	0
Fagor	4	3	5	0	0	0
GEC Plessey	74	37	60	0.6	0.2	0.3
Mietec	3	4	5	0	0	0
Philips	424	517	763	3.6	3.0	3.4
Semikron	11	11	14	0.1	0.1	0.1
SGS-Thomson	303	432	564	2.6	2.5	2.5
Siemens	91	203	314	0.8	1.2	1.4
TEMIC	NA	143	159	0	0.8	0.7
Zetex	6	6	6	0.1	0	0
Other European Companies	94	9	9	0.8	0.1	0
Asia/Pacific Companies	2,125	3,092	4,117	18.1	18.1	18.2
Acer Labs	NA	50	70	0	0.3	0.3
Daewoo	23	31	38	0.2	0.2	0.2
Dongsung Semiconductor	10	2	0	0.1	0	0
Goldstar	312	590	674	2.7	3.4	3.0
Holtek	0	50	66	0	0.3	0.3
Hualon Microelectronics Corporation	75	83	89	0.6	0.5	0.4
Hyundai	248	323	541	2.1	1.9	2.4

(Continued)

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Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Korean Electronic Co.	111	140	185	0.9	0.8	0.8
Macronix	48	72	99	0.4	0.4	0.4
MOSel/Vitelic	84	91	102	0.7	0.5	0.5
Samsung	821	1,188	1,593	7.0	6.9	7.1
Silicon Integrated Systems	39	70	101	0.3	0.4	0.4
United Microelectronics	184	231	352	1.6	1.3	1.6
Winbond Electronics	105	149	207	0.9	0.9	0.9
Other Asia/Pacific Companies	65	22	0	0.6	0.1	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-2
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	11,622	16,947	22,333	100.0	100.0	100.0
North American Companies	4,424	6,329	7,855	38.1	37.3	35.2
ACC Microelectronics	19	28	35	0.2	0.2	0.2
Actel	3	5	6	0	0	0
Adaptec	24	41	36	0.2	0.2	0.2
Advanced Micro Devices	361	314	445	3.1	1.9	2.0
Allegro MicroSystems	19	19	21	0.2	0.1	0.1
Alliance Semiconductor	0	23	35	0	0.1	0.2
Altera	6	9	13	0.1	0.1	0.1
Analog Devices	33	74	98	0.3	0.4	0.4
Appian Technology	2	1	1	0	0	0
Applied Micro Circuits Corporation	0	0	4	0	0	0
AT&T	15	43	148	0.1	0.3	0.7
Atmel	23	39	59	0.2	0.2	0.3
Brooktree	7	8	15	0.1	0	0.1
Burr-Brown	4	4	6	0	0	0
California Micro Devices	2	7	4	0	0	0
Catalyst	4	5	10	0	0	0
Cherry Semiconductor	6	6	7	0.1	0	0
Chips & Technologies	58	44	46	0.5	0.3	0.2
Cirrus Logic	94	187	249	0.8	1.1	1.1
Cypress Semiconductor	10	10	23	0.1	0.1	0.1
Cyrix	21	25	40	0.2	0.1	0.2
Dallas Semiconductor	16	11	47	0.1	0.1	0.2
DSP Semiconductor	0	0	15	0	0	0.1
ETEQ Microsystems	12	12	1	0.1	0.1	0
Exar	16	19	18	0.1	0.1	0.1
General Instrument	71	82	88	0.6	0.5	0.4
Gennum	2	2	2	0	0	0
Gould AMI	5	6	19	0	0	0.1
Harris	59	75	61	0.5	0.4	0.3
Hewlett-Packard	39	45	65	0.3	0.3	0.3
IBM	NA	333	330	0	2.0	1.5
IMI	0	0	1	0	0	0
Integrated Circuit Systems	10	12	41	0.1	0.1	0.2
Integrated Device Technology	19	30	20	0.2	0.2	0.1

(Continued)

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Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Integrated Information Technology	8	10	8	0.1	0.1	0
Integrated Silicon Solution	NA	NA	26	0	0	0.1
Intel	856	1,170	1,560	7.4	6.9	7.0
IMP	3	2	4	0	0	0
International CMOS Technology	NA	NA	1	0	0	0
International Rectifier	38	41	58	0.3	0.2	0.3
ITT	19	22	48	0.2	0.1	0.2
Kulite	1	1	0	0	0	0
Lattice	12	19	21	0.1	0.1	0.1
Linear Technology	13	17	34	0.1	0.1	0.2
Linfinity	4	6	5	0	0	0
Logic Devices	1	1	1	0	0	0
LSI Logic	36	31	14	0.3	0.2	0.1
Maxim	14	16	21	0.1	0.1	0.1
Micrel	0	2	3	0	0	0
Micro Linear	7	10	6	0.1	0.1	0
Micro Power Systems	1	1	1	0	0	0
Microchip Technology	22	35	47	0.2	0.2	0.2
Micron Technology	67	167	245	0.6	1.0	1.1
Microsemi	2	2	4	0	0	0
Mitel	10	18	14	0.1	0.1	0.1
Motorola	816	1,173	1,259	7.0	6.9	5.6
NCR	9	11	27	0.1	0.1	0.1
National Semiconductor	389	523	471	3.3	3.1	2.1
Oak Technology	36	38	26	0.3	0.2	0.1
Optek	1	1	1	0	0	0
OPTi	64	43	53	0.6	0.3	0.2
Paradigm	0	1	2	0	0	0
Performance Semiconductor	3	1	1	0	0	0
Q Logic	NA	7	7	0	0	0
Quality Semiconductor	4	5	5	0	0	0
Quality Technologies	7	8	9	0.1	0	0
Ramtron	NA	NA	9	0	0	0
Raytheon	2	4	4	0	0	0
Rockwell	28	28	28	0.2	0.2	0.1
S3	10	44	24	0.1	0.3	0.1
SEEQ Technology	1	1	0	0	0	0

(Continued)

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Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Semtech	0	0	1	0	0	0
Sierra Semiconductor	14	15	25	0.1	0.1	0.1
Silicon Systems	96	135	175	0.8	0.8	0.8
Standard Microsystems	12	18	30	0.1	0.1	0.1
Supertex	1	1	2	0	0	0
Symphony Laboratories	14	53	11	0.1	0.3	0
Teccor Electronics	5	5	9	0	0	0
Telcom	NA	NA	4	0	0	0
Teledyne	5	6	0	0	0	0
Tektronix	2	2	0	0	0	0
Texas Instruments	446	696	1,058	3.8	4.1	4.7
Trident Microsystems	71	54	75	0.6	0.3	0.3
Tseng Labs	17	16	18	0.1	0.1	0.1
Unitrode	8	10	13	0.1	0.1	0.1
VLSI Technology	81	118	158	0.7	0.7	0.7
VTC	33	51	51	0.3	0.3	0.2
WaferScale Integration	3	3	3	0	0	0
Western Digital	46	68	55	0.4	0.4	0.2
Xicor	8	9	2	0.1	0.1	0
Xilinx	4	9	14	0	0.1	0.1
Zilog	38	58	75	0.3	0.3	0.3
Other North American Companies	76	24	20	0.7	0.1	0.1
Japanese Companies	4,053	6,149	8,446	34.9	36.3	37.8
Fuji Electric	45	69	104	0.4	0.4	0.5
Fujitsu	217	266	427	1.9	1.6	1.9
Hitachi	485	740	1,078	4.2	4.4	4.8
Matsushita	236	424	512	2.0	2.5	2.3
Mitsubishi	369	528	811	3.2	3.1	3.6
NEC	470	712	1,066	4.0	4.2	4.8
New JRC	29	56	69	0.2	0.3	0.3
Nittetsu Semiconductor	62	57	58	0.5	0.3	0.3
OKI	147	226	273	1.3	1.3	1.2
Ricoh	2	18	20	0	0.1	0.1
Rohm	114	133	264	1.0	0.8	1.2
Sanken	67	80	96	0.6	0.5	0.4
Sanyo	411	704	913	3.5	4.2	4.1

(Continued)

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Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Seiko Epson	14	18	24	0.1	0.1	0.1
Shindengen Electric	19	28	40	0.2	0.2	0.2
Sharp	164	306	424	1.4	1.8	1.9
Sony	157	295	273	1.4	1.7	1.2
Toko	11	22	27	0.1	0.1	0.1
Toshiba	982	1,324	1,706	8.4	7.8	7.6
Yamaha	22	63	161	0.2	0.4	0.7
Other Japanese Companies	30	80	100	0.3	0.5	0.4
European Companies	1,020	1,377	1,915	8.8	8.1	8.6
ABB-IXYS	0	0	6	0	0	0
Austria Mikro Systeme	6	6	9	0.1	0	0
EM Microelectronics Marin	5	7	3	0	0	0
Ericsson	3	0	7	0	0	0
Eupec	4	4	5	0	0	0
Fagor	4	3	5	0	0	0
GEC Plessey	74	37	60	0.6	0.2	0.3
Mietec	3	4	5	0	0	0
Philips	421	517	753	3.6	3.1	3.4
Semikron	11	11	14	0.1	0.1	0.1
SGS-Thomson	303	432	564	2.6	2.5	2.5
Siemens	91	203	314	0.8	1.2	1.4
TEMIC	NA	141	159	0	0.8	0.7
Zetex	6	6	6	0.1	0	0
Other European Companies	89	6	5	0.8	0	0
Asia/Pacific Companies	2,125	3,092	4,117	18.3	18.2	18.4
Acer Labs	NA	50	70	0	0.3	0.3
Daewoo	23	31	38	0.2	0.2	0.2
Dongsung Semiconductor	10	2	0	0.1	0	0
Goldstar	312	590	674	2.7	3.5	3.0
Holtek	0	50	66	0	0.3	0.3
Hualon Microelectronics Corporation	75	83	89	0.6	0.5	0.4
Hyundai	248	323	541	2.1	1.9	2.4
Korean Electronic Co.	111	140	185	1.0	0.8	0.8
Macronix	48	72	99	0.4	0.4	0.4
MOSel/Vitelic	84	91	102	0.7	0.5	0.5

(Continued)

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Table 1-2 (Continued)
Each Company's Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Samsung	821	1,188	1,593	7.1	7.0	7.1
Silicon Integrated Systems	39	70	101	0.3	0.4	0.5
United Microelectronics	184	231	352	1.6	1.4	1.6
Winbond Electronics	105	149	207	0.9	0.9	0.9
Other Asia/Pacific Companies	65	22	0	0.6	0.1	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-3
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	9,894	14,709	19,589	100.0	100.0	100.0
North American Companies	4,028	5,909	7,384	40.7	40.2	37.7
ACC Microelectronics	19	28	35	0.2	0.2	0.2
Actel	3	5	6	0	0	0
Adaptec	24	41	36	0.2	0.3	0.2
Advanced Micro Devices	361	314	445	3.6	2.1	2.3
Allegro MicroSystems	18	16	19	0.2	0.1	0.1
Alliance Semiconductor	0	23	35	0	0.2	0.2
Altera	6	9	13	0.1	0.1	0.1
Analog Devices	35	76	102	0.4	0.5	0.5
Appian Technology	2	1	1	0	0	0
Applied Micro Circuits Corporation	0	0	4	0	0	0
AT&T	15	43	148	0.2	0.3	0.8
Atmel	23	39	59	0.2	0.3	0.3
Brooktree	7	8	15	0.1	0.1	0.1
Burr-Brown	5	5	6	0.1	0	0
California Micro Devices	2	7	4	0	0	0
Catalyst	4	5	10	0	0	0.1
Cherry Semiconductor	6	6	7	0.1	0	0
Chips & Technologies	58	44	46	0.6	0.3	0.2
Cirrus Logic	94	187	249	1.0	1.3	1.3
Cypress Semiconductor	10	10	23	0.1	0.1	0.1
Cyrix	21	25	40	0.2	0.2	0.2
Dallas Semiconductor	16	11	47	0.2	0.1	0.2
DSP Semiconductor	0	0	15	0	0	0.1
ETEQ Microsystems	12	12	1	0.1	0.1	0
Exar	16	19	18	0.2	0.1	0.1
General Instrument	0	0	0	0	0	0
Gennum	2	2	2	0	0	0
Gould AMI	5	6	19	0.1	0	0.1
Harris	51	61	43	0.5	0.4	0.2
Hewlett-Packard	30	34	37	0.3	0.2	0.2
IBM	NA	333	330	0	2.3	1.7
IMI	0	0	1	0	0	0
Integrated Circuit Systems	10	12	41	0.1	0.1	0.2
Integrated Device Technology	19	30	20	0.2	0.2	0.1

(Continued)

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Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Integrated Information Technology	8	10	8	0.1	0.1	0
Integrated Silicon Solution	NA	NA	26	0	0	0.1
Intel	856	1,170	1,560	8.7	8.0	8.0
IMP	3	2	4	0	0	0
International CMOS Technology	NA	NA	1	0	0	0
International Rectifier	0	0	1	0	0	0
ITT	6	7	26	0.1	0	0.1
Kulite	1	1	0	0	0	0
Lattice	12	19	21	0.1	0.1	0.1
Linear Technology	13	17	34	0.1	0.1	0.2
Linfinity	4	6	5	0	0	0
Logic Devices	1	1	1	0	0	0
LSI Logic	36	31	14	0.4	0.2	0.1
Maxim	14	16	21	0.1	0.1	0.1
Micrel	0	2	3	0	0	0
Micro Linear	7	10	6	0.1	0.1	0
Micro Power Systems	1	1	1	0	0	0
Microchip Technology	22	35	47	0.2	0.2	0.2
Micron Technology	67	167	245	0.7	1.1	1.3
Mitel	12	22	29	0.1	0.1	0.1
Motorola	647	979	1,061	6.5	6.7	5.4
NCR	9	11	27	0.1	0.1	0.1
National Semiconductor	368	493	435	3.7	3.4	2.2
Oak Technology	36	38	26	0.4	0.3	0.1
OPTi	64	43	53	0.6	0.3	0.3
Paradigm	0	1	2	0	0	0
Performance Semiconductor	3	1	1	0	0	0
Q Logic	NA	7	7	0	0	0
Quality Semiconductor	4	5	5	0	0	0
Ramtron	NA	NA	9	0	0	0
Raytheon	2	4	4	0	0	0
Rockwell	28	28	28	0.3	0.2	0.1
S3	10	44	24	0.1	0.3	0.1
SEEQ Technology	1	1	0	0	0	0
Semtech	0	0	1	0	0	0
Sierra Semiconductor	14	15	25	0.1	0.1	0.1
Silicon Systems	96	135	175	1.0	0.9	0.9

(Continued)

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Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Sipex	1	1	1	0	0	0
Standard Microsystems	12	18	30	0.1	0.1	0.2
Supertex	1	1	2	0	0	0
Symphony Laboratories	14	53	11	0.1	0.4	0.1
Telcom	NA	NA	4	0	0	0
Teledyne	5	6	0	0.1	0	0
Tektronix	2	2	0	0	0	0
Texas Instruments	442	695	1,056	4.5	4.7	5.4
Trident Microsystems	71	54	75	0.7	0.4	0.4
Tseng Labs	17	16	18	0.2	0.1	0.1
Unitrode	11	13	16	0.1	0.1	0.1
VLSI Technology	81	118	158	0.8	0.8	0.8
VTC	33	51	51	0.3	0.3	0.3
WaferScale Integration	3	3	3	0	0	0
Western Digital	46	68	55	0.5	0.5	0.3
Xicor	8	9	2	0.1	0.1	0
Xilinx	4	9	14	0	0.1	0.1
Zilog	38	58	75	0.4	0.4	0.4
Other North American Companies	20	0	0	0.2	0	0
Japanese Companies	3,211	4,941	6,901	32.5	33.6	35.2
Fuji Electric	6	14	22	0.1	0.1	0.1
Fujitsu	199	248	409	2.0	1.7	2.1
Hitachi	386	603	906	3.9	4.1	4.6
Matsushita	164	288	345	1.7	2.0	1.8
Mitsubishi	327	467	728	3.3	3.2	3.7
NEC	378	604	950	3.8	4.1	4.8
New JRC	28	55	66	0.3	0.4	0.3
Nittetsu Semiconductor	62	57	58	0.6	0.4	0.3
OKI	147	226	273	1.5	1.5	1.4
Ricoh	2	18	20	0	0.1	0.1
Rohm	68	79	150	0.7	0.5	0.8
Sanken	40	60	80	0.4	0.4	0.4
Sanyo	351	614	786	3.5	4.2	4.0
Seiko Epson	14	18	24	0.1	0.1	0.1
Shindengen Electric	1	1	0	0	0	0
Sharp	121	234	324	1.2	1.6	1.7

(Continued)

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Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Sony	148	268	250	1.5	1.8	1.3
Toko	5	7	9	0.1	0	0
Toshiba	742	992	1,310	7.5	6.7	6.7
Yamaha	22	63	161	0.2	0.4	0.8
Other Japanese Companies	0	25	30	0	0.2	0.2
European Companies	765	1,021	1,481	7.7	6.9	7.6
Austria Mikro Systeme	6	6	9	0.1	0	0
EM Microelectronics Marin	5	7	3	0.1	0	0
Ericsson	3	0	16	0	0	0.1
GEC Plessey	71	34	57	0.7	0.2	0.3
Mietec	3	4	5	0	0	0
Philips	317	377	571	3.2	2.6	2.9
SGS-Thomson	251	355	474	2.5	2.4	2.4
Siemens	60	167	272	0.6	1.1	1.4
TEMIC	NA	68	70	0	0.5	0.4
Other European Companies	49	3	4	0.5	0	0
Asia/Pacific Companies	1,890	2,838	3,823	19.1	19.3	19.5
Acer Labs	NA	50	70	0	0.3	0.4
Daewoo	23	31	38	0.2	0.2	0.2
Goldstar	301	590	674	3.0	4.0	3.4
Holtek	0	50	66	0	0.3	0.3
Hualon Microelectronics Corporation	75	83	89	0.8	0.6	0.5
Hyundai	248	323	541	2.5	2.2	2.8
Korean Electronic Co.	27	32	42	0.3	0.2	0.2
Macronix	48	72	99	0.5	0.5	0.5
MOSel/Vitelic	84	91	102	0.8	0.6	0.5
Samsung	731	1,066	1,442	7.4	7.2	7.4
Silicon Integrated Systems	39	70	101	0.4	0.5	0.5
United Microelectronics	184	231	352	1.9	1.6	1.8
Winbond Electronics	105	149	207	1.1	1.0	1.1
Other Asia/Pacific Companies	25	0	0	0.3	0	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-4
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	9,772	14,535	19,339	100.0	100.0	100.0
North American Companies	4,012	5,882	7,336	41.1	40.5	37.9
ACC Microelectronics	19	28	35	0.2	0.2	0.2
Actel	3	5	6	0	0	0
Adaptec	24	41	36	0.2	0.3	0.2
Advanced Micro Devices	361	314	445	3.7	2.2	2.3
Allegro MicroSystems	18	16	19	0.2	0.1	0.1
Alliance Semiconductor	0	23	35	0	0.2	0.2
Altera	6	9	13	0.1	0.1	0.1
Analog Devices	33	74	98	0.3	0.5	0.5
Appian Technology	2	1	1	0	0	0
Applied Micro Circuits Corporation	0	0	4	0	0	0
AT&T	15	43	148	0.2	0.3	0.8
Atmel	23	39	59	0.2	0.3	0.3
Brooktree	7	8	15	0.1	0.1	0.1
Burr-Brown	4	4	6	0	0	0
California Micro Devices	2	7	4	0	0	0
Catalyst	4	5	10	0	0	0.1
Cherry Semiconductor	6	6	7	0.1	0	0
Chips & Technologies	58	44	46	0.6	0.3	0.2
Cirrus Logic	94	187	249	1.0	1.3	1.3
Cypress Semiconductor	10	10	23	0.1	0.1	0.1
Cyrix	21	25	40	0.2	0.2	0.2
Dallas Semiconductor	16	11	47	0.2	0.1	0.2
DSP Semiconductor	0	0	15	0	0	0.1
ETEQ Microsystems	12	12	1	0.1	0.1	0
Exar	16	19	18	0.2	0.1	0.1
Gennum	2	2	2	0	0	0
Gould AMI	5	6	19	0.1	0	0.1
Harris	51	61	43	0.5	0.4	0.2
Hewlett-Packard	30	34	37	0.3	0.2	0.2
IBM	NA	333	330	0	2.3	1.7
IMI	0	0	1	0	0	0
Integrated Circuit Systems	10	12	41	0.1	0.1	0.2
Integrated Device Technology	19	30	20	0.2	0.2	0.1
Integrated Information Technology	8	10	8	0.1	0.1	0

(Continued)

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Table 1-4 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Integrated Silicon Solution	NA	NA	26	0	0	0.1
Intel	856	1,170	1,560	8.8	8.0	8.1
IMP	3	2	4	0	0	0
International CMOS Technology	NA	NA	1	0	0	0
International Rectifier	0	0	1	0	0	0
ITT	6	7	26	0.1	0	0.1
Kulite	1	1	0	0	0	0
Lattice	12	19	21	0.1	0.1	0.1
Linear Technology	13	17	34	0.1	0.1	0.2
Linfinity	4	6	5	0	0	0
Logic Devices	1	1	1	0	0	0
LSI Logic	36	31	14	0.4	0.2	0.1
Maxim	14	16	21	0.1	0.1	0.1
Micrel	0	2	3	0	0	0
Micro Linear	7	10	6	0.1	0.1	0
Micro Power Systems	1	1	1	0	0	0
Microchip Technology	22	35	47	0.2	0.2	0.2
Micron Technology	67	167	245	0.7	1.1	1.3
Mitel	10	18	14	0.1	0.1	0.1
Motorola	644	964	1,036	6.6	6.6	5.4
NCR	9	11	27	0.1	0.1	0.1
National Semiconductor	365	493	435	3.7	3.4	2.2
Oak Technology	36	38	26	0.4	0.3	0.1
OPTi	64	43	53	0.7	0.3	0.3
Paradigm	0	1	2	0	0	0
Performance Semiconductor	3	1	1	0	0	0
Q Logic	NA	7	7	0	0	0
Quality Semiconductor	4	5	5	0	0	0
Ramtron	NA	NA	9	0	0	0
Raytheon	2	4	4	0	0	0
Rockwell	28	28	28	0.3	0.2	0.1
S3	10	44	24	0.1	0.3	0.1
SEEQ Technology	1	1	0	0	0	0
Semtech	0	0	1	0	0	0
Sierra Semiconductor	14	15	25	0.1	0.1	0.1
Silicon Systems	96	135	175	1.0	0.9	0.9
Standard Microsystems	12	18	30	0.1	0.1	0.2

(Continued)

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Table 1-4 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Supertex	1	1	2	0	0	0
Symphony Laboratories	14	53	11	0.1	0.4	0.1
Telcom	NA	NA	4	0	0	0
Teledyne	5	6	0	0.1	0	0
Tektronix	1	1	0	0	0	0
Texas Instruments	442	695	1,056	4.5	4.8	5.5
Trident Microsystems	71	54	75	0.7	0.4	0.4
Tseng Labs	17	16	18	0.2	0.1	0.1
Unitrode	8	10	13	0.1	0.1	0.1
VLSI Technology	81	118	158	0.8	0.8	0.8
VTC	33	51	51	0.3	0.4	0.3
WaferScale Integration	3	3	3	0	0	0
Western Digital	46	68	55	0.5	0.5	0.3
Xicor	8	9	2	0.1	0.1	0
Xilinx	4	9	14	0	0.1	0.1
Zilog	38	58	75	0.4	0.4	0.4
Other North American Companies	20	0	0	0.2	0	0
Japanese Companies	3,113	4,799	6,723	31.9	33.0	34.8
Fuji Electric	5	12	19	0.1	0.1	0.1
Fujitsu	195	244	404	2.0	1.7	2.1
Hitachi	380	596	895	3.9	4.1	4.6
Matsushita	164	288	345	1.7	2.0	1.8
Mitsubishi	326	466	727	3.3	3.2	3.8
NEC	377	603	949	3.9	4.1	4.9
New JRC	28	55	66	0.3	0.4	0.3
Nittetsu Semiconductor	62	57	58	0.6	0.4	0.3
OKI	147	226	273	1.5	1.6	1.4
Ricoh	2	18	20	0	0.1	0.1
Rohm	59	69	138	0.6	0.5	0.7
Sanyo	326	569	733	3.3	3.9	3.8
Seiko Epson	14	18	24	0.1	0.1	0.1
Sharp	121	234	324	1.2	1.6	1.7
Sony	139	258	239	1.4	1.8	1.2
Toko	4	6	8	0	0	0
Toshiba	742	992	1,310	7.6	6.8	6.8
Yamaha	22	63	161	0.2	0.4	0.8
Other Japanese Companies	0	25	30	0	0.2	0.2

(Continued)

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Table 1-4 (Continued)
Each Company's Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
European Companies	757	1,016	1,457	7.7	7.0	7.5
Austria Mikro Systeme	6	6	9	0.1	0	0
EM Microelectronics Marin	5	7	3	0.1	0	0
Ericsson	3	0	6	0	0	0
GEC Plessey	71	34	57	0.7	0.2	0.3
Mietec	3	4	5	0	0	0
Philips	314	377	561	3.2	2.6	2.9
SGS-Thomson	251	355	474	2.6	2.4	2.5
Siemens	60	167	272	0.6	1.1	1.4
TEMIC	NA	66	70	0	0.5	0.4
Other European Companies	44	0	0	0.5	0	0
Asia/Pacific Companies	1,890	2,838	3,823	19.3	19.5	19.8
Acer Labs	NA	50	70	0	0.3	0.4
Daewoo	23	31	38	0.2	0.2	0.2
Goldstar	301	590	674	3.1	4.1	3.5
Holtek	0	50	66	0	0.3	0.3
Hualon Microelectronics Corporation	75	83	89	0.8	0.6	0.5
Hyundai	248	323	541	2.5	2.2	2.8
Korean Electronic Co.	27	32	42	0.3	0.2	0.2
Macronix	48	72	99	0.5	0.5	0.5
MOSel/Vitelic	84	91	102	0.9	0.6	0.5
Samsung	731	1,066	1,442	7.5	7.3	7.5
Silicon Integrated Systems	39	70	101	0.4	0.5	0.5
United Microelectronics	184	231	352	1.9	1.6	1.8
Winbond Electronics	105	149	207	1.1	1.0	1.1
Other Asia/Pacific Companies	25	0	0	0.3	0	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-5
Each Company's Factory Revenue from Shipments of Bipolar Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	372	386	362	100.0	100.0	100.0
North American Companies	190	238	220	51.1	61.7	60.8
Advanced Micro Devices	17	17	13	4.6	4.4	3.6
Applied Micro Circuits Corporation	0	0	2	0	0	0.6
AT&T	0	0	11	0	0	3.0
Chips & Technologies	2	2	0	0.5	0.5	0
Motorola	41	55	58	11.0	14.2	16.0
National Semiconductor	68	77	59	18.3	19.9	16.3
Texas Instruments	62	87	77	16.7	22.5	21.3
Japanese Companies	99	92	91	26.6	23.8	25.1
Fujitsu	2	1	1	0.5	0.3	0.3
Hitachi	78	67	72	21.0	17.4	19.9
Matsushita	0	5	6	0	1.3	1.7
Mitsubishi	5	5	4	1.3	1.3	1.1
NEC	2	2	2	0.5	0.5	0.6
Toshiba	12	12	6	3.2	3.1	1.7
European Companies	61	18	13	16.4	4.7	3.6
GEC Plessey	6	3	4	1.6	0.8	1.1
Philips	50	14	9	13.4	3.6	2.5
SGS-Thomson	0	1	0	0	0.3	0
Siemens	5	0	0	1.3	0	0
Asia/Pacific Companies	22	38	38	5.9	9.8	10.5
Goldstar	22	38	38	5.9	9.8	10.5

NA = Not available
Source: Dataquest (March 1995)

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Table 1-6
Each Company's Factory Revenue from Shipments of Bipolar Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	12	7	6	100.0	100.0	100.0
North American Companies	4	3	2	33.3	42.9	33.3
Advanced Micro Devices	1	1	2	8.3	14.3	33.3
Motorola	1	0	0	8.3	0	0
National Semiconductor	1	1	0	8.3	14.3	0
Texas Instruments	1	1	0	8.3	14.3	0
Japanese Companies	5	4	3	41.7	57.1	50.0
Hitachi	5	4	3	41.7	57.1	50.0
European Companies	3	0	1	25.0	0	16.7
Philips	3	0	1	25.0	0	16.7

Source: Dataquest (March 1995)

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Table 1-7
Each Company's Factory Revenue from Shipments of Bipolar Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	360	379	356	100.0	100.0	100.0
North American Companies	186	235	218	51.7	62.0	61.2
Advanced Micro Devices	16	16	11	4.4	4.2	3.1
Applied Micro Circuits Corporation	0	0	2	0	0	0.6
AT&T	0	0	11	0	0	3.1
Chips & Technologies	2	2	0	0.6	0.5	0
Motorola	40	55	58	11.1	14.5	16.3
National Semiconductor	67	76	59	18.6	20.1	16.6
Texas Instruments	61	86	77	16.9	22.7	21.6
Japanese Companies	94	88	88	26.1	23.2	24.7
Fujitsu	2	1	1	0.6	0.3	0.3
Hitachi	73	63	69	20.3	16.6	19.4
Matsushita	0	5	6	0	1.3	1.7
Mitsubishi	5	5	4	1.4	1.3	1.1
NEC	2	2	2	0.6	0.5	0.6
Toshiba	12	12	6	3.3	3.2	1.7
European Companies	58	18	12	16.1	4.7	3.4
GEC Plessey	6	3	4	1.7	0.8	1.1
Philips	47	14	8	13.1	3.7	2.2
SGS-Thomson	0	1	0	0	0.3	0
Siemens	5	0	0	1.4	0	0
Asia/Pacific Companies	22	38	38	6.1	10.0	10.7
Goldstar	22	38	38	6.1	10.0	10.7

Source: Dataquest (March 1995)

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Table 1-8
Each Company's Factory Revenue from Shipments of MOS Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	7,148	11,049	15,011	100.0	100.0	100.0
North American Companies	3,072	4,604	5,776	43.0	41.7	38.5
ACC Microelectronics	19	28	35	0.3	0.3	0.2
Actel	3	5	6	0	0	0
Adaptec	24	41	36	0.3	0.4	0.2
Advanced Micro Devices	332	272	392	4.6	2.5	2.6
Alliance Semiconductor	0	23	35	0	0.2	0.2
Altera	6	9	13	0.1	0.1	0.1
Analog Devices	6	7	8	0.1	0.1	0.1
Appian Technology	2	1	1	0	0	0
Applied Micro Circuits Corporation	0	0	2	0	0	0
AT&T	8	42	81	0.1	0.4	0.5
Atmel	22	38	59	0.3	0.3	0.4
California Micro Devices	1	3	2	0	0	0
Catalyst	4	5	10	0.1	0	0.1
Chips & Technologies	56	42	46	0.8	0.4	0.3
Cirrus Logic	92	176	232	1.3	1.6	1.5
Cypress Semiconductor	10	10	23	0.1	0.1	0.2
Cyrix	21	25	40	0.3	0.2	0.3
Dallas Semiconductor	16	11	47	0.2	0.1	0.3
DSP Semiconductor	0	0	15	0	0	0.1
ETEQ Microsystems	12	12	1	0.2	0.1	0
Gould AMI	2	2	19	0	0	0.1
Harris	27	27	18	0.4	0.2	0.1
Hewlett-Packard	30	34	37	0.4	0.3	0.2
IBM	NA	333	330	0	3.0	2.2
IMI	0	0	1	0	0	0
Integrated Circuit Systems	10	8	17	0.1	0.1	0.1
Integrated Device Technology	19	30	20	0.3	0.3	0.1
Integrated Information Technology	8	10	8	0.1	0.1	0.1
Integrated Silicon Solution	NA	NA	26	0	0	0.2
Intel	856	1,170	1,560	12.0	10.6	10.4
IMP	3	0	0	0	0	0
International CMOS Technology	NA	NA	1	0	0	0
ITT	6	7	24	0.1	0.1	0.2
Lattice	12	19	21	0.2	0.2	0.1

(Continued)

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Table 1-8 (Continued)
Each Company's Factory Revenue from Shipments of MOS Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Logic Devices	1	1	1	0	0	0
LSI Logic	36	31	14	0.5	0.3	0.1
Micrel	0	0	1	0	0	0
Microchip Technology	22	35	47	0.3	0.3	0.3
Micron Technology	67	167	245	0.9	1.5	1.6
Motorola	454	709	745	6.4	6.4	5.0
NCR	5	6	18	0.1	0.1	0.1
National Semiconductor	137	190	137	1.9	1.7	0.9
Oak Technology	36	38	26	0.5	0.3	0.2
OPTi	64	43	53	0.9	0.4	0.4
Paradigm	0	1	2	0	0	0
Performance Semiconductor	3	1	1	0	0	0
Q Logic	NA	7	7	0	0.1	0
Quality Semiconductor	4	5	5	0.1	0	0
Ramtron	NA	NA	9	0	0	0.1
Rockwell	2	2	1	0	0	0
S3	10	44	24	0.1	0.4	0.2
Sierra Semiconductor	0	0	8	0	0	0.1
Standard Microsystems	12	18	30	0.2	0.2	0.2
Symphony Laboratories	14	53	11	0.2	0.5	0.1
Texas Instruments	316	528	825	4.4	4.8	5.5
Trident Microsystems	71	54	75	1.0	0.5	0.5
Tseng Labs	17	16	18	0.2	0.1	0.1
VLSI Technology	81	118	158	1.1	1.1	1.1
WaferScale Integration	3	3	3	0	0	0
Western Digital	46	68	55	0.6	0.6	0.4
Xicor	8	9	2	0.1	0.1	0
Xilinx	4	9	14	0.1	0.1	0.1
Zilog	38	58	75	0.5	0.5	0.5
Other North American Companies	14	0	0	0.2	0	0
Japanese Companies	2,136	3,512	5,110	29.9	31.8	34.0
Fuji Electric	5	7	10	0.1	0.1	0.1
Fujitsu	185	237	395	2.6	2.1	2.6
Hitachi	263	478	752	3.7	4.3	5.0
Matsushita	74	160	185	1.0	1.4	1.2
Mitsubishi	263	362	604	3.7	3.3	4.0

(Continued)

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Table 1-8 (Continued)
Each Company's Factory Revenue from Shipments of MOS Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
NEC	292	500	818	4.1	4.5	5.4
New JRC	2	3	8	0	0	0.1
Nittetsu Semiconductor	62	57	58	0.9	0.5	0.4
OKI	147	226	272	2.1	2.0	1.8
Ricoh	0	15	16	0	0.1	0.1
Rohm	17	22	37	0.2	0.2	0.2
Sanyo	133	291	336	1.9	2.6	2.2
Seiko Epson	13	17	22	0.2	0.2	0.1
Sharp	115	215	300	1.6	1.9	2.0
Sony	44	116	143	0.6	1.0	1.0
Toshiba	505	723	972	7.1	6.5	6.5
Yamaha	16	58	152	0.2	0.5	1.0
Other Japanese Companies	0	25	30	0	0.2	0.2
European Companies	281	442	686	3.9	4.0	4.6
Austria Mikro Systeme	4	4	6	0.1	0	0
GEC Plessey	3	6	24	0	0.1	0.2
Mietec	1	1	1	0	0	0
Philips	135	150	251	1.9	1.4	1.7
SGS-Thomson	80	135	148	1.1	1.2	1.0
Siemens	40	124	234	0.6	1.1	1.6
TEMIC	NA	22	22	0	0.2	0.1
Other European Companies	18	0	0	0.3	0	0
Asia/Pacific Companies	1,659	2,491	3,439	23.2	22.5	22.9
Acer Labs	NA	50	70	0	0.5	0.5
Daewoo	7	11	21	0.1	0.1	0.1
Goldstar	261	515	592	3.7	4.7	3.9
Holtek	0	35	66	0	0.3	0.4
Hualon Microelectronics Corporation	74	76	80	1.0	0.7	0.5
Hyundai	248	323	541	3.5	2.9	3.6
Macronix	48	72	99	0.7	0.7	0.7
MOSel/Vitelic	84	91	102	1.2	0.8	0.7
Samsung	622	918	1,251	8.7	8.3	8.3
Silicon Integrated Systems	39	70	101	0.5	0.6	0.7
United Microelectronics	184	231	352	2.6	2.1	2.3
Winbond Electronics	92	99	164	1.3	0.9	1.1

NA = Not available
Source: Dataquest (March 1995)

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Table 1-9
Each Company's Factory Revenue from Shipments of MOS Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	2,878	4,833	7,181	100.0	100.0	100.0
North American Companies	502	1,027	1,351	17.4	21.2	18.8
Advanced Micro Devices	38	38	49	1.3	0.8	0.7
Alliance Semiconductor	0	23	35	0	0.5	0.5
Atmel	19	35	56	0.7	0.7	0.8
Catalyst	4	5	10	0.1	0.1	0.1
Cypress Semiconductor	9	10	18	0.3	0.2	0.3
Dallas Semiconductor	4	0	9	0.1	0	0.1
Gould AMI	2	2	17	0.1	0	0.2
IBM	NA	133	80	0	2.8	1.1
Integrated Device Technology	14	22	13	0.5	0.5	0.2
Integrated Silicon Solution	NA	NA	26	0	0	0.4
Intel	26	40	45	0.9	0.8	0.6
ITT	0	0	10	0	0	0.1
Logic Devices	1	1	0	0	0	0
Microchip Technology	10	14	18	0.3	0.3	0.3
Micron Technology	67	167	245	2.3	3.5	3.4
Motorola	93	154	163	3.2	3.2	2.3
National Semiconductor	25	40	33	0.9	0.8	0.5
Paradigm	0	1	2	0	0	0
Performance Semiconductor	2	1	1	0.1	0	0
Quality Semiconductor	3	4	2	0.1	0.1	0
Ramtron	NA	NA	9	0	0	0.1
Texas Instruments	176	327	506	6.1	6.8	7.0
WaferScale Integration	1	1	2	0	0	0
Xicor	8	9	2	0.3	0.2	0
Japanese Companies	1,062	1,750	2,861	36.9	36.2	39.8
Fujitsu	138	171	310	4.8	3.5	4.3
Hitachi	149	298	529	5.2	6.2	7.4
Matsushita	28	61	63	1.0	1.3	0.9
Mitsubishi	126	181	404	4.4	3.7	5.6
NEC	122	275	548	4.2	5.7	7.6
Nittetsu Semiconductor	62	57	58	2.2	1.2	0.8
OKI	88	112	146	3.1	2.3	2.0
Ricoh	0	3	3	0	0.1	0

(Continued)

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Table 1-9 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Rohm	6	8	9	0.2	0.2	0.1
Sanyo	22	80	90	0.8	1.7	1.3
Seiko Epson	2	3	4	0.1	0.1	0.1
Sharp	43	91	134	1.5	1.9	1.9
Sony	28	51	47	1.0	1.1	0.7
Toshiba	248	350	506	8.6	7.2	7.0
Other Japanese Companies	0	9	10	0	0.2	0.1
European Companies	89	199	323	3.1	4.1	4.5
Philips	10	7	5	0.3	0.1	0.1
SGS-Thomson	46	70	88	1.6	1.4	1.2
Siemens	31	119	228	1.1	2.5	3.2
TEMIC	NA	3	2	0	0.1	0
Other European Companies	2	0	0	0.1	0	0
Asia/Pacific Companies	1,225	1,857	2,646	42.6	38.4	36.8
Acer Labs	NA	0	0	0	0	0
Daewoo	1	1	0	0	0	0
Goldstar	235	465	521	8.2	9.6	7.3
Holtek	0	0	0	0	0	0
Hualon Microelectronics Corporation	29	36	46	1.0	0.7	0.6
Hyundai	248	322	536	8.6	6.7	7.5
Macronix	43	58	80	1.5	1.2	1.1
MOSel/Vitelic	59	91	102	2.1	1.9	1.4
Samsung	493	739	1,094	17.1	15.3	15.2
Silicon Integrated Systems	21	5	0	0.7	0.1	0
United Microelectronics	58	73	156	2.0	1.5	2.2
Winbond Electronics	38	67	111	1.3	1.4	1.5

NA = Not available
Source: Dataquest (March 1995)

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Table 1-10
Each Company's Factory Revenue from Shipments of MOS Microcomponent ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	3,022	4,225	5,438	100.0	100.0	100.0
North American Companies	2,191	2,926	3,638	72.5	69.3	66.9
ACC Microelectronics	19	28	35	0.6	0.7	0.6
Adaptec	24	41	36	0.8	1.0	0.7
Advanced Micro Devices	270	206	309	8.9	4.9	5.7
Analog Devices	6	7	8	0.2	0.2	0.1
Appian Technology	1	1	1	0	0	0
AT&T	4	33	37	0.1	0.8	0.7
Atmel	2	1	2	0.1	0	0
California Micro Devices	1	3	2	0	0.1	0
Chips & Technologies	56	42	46	1.9	1.0	0.8
Cirrus Logic	92	176	232	3.0	4.2	4.3
Cypress Semiconductor	1	0	2	0	0	0
Cyrix	21	25	40	0.7	0.6	0.7
Dallas Semiconductor	10	8	7	0.3	0.2	0.1
DSP Semiconductor	0	0	15	0	0	0.3
ETEQ Microsystems	12	12	0	0.4	0.3	0
Harris	7	3	4	0.2	0.1	0.1
IBM	NA	44	113	0	1.0	2.1
Integrated Device Technology	0	0	3	0	0	0.1
Integrated Information Technology	8	10	8	0.3	0.2	0.1
Intel	830	1,123	1,512	27.5	26.6	27.8
ITT	1	1	0	0	0	0
LSI Logic	10	16	4	0.3	0.4	0.1
Microchip Technology	11	20	29	0.4	0.5	0.5
Motorola	272	441	456	9.0	10.4	8.4
NCR	0	0	3	0	0	0.1
National Semiconductor	86	120	76	2.8	2.8	1.4
Oak Technology	36	38	26	1.2	0.9	0.5
OPTi	64	43	53	2.1	1.0	1.0
Performance Semiconductor	1	0	0	0	0	0
Q Logic	NA	7	7	0	0.2	0.1
Ramtron	NA	NA	0	0	0	0
Rockwell	2	2	1	0.1	0	0

(Continued)

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Table 1-10 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponent ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
S3	10	44	24	0.3	1.0	0.4
Sierra Semiconductor	0	0	8	0	0	0.1
Standard Microsystems	12	18	30	0.4	0.4	0.6
Symphony Laboratories	14	53	11	0.5	1.3	0.2
Texas Instruments	77	115	168	2.5	2.7	3.1
Trident Microsystems	71	54	75	2.3	1.3	1.4
Tseng Labs	17	16	18	0.6	0.4	0.3
VLSI Technology	43	47	106	1.4	1.1	1.9
WaferScale Integration	2	2	1	0.1	0	0
Western Digital	46	68	55	1.5	1.6	1.0
Zilog	38	58	75	1.3	1.4	1.4
Other North American Companies	14	0	0	0.5	0	0
Japanese Companies	555	891	1,144	18.4	21.1	21.0
Fujitsu	28	30	41	0.9	0.7	0.8
Hitachi	72	116	143	2.4	2.7	2.6
Matsushita	12	26	35	0.4	0.6	0.6
Mitsubishi	127	169	185	4.2	4.0	3.4
NEC	112	150	174	3.7	3.6	3.2
OKI	30	50	52	1.0	1.2	1.0
Ricoh	0	12	13	0	0.3	0.2
Rohm	2	3	7	0.1	0.1	0.1
Sanyo	50	85	76	1.7	2.0	1.4
Seiko Epson	2	3	4	0.1	0.1	0.1
Sharp	19	35	46	0.6	0.8	0.8
Sony	0	27	35	0	0.6	0.6
Toshiba	101	136	188	3.3	3.2	3.5
Yamaha	0	49	145	0	1.2	2.7
European Companies	100	94	129	3.3	2.2	2.4
GEC Plessey	0	2	2	0	0	0
Philips	70	58	88	2.3	1.4	1.6
SGS-Thomson	19	25	28	0.6	0.6	0.5
Siemens	7	4	6	0.2	0.1	0.1
TEMIC	NA	5	5	0	0.1	0.1
Other European Companies	4	0	0	0.1	0	0

(Continued)

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Table 1-10 (Continued)
Each Company's Factory Revenue from Shipments of MOS Microcomponent ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Asia/Pacific Companies	176	314	527	5.8	7.4	9.7
Acer Labs	NA	50	68	0	1.2	1.3
Daewoo	4	7	17	0.1	0.2	0.3
Goldstar	11	12	29	0.4	0.3	0.5
Holtek	0	17	19	0	0.4	0.3
Hualon Microelectronics Corporation	10	10	0	0.3	0.2	0
Hyundai	0	0	2	0	0	0
Macronix	5	14	19	0.2	0.3	0.3
Samsung	19	40	33	0.6	0.9	0.6
Silicon Integrated Systems	18	25	101	0.6	0.6	1.9
United Microelectronics	68	111	196	2.3	2.6	3.6
Winbond Electronics	41	28	43	1.4	0.7	0.8

NA = Not available
Source: Dataquest (March 1995)

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Table 1-11
Each Company's Factory Revenue from Shipments of MOS Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,248	1,991	2,392	100.0	100.0	100.0
North American Companies	379	651	787	30.4	32.7	32.9
Actel	3	5	6	0.2	0.3	0.3
Advanced Micro Devices	24	28	34	1.9	1.4	1.4
Altera	6	9	13	0.5	0.5	0.5
Appian Technology	1	0	0	0.1	0	0
Applied Micro Circuits Corporation	0	0	2	0	0	0.1
AT&T	4	9	44	0.3	0.5	1.8
Atmel	1	2	1	0.1	0.1	0
Cypress Semiconductor	0	0	3	0	0	0.1
Dallas Semiconductor	2	3	31	0.2	0.2	1.3
ETEQ Microsystems	0	0	1	0	0	0
Gould AMI	0	0	2	0	0	0.1
Harris	20	24	14	1.6	1.2	0.6
Hewlett-Packard	30	34	37	2.4	1.7	1.5
IBM	NA	156	137	0	7.8	5.7
IMI	0	0	1	0	0	0
Integrated Circuit Systems	10	8	17	0.8	0.4	0.7
Integrated Device Technology	5	8	4	0.4	0.4	0.2
Intel	0	7	3	0	0.4	0.1
IMP	3	0	0	0.2	0	0
International CMOS Technology	NA	NA	1	0	0	0
ITT	5	6	14	0.4	0.3	0.6
Lattice	12	19	21	1.0	1.0	0.9
Logic Devices	0	0	1	0	0	0
LSI Logic	26	15	10	2.1	0.8	0.4
Micrel	0	0	1	0	0	0
Microchip Technology	1	1	0	0.1	0.1	0
Motorola	89	114	126	7.1	5.7	5.3
NCR	5	6	15	0.4	0.3	0.6
National Semiconductor	26	30	28	2.1	1.5	1.2
Quality Semiconductor	1	1	3	0.1	0.1	0.1
Texas Instruments	63	86	151	5.0	4.3	6.3
VLSI Technology	38	71	52	3.0	3.6	2.2
Xilinx	4	9	14	0.3	0.5	0.6

(Continued)

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Table 1-11 (Continued)
Each Company's Factory Revenue from Shipments of MOS Logic ICs to Asia/Pacific
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Japanese Companies	519	871	1,105	41.6	43.7	46.2
Fuji Electric	5	7	10	0.4	0.4	0.4
Fujitsu	19	36	44	1.5	1.8	1.8
Hitachi	42	64	80	3.4	3.2	3.3
Matsushita	34	73	87	2.7	3.7	3.6
Mitsubishi	10	12	15	0.8	0.6	0.6
NEC	58	75	96	4.6	3.8	4.0
New JRC	2	3	8	0.2	0.2	0.3
OKI	29	64	74	2.3	3.2	3.1
Rohm	9	11	21	0.7	0.6	0.9
Sanyo	61	126	170	4.9	6.3	7.1
Seiko Epson	9	11	14	0.7	0.6	0.6
Sharp	53	89	120	4.2	4.5	5.0
Sony	16	38	61	1.3	1.9	2.6
Toshiba	156	237	278	12.5	11.9	11.6
Yamaha	16	9	7	1.3	0.5	0.3
Other Japanese Companies	0	16	20	0	0.8	0.8
European Companies	92	149	234	7.4	7.5	9.8
Austria Mikro Systeme	4	4	6	0.3	0.2	0.3
GEC Plessey	3	4	22	0.2	0.2	0.9
Mietec	1	1	1	0.1	0.1	0
Philips	55	85	158	4.4	4.3	6.6
SGS-Thomson	15	40	32	1.2	2.0	1.3
Siemens	2	1	0	0.2	0.1	0
TEMIC	NA	14	15	0	0.7	0.6
Other European Companies	12	0	0	1.0	0	0
Asia/Pacific Companies	258	320	266	20.7	16.1	11.1
Acer Labs	NA	0	2	0	0	0.1
Daewoo	2	3	4	0.2	0.2	0.2
Goldstar	15	38	42	1.2	1.9	1.8
Holtek	0	18	47	0	0.9	2.0
Hualon Microelectronics Corporation	35	30	34	2.8	1.5	1.4
Hyundai	0	1	3	0	0.1	0.1
MOSel/Vitelic	25	0	0	2.0	0	0
Samsung	110	139	124	8.8	7.0	5.2

(Continued)

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Table 1-11 (Continued)
Each Company's Factory Revenue from Shipments of MOS Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Silicon Integrated Systems	0	40	0	0	2.0	0
United Microelectronics	58	47	0	4.6	2.4	0
Winbond Electronics	13	4	10	1.0	0.2	0.4

NA = Not available
Source: Dataquest (March 1995)

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Table 1-12
Each Company's Factory Revenue from Shipments of Monolithic Analog ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	2,252	3,100	3,966	100.0	100.0	100.0
North American Companies	750	1,040	1,340	33.3	33.5	33.8
Advanced Micro Devices	12	25	40	0.5	0.8	1.0
Allegro MicroSystems	18	16	19	0.8	0.5	0.5
Analog Devices	27	67	90	1.2	2.2	2.3
AT&T	7	1	56	0.3	0	1.4
Atmel	1	1	0	0	0	0
Brooktree	7	8	15	0.3	0.3	0.4
Burr-Brown	4	4	6	0.2	0.1	0.2
California Micro Devices	1	4	2	0	0.1	0.1
Cherry Semiconductor	6	6	7	0.3	0.2	0.2
Cirrus Logic	2	11	17	0.1	0.4	0.4
Exar	16	19	18	0.7	0.6	0.5
Gennum	2	2	2	0.1	0.1	0.1
Gould AMI	3	4	0	0.1	0.1	0
Harris	24	34	25	1.1	1.1	0.6
Integrated Circuit Systems	0	4	24	0	0.1	0.6
IMP	0	2	4	0	0.1	0.1
International Rectifier	0	0	1	0	0	0
ITT	0	0	2	0	0	0.1
Kulite	1	1	0	0	0	0
Linear Technology	13	17	34	0.6	0.5	0.9
Linfinity	4	6	5	0.2	0.2	0.1
Maxim	14	16	21	0.6	0.5	0.5
Micrel	0	2	2	0	0.1	0.1
Micro Linear	7	10	6	0.3	0.3	0.2
Micro Power Systems	1	1	1	0	0	0
Mitel	10	18	14	0.4	0.6	0.4
Motorola	149	200	233	6.6	6.5	5.9
NCR	4	5	9	0.2	0.2	0.2
National Semiconductor	160	226	239	7.1	7.3	6.0
Raytheon	2	4	4	0.1	0.1	0.1
Rockwell	26	26	27	1.2	0.8	0.7
SEEQ Technology	1	1	0	0	0	0

(Continued)

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Table 1-12 (Continued)
Each Company's Factory Revenue from Shipments of Monolithic Analog ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Semtech	0	0	1	0	0	0
Sierra Semiconductor	14	15	17	0.6	0.5	0.4
Silicon Systems	96	135	175	4.3	4.4	4.4
Supertex	1	1	2	0	0	0.1
Telcom	NA	NA	4	0	0	0.1
Teledyne	5	6	0	0.2	0.2	0
Tektronix	1	1	0	0	0	0
Texas Instruments	64	80	154	2.8	2.6	3.9
Unitrode	8	10	13	0.4	0.3	0.3
VTC	33	51	51	1.5	1.6	1.3
Other North American Companies	6	0	0	0.3	0	0
Japanese Companies	878	1,195	1,522	39.0	38.5	38.4
Fuji Electric	0	5	9	0	0.2	0.2
Fujitsu	8	6	8	0.4	0.2	0.2
Hitachi	39	51	71	1.7	1.6	1.8
Matsushita	90	123	154	4.0	4.0	3.9
Mitsubishi	58	99	119	2.6	3.2	3.0
NEC	83	101	129	3.7	3.3	3.3
New JRC	26	52	58	1.2	1.7	1.5
OKI	0	0	1	0	0	0
Ricoh	2	3	4	0.1	0.1	0.1
Rohm	42	47	101	1.9	1.5	2.5
Sanyo	193	278	397	8.6	9.0	10.0
Seiko Epson	1	1	2	0	0	0.1
Sharp	6	19	24	0.3	0.6	0.6
Sony	95	142	96	4.2	4.6	2.4
Toko	4	6	8	0.2	0.2	0.2
Toshiba	225	257	332	10.0	8.3	8.4
Yamaha	6	5	9	0.3	0.2	0.2
European Companies	415	556	758	18.4	17.9	19.1
Austria Mikro Systeme	2	2	3	0.1	0.1	0.1
EM Microelectronics Marin	5	7	3	0.2	0.2	0.1
Ericsson	3	0	6	0.1	0	0.2

(Continued)

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Table 1-12 (Continued)
Each Company's Factory Revenue from Shipments of Monolithic Analog ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
GEC Plessey	62	25	29	2.8	0.8	0.7
Mietec	2	3	4	0.1	0.1	0.1
Philips	129	213	301	5.7	6.9	7.6
SGS-Thomson	171	219	326	7.6	7.1	8.2
Siemens	15	43	38	0.7	1.4	1.0
TEMIC	NA	44	48	0	1.4	1.2
Other European Companies	26	0	0	1.2	0	0
Asia/Pacific Companies	209	309	346	9.3	10.0	8.7
Daewoo	16	20	17	0.7	0.6	0.4
Goldstar	18	37	44	0.8	1.2	1.1
Holtek	0	15	0	0	0.5	0
Hualon Microelectronics Corporation	1	7	9	0	0.2	0.2
Korean Electronic Co.	27	32	42	1.2	1.0	1.1
Samsung	109	148	191	4.8	4.8	4.8
Winbond Electronics	13	50	43	0.6	1.6	1.1
Other Asia/Pacific Companies	25	0	0	1.1	0	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-13
Each Company's Factory Revenue from Shipments of Hybrid ICs to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	122	174	250	100.0	100.0	100.0
North American Companies	16	27	48	13.1	15.5	19.2
Analog Devices	2	2	4	1.6	1.1	1.6
Burr-Brown	1	1	0	0.8	0.6	0
Mitel	2	4	15	1.6	2.3	6.0
Motorola	3	15	25	2.5	8.6	10.0
National Semiconductor	3	0	0	2.5	0	0
Sipex	1	1	1	0.8	0.6	0.4
Tektronix	1	1	0	0.8	0.6	0
Unitrode	3	3	3	2.5	1.7	1.2
Japanese Companies	98	142	178	80.3	81.6	71.2
Fuji Electric	1	2	3	0.8	1.1	1.2
Fujitsu	4	4	5	3.3	2.3	2.0
Hitachi	6	7	11	4.9	4.0	4.4
Mitsubishi	1	1	1	0.8	0.6	0.4
NEC	1	1	1	0.8	0.6	0.4
Rohm	9	10	12	7.4	5.7	4.8
Sanken	40	60	80	32.8	34.5	32.0
Sanyo	25	45	53	20.5	25.9	21.2
Shindengen Electric	1	1	0	0.8	0.6	0
Sony	9	10	11	7.4	5.7	4.4
Toko	1	1	1	0.8	0.6	0.4
European Companies	8	5	24	6.6	2.9	9.6
Ericsson	0	0	10	0	0	4.0
Philips	3	0	10	2.5	0	4.0
TEMIC	NA	2	0	0	1.1	0
Other European Companies	5	3	4	4.1	1.7	1.6

NA = Not available
Source: Dataquest (March 1995)

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Table 1-14
Each Company's Factory Revenue from Shipments of Discrete Semiconductors to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	1,586	2,019	2,478	100.0	100.0	100.0
North American Companies	367	393	456	23.1	19.5	18.4
Allegro MicroSystems	1	3	2	0.1	0.1	0.1
General Instrument	71	82	88	4.5	4.1	3.6
Harris	8	14	18	0.5	0.7	0.7
Hewlett-Packard	2	2	7	0.1	0.1	0.3
International Rectifier	38	41	57	2.4	2.0	2.3
ITT	13	15	22	0.8	0.7	0.9
Microsemi	2	2	4	0.1	0.1	0.2
Motorola	166	198	211	10.5	9.8	8.5
National Semiconductor	24	30	36	1.5	1.5	1.5
Teccor Electronics	5	5	9	0.3	0.2	0.4
Telcom	NA	NA	0	0	0	0
Texas Instruments	1	1	2	0.1	0	0.1
Other North American Companies	36	0	0	2.3	0	0
Japanese Companies	761	1,065	1,307	48.0	52.7	52.7
Fuji Electric	40	57	85	2.5	2.8	3.4
Fujitsu	15	17	18	0.9	0.8	0.7
Hitachi	95	132	165	6.0	6.5	6.7
Matsushita	59	104	126	3.7	5.2	5.1
Mitsubishi	43	62	69	2.7	3.1	2.8
NEC	87	102	109	5.5	5.1	4.4
Rohm	47	55	98	3.0	2.7	4.0
Sanken	61	78	94	3.8	3.9	3.8
Sanyo	65	113	147	4.1	5.6	5.9
Shindengen Electric	19	28	40	1.2	1.4	1.6
Sony	8	19	9	0.5	0.9	0.4
Toko	7	16	19	0.4	0.8	0.8
Toshiba	215	282	328	13.6	14.0	13.2
European Companies	248	341	433	15.6	16.9	17.5
ABB-IXYS	0	0	6	0	0	0.2
Eupec	4	4	5	0.3	0.2	0.2

(Continued)

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Table 1-14 (Continued)
Each Company's Factory Revenue from Shipments of Discrete Semiconductors to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Fagor	4	3	5	0.3	0.1	0.2
GEC Plessey	3	3	3	0.2	0.1	0.1
Philips	107	140	192	6.7	6.9	7.7
Semikron	11	11	14	0.7	0.5	0.6
SGS-Thomson	52	77	90	3.3	3.8	3.6
Siemens	26	30	33	1.6	1.5	1.3
TEMIC	NA	62	75	0	3.1	3.0
Zetex	6	6	6	0.4	0.3	0.2
Other European Companies	35	5	4	2.2	0.2	0.2
Asia/Pacific Companies	210	220	282	13.2	10.9	11.4
Dongsung Semiconductor	10	2	0	0.6	0.1	0
Goldstar	11	0	0	0.7	0	0
Korean Electronic Co.	78	100	134	4.9	5.0	5.4
Samsung	90	118	148	5.7	5.8	6.0
Other Asia/Pacific Companies	21	0	0	1.3	0	0

NA = Not available
Source: Dataquest (March 1995)

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Table 1-15
Each Company's Factory Revenue from Shipments of Optoelectronic Semiconductors to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1992	1993	1994	1992	1993	1994
Total Market	264	393	516	100.0	100.0	100.0
North American Companies	45	54	63	17.0	13.7	12.2
Hewlett-Packard	7	9	21	2.7	2.3	4.1
Motorola	6	11	12	2.3	2.8	2.3
Optek	1	1	1	0.4	0.3	0.2
Quality Technologies	7	8	9	2.7	2.0	1.7
Tektronix	1	1	0	0.4	0.3	0
Texas Instruments	3	0	0	1.1	0	0
Other North American Companies	20	24	20	7.6	6.1	3.9
Japanese Companies	179	285	416	67.8	72.5	80.6
Fujitsu	7	5	5	2.7	1.3	1.0
Hitachi	10	12	18	3.8	3.1	3.5
Matsushita	13	32	41	4.9	8.1	7.9
Mitsubishi	0	0	15	0	0	2.9
NEC	6	7	8	2.3	1.8	1.6
New JRC	1	1	3	0.4	0.3	0.6
Rohm	8	9	28	3.0	2.3	5.4
Sanken	6	2	2	2.3	0.5	0.4
Sanyo	20	22	33	7.6	5.6	6.4
Sharp	43	72	100	16.3	18.3	19.4
Sony	10	18	25	3.8	4.6	4.8
Toshiba	25	50	68	9.5	12.7	13.2
Other Japanese Companies	30	55	70	11.4	14.0	13.6
European Companies	15	20	25	5.7	5.1	4.8
Ericsson	0	0	1	0	0	0.2
Siemens	5	6	9	1.9	1.5	1.7
TEMIC	NA	13	14	0	3.3	2.7
Other European Companies	10	1	1	3.8	0.3	0.2
Asia/Pacific Companies	25	34	12	9.5	8.7	2.3
Korean Electronic Co.	6	8	9	2.3	2.0	1.7
Samsung	0	4	3	0	1.0	0.6
Other Asia/Pacific Companies	19	22	0	7.2	5.6	0

NA = Not available
Source: Dataquest (March 1995)

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Section 2: Final 1994 Asia/Pacific Semiconductor Market Share Rankings

Table 2-1
Top 40 Companies' Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Toshiba	1,324	1,706	29	7.6
2	2	Samsung	1,188	1,593	34	7.1
3	4	Intel	1,170	1,560	33	6.9
4	3	Motorola	1,188	1,284	8	5.7
5	6	Hitachi	747	1,089	46	4.8
6	7	NEC	713	1,067	50	4.7
7	8	Texas Instruments	696	1,058	52	4.7
8	5	Sanyo	749	966	29	4.3
9	10	Mitsubishi	529	812	53	3.6
10	12	Philips	517	763	48	3.4
11	9	Goldstar	590	674	14	3.0
12	13	SGS-Thomson	432	564	31	2.5
13	16	Hyundai	323	541	67	2.4
14	14	Matsushita	424	512	21	2.3
15	11	National Semiconductor	523	471	-10	2.1
16	17	Advanced Micro Devices	314	445	42	2.0
17	20	Fujitsu	270	432	60	1.9
18	18	Sharp	306	424	39	1.9
19	21	United Microelectronics	231	352	52	1.6
20	15	IBM	333	330	-1	1.5
21	23	Siemens	203	314	55	1.4
22	19	Sony	305	284	-7	1.3
23	27	Rohm	143	276	93	1.2
24	22	OKI	226	273	21	1.2
25	24	Cirrus Logic	187	249	33	1.1
26	25	Micron Technology	167	245	47	1.1
27	26	Winbond	149	207	39	0.9
28	29	Korean Electronic Co.	140	185	32	0.8
29	30	Sanken	140	176	26	0.8
30	31	Silicon Systems	135	175	30	0.8
31	42	Yamaha	63	161	156	0.7
32	28	TEMIC	143	159	11	0.7

(Continued)

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Table 2-1 (Continued)
Top 40 Companies' Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
33	32	VLSI Technology	118	158	34	0.7
34	54	AT&T	43	148	244	0.7
35	39	Fuji Electric	71	107	51	0.5
36	33	MOSel/Vitelic	91	102	12	0.5
37	36	Analog Devices	76	102	34	0.5
38	40	Silicon Integrated Systems	70	101	44	0.4
39	38	Macronix	72	99	38	0.4
40	34	Hualon Microelectronics Corporation	83	89	7	0.4
		All Others	1,929	2,330	21	10.3
		North American Companies	6,356	7,903	24	35.0
		Japanese Companies	6,291	8,624	37	38.2
		European Companies	1,382	1,939	40	8.6
		Asia/Pacific Companies	3,092	4,117	33	18.2
		Total Market	17,121	22,583	32	100.0

Source: Dataquest (March 1995)

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Table 2-2
Top 40 Companies' Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Toshiba	1,324	1,706	29	7.6
2	2	Samsung	1,188	1,593	34	7.1
3	4	Intel	1,170	1,560	33	7.0
4	3	Motorola	1,173	1,259	7	5.6
5	5	Hitachi	740	1,078	46	4.8
6	6	NEC	712	1,066	50	4.8
7	8	Texas Instruments	696	1,058	52	4.7
8	7	Sanyo	704	913	30	4.1
9	10	Mitsubishi	528	811	54	3.6
10	12	Philips	517	753	46	3.4
11	9	Goldstar	590	674	14	3.0
12	13	SGS-Thomson	432	564	31	2.5
13	16	Hyundai	323	541	67	2.4
14	14	Matsushita	424	512	21	2.3
15	11	National Semiconductor	523	471	-10	2.1
16	17	Advanced Micro Devices	314	445	42	2.0
17	20	Fujitsu	266	427	61	1.9
18	18	Sharp	306	424	39	1.9
19	21	United Microelectronics	231	352	52	1.6
20	15	IBM	333	330	-1	1.5
21	23	Siemens	203	314	55	1.4
22	19	Sony	295	273	-7	1.2
23	22	OKI	226	273	21	1.2
24	30	Rohm	133	264	98	1.2
25	24	Cirrus Logic	187	249	33	1.1
26	25	Micron Technology	167	245	47	1.1
27	26	Winbond	149	207	39	0.9
28	28	Korean Electronic Co.	140	185	32	0.8
29	29	Silicon Systems	135	175	30	0.8
30	42	Yamaha	63	161	156	0.7
31	27	TEMIC	141	159	13	0.7
32	31	VLSI Technology	118	158	34	0.7
33	54	AT&T	43	148	244	0.7
34	40	Fuji Electric	69	104	51	0.5

(Continued)

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Table 2-2 (Continued)
Top 40 Companies' Factory Revenue from Shipments of Semiconductors to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
35	32	MOSel/Vitelic	91	102	12	0.5
36	39	Silicon Integrated Systems	70	101	44	0.5
37	38	Macronix	72	99	38	0.4
38	37	Analog Devices	74	98	32	0.4
39	35	Sanken	80	96	20	0.4
40	33	Hualon Microelectronics Corporation	83	89	7	0.4
		All Others	1,914	2,296	20	10.3
		North American Companies	6,329	7,855	24	35.2
		Japanese Companies	6,149	8,446	37	37.8
		European Companies	1,377	1,915	39	8.6
		Asia/Pacific Companies	3,092	4,117	33	18.4
		Total Market	16,947	22,333	32	100.0

Source: Dataquest (March 1995)

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Table 2-3
Top 40 Companies' Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Intel	1,170	1,560	33	8.0
2	2	Samsung	1,066	1,442	35	7.4
3	3	Toshiba	992	1,310	32	6.7
4	4	Motorola	979	1,061	8	5.4
5	5	Texas Instruments	695	1,056	52	5.4
6	7	NEC	604	950	57	4.8
7	8	Hitachi	603	906	50	4.6
8	6	Sanyo	614	786	28	4.0
9	11	Mitsubishi	467	728	56	3.7
10	9	Goldstar	590	674	14	3.4
11	12	Philips	377	571	51	2.9
12	15	Hyundai	323	541	67	2.8
13	13	SGS-Thomson	355	474	34	2.4
14	16	Advanced Micro Devices	314	445	42	2.3
15	10	National Semiconductor	493	435	-12	2.2
16	19	Fujitsu	248	409	65	2.1
17	21	United Microelectronics	231	352	52	1.8
18	17	Matsushita	288	345	20	1.8
19	14	IBM	333	330	-1	1.7
20	20	Sharp	234	324	38	1.7
21	22	OKI	226	273	21	1.4
22	24	Siemens	167	272	63	1.4
23	18	Sony	268	250	-7	1.3
24	23	Cirrus Logic	187	249	33	1.3
25	25	Micron Technology	167	245	47	1.3
26	26	Winbond	149	207	39	1.1
27	27	Silicon Systems	135	175	30	0.9
28	37	Yamaha	63	161	156	0.8
29	28	VLSI Technology	118	158	34	0.8
30	31	Rohm	79	150	90	0.8
31	50	AT&T	43	148	244	0.8
32	29	MOSel/Vitelic	91	102	12	0.5
33	32	Analog Devices	76	102	34	0.5
34	34	Silicon Integrated Systems	70	101	44	0.5

(Continued)

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Table 2-3 (Continued)
Top 40 Companies' Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
35	33	Macronix	72	99	38	0.5
36	30	Hualon Microelectronics Corporation	83	89	7	0.5
37	39	Sanken	60	80	33	0.4
38	40	Zilog	58	75	29	0.4
39	43	Trident Microsystems	54	75	39	0.4
40	35	TEMIC	68	70	3	0.4
		All Others	1,499	1,809	21	9.2
		North American Companies	5,909	7,384	25	37.7
		Japanese Companies	4,941	6,901	40	35.2
		European Companies	1,021	1,481	45	7.6
		Asia/Pacific Companies	2,838	3,823	35	19.5
		Total Market	14,709	19,589	33	100.0

Source: Dataquest (March 1995)

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Table 2-4
Top 40 Companies' Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Intel	1,170	1,560	33	8.1
2	2	Samsung	1,066	1,442	35	7.5
3	3	Toshiba	992	1,310	32	6.8
4	5	Texas Instruments	695	1,056	52	5.5
5	4	Motorola	964	1,036	7	5.4
6	6	NEC	603	949	57	4.9
7	7	Hitachi	596	895	50	4.6
8	9	Sanyo	569	733	29	3.8
9	11	Mitsubishi	466	727	56	3.8
10	8	Goldstar	590	674	14	3.5
11	12	Philips	377	561	49	2.9
12	15	Hyundai	323	541	67	2.8
13	13	SGS-Thomson	355	474	34	2.5
14	16	Advanced Micro Devices	314	445	42	2.3
15	10	National Semiconductor	493	435	-12	2.2
16	19	Fujitsu	244	404	66	2.1
17	21	United Microelectronics	231	352	52	1.8
18	17	Matsushita	288	345	20	1.8
19	14	IBM	333	330	-1	1.7
20	20	Sharp	234	324	38	1.7
21	22	OKI	226	273	21	1.4
22	24	Siemens	167	272	63	1.4
23	23	Cirrus Logic	187	249	33	1.3
24	25	Micron Technology	167	245	47	1.3
25	18	Sony	258	239	-7	1.2
26	26	Winbond	149	207	39	1.1
27	27	Silicon Systems	135	175	30	0.9
28	37	Yamaha	63	161	156	0.8
29	28	VLSI Technology	118	158	34	0.8
30	49	AT&T	43	148	244	0.8
31	34	Rohm	69	138	100	0.7
32	29	MOSel/Vitelic	91	102	12	0.5
33	33	Silicon Integrated Systems	70	101	44	0.5
34	32	Macronix	72	99	38	0.5

(Continued)

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Table 2-4 (Continued)
Top 40 Companies' Factory Revenue from Shipments of Integrated Circuits to Asia/Pacific, Excluding Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
35	31	Analog Devices	74	98	32	0.5
36	30	Hualon Microelectronics Corporation	83	89	7	0.5
37	39	Zilog	58	75	29	0.4
38	42	Trident Microsystems	54	75	39	0.4
39	36	TEMIC	66	70	6	0.4
40	45	Acer Labs	50	70	40	0.4
		All Others	1,432	1,702	19	8.8
		North American Companies	5,882	7,336	25	37.9
		Japanese Companies	4,799	6,723	40	34.8
		European Companies	1,016	1,457	43	7.5
		Asia/Pacific Companies	2,838	3,823	35	19.8
		Total Market	14,535	19,339	33	100.0

Source: Dataquest (March 1995)

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Table 2-5
Top 10 Companies' Factory Revenue from Shipments of Bipolar Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Texas Instruments	87	77	-11	21.3
2	3	Hitachi	67	72	7	19.9
3	2	National Semiconductor	77	59	-23	16.3
4	4	Motorola	55	58	5	16.0
5	5	Goldstar	38	38	0	10.5
6	6	Advanced Micro Devices	17	13	-24	3.6
7	NA	AT&T	0	11		3.0
8	7	Philips	14	9	-36	2.5
9	8	Toshiba	12	6	-50	1.7
10	9	Matsushita	5	6	20	1.7
		All Others	14	13	-7	3.6
		North American Companies	238	220	-8	60.8
		Japanese Companies	92	91	-1	25.1
		European Companies	18	13	-28	3.6
		Asia/Pacific Companies	38	38	0	10.5
		Total Market	386	362	-6	100.0

NA = Not available
Source: Dataquest (March 1995)

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Table 2-6
Top Four Companies' Factory Revenue from Shipments of Bipolar Digital Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Hitachi	4	3	-25	50.0
2	2	Advanced Micro Devices	1	2	100	33.3
3	NA	Philips	0	1		16.7
4	3	Texas Instruments	1	0	-100	0
		All Others	1	0	-100	0
		North American Companies	3	2	-33	33.3
		Japanese Companies	4	3	-25	50.0
		European Companies	0	1		16.7
		Asia/Pacific Companies	0	0		0
		Total Market	7	6	-14	100.0

NA = Not available
Source: Dataquest (March 1995)

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Table 2-7
Top 10 Companies' Factory Revenue from Shipments of Bipolar Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Texas Instruments	86	77	-10	21.6
2	3	Hitachi	63	69	10	19.4
3	2	National Semiconductor	76	59	-22	16.6
4	4	Motorola	55	58	5	16.3
5	5	Goldstar	38	38	0	10.7
6	6	Advanced Micro Devices	16	11	-31	3.1
7	NA	AT&T	0	11		3.1
8	7	Philips	14	8	-43	2.2
9	8	Toshiba	12	6	-50	1.7
10	9	Matsushita	5	6	20	1.7
		All Others	14	13	-7	3.7
		North American Companies	235	218	-7	61.2
		Japanese Companies	88	88	0	24.7
		European Companies	18	12	-33	3.4
		Asia/Pacific Companies	38	38	0	10.7
		Total Market	379	356	-6	100.0

Source: Dataquest (March 1995)

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Table 2-8
Top 40 Companies' Factory Revenue from Shipments of MOS Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Intel	1,170	1,560	33	10.4
2	2	Samsung	918	1,251	36	8.3
3	3	Toshiba	723	972	34	6.5
4	5	Texas Instruments	528	825	56	5.5
5	7	NEC	500	818	64	5.4
6	8	Hitachi	478	752	57	5.0
7	4	Motorola	709	745	5	5.0
8	9	Mitsubishi	362	604	67	4.0
9	6	Goldstar	515	592	15	3.9
10	11	Hyundai	323	541	67	3.6
11	14	Fujitsu	237	395	67	2.6
12	13	Advanced Micro Devices	272	392	44	2.6
13	15	United Microelectronics	231	352	52	2.3
14	12	Sanyo	291	336	15	2.2
15	10	IBM	333	330	-1	2.2
16	17	Sharp	215	300	40	2.0
17	16	OKI	226	272	20	1.8
18	22	Philips	150	251	67	1.7
19	20	Micron Technology	167	245	47	1.6
20	24	Siemens	124	234	89	1.6
21	19	Cirrus Logic	176	232	32	1.5
22	21	Matsushita	160	185	16	1.2
23	27	Winbond	99	164	66	1.1
24	25	VLSI Technology	118	158	34	1.1
25	33	Yamaha	58	152	162	1.0
26	23	SGS-Thomson	135	148	10	1.0
27	26	Sony	116	143	23	1.0
28	18	National Semiconductor	190	137	-28	0.9
29	28	MOSel/Vitelic	91	102	12	0.7
30	31	Silicon Integrated Systems	70	101	44	0.7
31	30	Macronix	72	99	38	0.7
32	41	AT&T	42	81	93	0.5
33	29	Hualon Microelectronics Corporation	76	80	5	0.5
34	34	Zilog	58	75	29	0.5

(Continued)

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Table 2-8 (Continued)
Top 40 Companies' Factory Revenue from Shipments of MOS Digital ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
35	36	Trident Microsystems	54	75	39	0.5
36	38	Acer Labs	50	70	40	0.5
37	46	Holtek	35	66	89	0.4
38	44	Atmel	38	59	55	0.4
39	35	Nittetsu Semiconductor	57	58	2	0.4
40	32	Western Digital	68	55	-19	0.4
		All Others	814	1,004	23	6.7
		North American Companies	4,604	5,776	25	38.5
		Japanese Companies	3,512	5,110	46	34.0
		European Companies	442	686	55	4.6
		Asia/Pacific Companies	2,491	3,439	38	22.9
		Total Market	11,049	15,011	36	100.0

Source: Dataquest (March 1995)

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Table 2-9
Top 30 Companies' Factory Revenue from Shipments of MOS Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Samsung	739	1,094	48	15.2
2	7	NEC	275	548	99	7.6
3	5	Hyundai	322	536	66	7.5
4	6	Hitachi	298	529	78	7.4
5	2	Goldstar	465	521	12	7.3
6	3	Toshiba	350	506	45	7.0
7	4	Texas Instruments	327	506	55	7.0
8	8	Mitsubishi	181	404	123	5.6
9	9	Fujitsu	171	310	81	4.3
10	10	Micron Technology	167	245	47	3.4
11	13	Siemens	119	228	92	3.2
12	11	Motorola	154	163	6	2.3
13	18	United Microelectronics	73	156	114	2.2
14	14	OKI	112	146	30	2.0
15	15	Sharp	91	134	47	1.9
16	20	Winbond	67	111	66	1.5
17	16	MOSel/Vitelic	91	102	12	1.4
18	17	Sanyo	80	90	13	1.3
19	19	SGS-Thomson	70	88	26	1.2
20	12	IBM	133	80	-40	1.1
21	22	Macronix	58	80	38	1.1
22	21	Matsushita	61	63	3	0.9
23	23	Nittetsu Semiconductor	57	58	2	0.8
24	29	Atmel	35	56	60	0.8
25	27	Advanced Micro Devices	38	49	29	0.7
26	24	Sony	51	47	-8	0.7
27	28	Hualon Microelectronics Corporation	36	46	28	0.6
28	25	Intel	40	45	13	0.6
29	30	Alliance Semiconductor	23	35	52	0.5
30	26	National Semiconductor	40	33	-18	0.5
		All Others	109	172	58	2.4

(Continued)

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Table 2-9 (Continued)
Top 30 Companies' Factory Revenue from Shipments of MOS Memory ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
		North American Companies	1,027	1,351	32	18.8
		Japanese Companies	1,750	2,861	63	39.8
		European Companies	199	323	62	4.5
		Asia/Pacific Companies	1,857	2,646	42	36.8
		Total Market	4,833	7,181	49	100.0

Source: Dataquest (March 1995)

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Table 2-10
Top 30 Companies' Factory Revenue from Shipments of MOS Microcomponent ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Intel	1,123	1,512	35	27.8
2	2	Motorola	441	456	3	8.4
3	3	Advanced Micro Devices	206	309	50	5.7
4	4	Cirrus Logic	176	232	32	4.3
5	11	United Microelectronics	111	196	77	3.6
6	7	Toshiba	136	188	38	3.5
7	5	Mitsubishi	169	185	9	3.4
8	6	NEC	150	174	16	3.2
9	10	Texas Instruments	115	168	46	3.1
10	20	Yamaha	49	145	196	2.7
11	9	Hitachi	116	143	23	2.6
12	22	IBM	44	113	157	2.1
13	21	VLSI Technology	47	106	126	1.9
14	36	Silicon Integrated Systems	25	101	304	1.9
15	14	Philips	58	88	52	1.6
16	8	National Semiconductor	120	76	-37	1.4
17	12	Sanyo	85	76	-11	1.4
18	15	Zilog	58	75	29	1.4
19	16	Trident Microsystems	54	75	39	1.4
20	18	Acer Labs	50	68	36	1.3
21	13	Western Digital	68	55	-19	1.0
22	24	OPTi	43	53	23	1.0
23	19	OKI	50	52	4	1.0
24	25	Chips & Technologies	42	46	10	0.8
25	29	Sharp	35	46	31	0.8
26	32	Winbond	28	43	54	0.8
27	31	Fujitsu	30	41	37	0.8
28	37	Cyrix	25	40	60	0.7
29	30	AT&T	33	37	12	0.7
30	26	Adaptec	41	36	-12	0.7
		All Others	497	503	1	9.2

(Continued)

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Table 2-10 (Continued)
Top 30 Companies' Factory Revenue from Shipments of MOS Microcomponent ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
		North American Companies	2,926	3,638	24	66.9
		Japanese Companies	891	1,144	28	21.0
		European Companies	94	129	37	2.4
		Asia/Pacific Companies	314	527	68	9.7
		Total Market	4,225	5,438	29	100.0

Source: Dataquest (March 1995)

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Table 2-11
Top 30 Companies' Factory Revenue from Shipments of MOS Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Toshiba	237	278	17	11.6
2	4	Sanyo	126	170	35	7.1
3	8	Philips	85	158	86	6.6
4	7	Texas Instruments	86	151	76	6.3
5	2	IBM	156	137	-12	5.7
6	5	Motorola	114	126	11	5.3
7	3	Samsung	139	124	-11	5.2
8	6	Sharp	89	120	35	5.0
9	9	NEC	75	96	28	4.0
10	10	Matsushita	73	87	19	3.6
11	12	Hitachi	64	80	25	3.3
12	13	OKI	64	74	16	3.1
13	17	Sony	38	61	61	2.6
14	11	VLSI Technology	71	52	-27	2.2
15	26	Holtek	18	47	161	2.0
16	19	Fujitsu	36	44	22	1.8
17	32	AT&T	9	44	389	1.8
18	18	Goldstar	38	42	11	1.8
19	20	Hewlett-Packard	34	37	9	1.5
20	21	Hualon Microelectronics Corporation	30	34	13	1.4
21	23	Advanced Micro Devices	28	34	21	1.4
22	15	SGS-Thomson	40	32	-20	1.3
23	46	Dallas Semiconductor	3	31	933	1.3
24	22	National Semiconductor	30	28	-7	1.2
25	43	GEC Plessey	4	22	450	0.9
26	25	Lattice	19	21	11	0.9
27	30	Rohm	11	21	91	0.9
28	36	Integrated Circuit Systems	8	17	113	0.7
29	28	TEMIC	14	15	7	0.6
30	29	Mitsubishi	12	15	25	0.6
		All Others	240	194	-19	8.1

(Continued)

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Table 2-11 (Continued)
Top 30 Companies' Factory Revenue from Shipments of MOS Logic ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
		North American Companies	651	787	21	32.9
		Japanese Companies	871	1,105	27	46.2
		European Companies	149	234	57	9.8
		Asia/Pacific Companies	320	266	-17	11.1
		Total Market	1,991	2,392	20	100.0

Source: Dataquest (March 1995)

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Table 2-12
Top 30 Companies' Factory Revenue from Shipments of Monolithic Analog ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Sanyo	278	397	43	10.0
2	2	Toshiba	257	332	29	8.4
3	4	SGS-Thomson	219	326	49	8.2
4	5	Philips	213	301	41	7.6
5	3	National Semiconductor	226	239	6	6.0
6	6	Motorola	200	233	17	5.9
7	7	Samsung	148	191	29	4.8
8	9	Silicon Systems	135	175	30	4.4
9	10	Matsushita	123	154	25	3.9
10	13	Texas Instruments	80	154	93	3.9
11	11	NEC	101	129	28	3.3
12	12	Mitsubishi	99	119	20	3.0
13	19	Rohm	47	101	115	2.5
14	8	Sony	142	96	-32	2.4
15	14	Analog Devices	67	90	34	2.3
16	16	Hitachi	51	71	39	1.8
17	15	New JRC	52	58	12	1.5
18	62	AT&T	1	56	5,500	1.4
19	17	VTC	51	51	0	1.3
20	20	TEMIC	44	48	9	1.2
21	22	Goldstar	37	44	19	1.1
22	18	Winbond	50	43	-14	1.1
23	24	Korean Electronic Co.	32	42	31	1.1
24	26	Advanced Micro Devices	25	40	60	1.0
25	21	Siemens	43	38	-12	1.0
26	32	Linear Technology	17	34	100	0.9
27	27	GEC Plessey	25	29	16	0.7
28	25	Rockwell	26	27	4	0.7
29	23	Harris	34	25	-26	0.6
30	29	Sharp	19	24	26	0.6
		All Others	258	299	16	7.5

(Continued)

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Table 2-12 (Continued)
Top 30 Companies' Factory Revenue from Shipments of Monolithic Analog ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
		North American Companies	1,040	1,340	29	33.8
		Japanese Companies	1,195	1,522	27	38.4
		European Companies	556	758	36	19.1
		Asia/Pacific Companies	309	346	12	8.7
		Total Market	3,100	3,966	28	100.0

Source: Dataquest (March 1995)

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Table 2-13
Top 10 Companies' Factory Revenue from Shipments of Hybrid ICs to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Sanken	60	80	33	32.0
2	2	Sanyo	45	53	18	21.2
3	3	Motorola	15	25	67	10.0
4	7	Mitel	4	15	275	6.0
5	4	Rohm	10	12	20	4.8
6	5	Sony	10	11	10	4.4
7	6	Hitachi	7	11	57	4.4
8	NA	Philips	0	10	NM	4.0
9	NA	Ericsson	0	10	NM	4.0
10	8	Fujitsu	4	5	25	2.0
		All Others	19	18	-5	7.2
		North American Companies	27	48	78	19.2
		Japanese Companies	142	178	25	71.2
		European Companies	5	24	380	9.6
		Asia/Pacific Companies	0	0	NM	0
		Total Market	174	250	44	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (March 1995)

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Table 2-14
Top 20 Companies' Factory Revenue from Shipments of Discrete Semiconductors to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Toshiba	282	328	16	13.2
2	2	Motorola	198	211	7	8.5
3	3	Philips	140	192	37	7.7
4	4	Hitachi	132	165	25	6.7
5	5	Samsung	118	148	25	6.0
6	6	Sanyo	113	147	30	5.9
7	9	Korean Electronic Co.	100	134	34	5.4
8	7	Matsushita	104	126	21	5.1
9	8	NEC	102	109	7	4.4
10	16	Rohm	55	98	78	4.0
11	11	Sanken	78	94	21	3.8
12	12	SGS-Thomson	77	90	17	3.6
13	10	General Instrument	82	88	7	3.6
14	15	Fuji Electric	57	85	49	3.4
15	13	TEMIC	62	75	21	3.0
16	14	Mitsubishi	62	69	11	2.8
17	17	International Rectifier	41	57	39	2.3
18	20	Shindengen Electric	28	40	43	1.6
19	18	National Semiconductor	30	36	20	1.5
20	19	Siemens	30	33	10	1.3
		All Others	128	153	20	6.2
		North American Companies	393	456	16	18.4
		Japanese Companies	1,065	1,307	23	52.7
		European Companies	341	433	27	17.5
		Asia/Pacific Companies	220	282	28	11.4
		Total Market	2,019	2,478	23	100.0

Source: Dataquest (March 1995)

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Table 2-15
Top 10 Companies' Factory Revenue from Shipments of Optoelectronic Semiconductors to Asia/Pacific (Millions of U.S. Dollars)

1994 Rank	1993 Rank		1993 Revenue	1994 Revenue	Percentage Change	1994 Market Share (%)
1	1	Sharp	72	100	39	19.4
2	2	Toshiba	50	68	36	13.2
3	3	Matsushita	32	41	28	7.9
4	4	Sanyo	22	33	50	6.4
5	9	Rohm	9	28	211	5.4
6	5	Sony	18	25	39	4.8
7	10	Hewlett-Packard	9	21	133	4.1
8	7	Hitachi	12	18	50	3.5
9	NA	Mitsubishi	0	15	NM	2.9
10	6	TEMIC	13	14	8	2.7
		All Others	156	153	-2	29.7
		North American Companies	54	63	17	12.2
		Japanese Companies	285	416	46	80.6
		European Companies	20	25	25	4.8
		Asia/Pacific Companies	34	12	-65	2.3
		Total Market	393	516	31	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (March 1995)

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Market Analysis



Semiconductors Asia/Pacific

Market Analysis

Asia/Pacific Semiconductor Pricing: 1995 in Review

Abstract: *This document presents an overview of 1995 pricing of selected semiconductor devices in South Korea, Taiwan, and Singapore. Market demand and growth of each device are shown by pricing fluctuations and lead times. Generally, the strong growth of devices such as memory products has been driven by the growth of application markets like communications and personal computers.*
By Ben Lee

Research Methodology

Dataquest tracks the monthly pricing of selected semiconductor devices by surveying semiconductor vendors, distributors, and end users. Within Asia/Pacific, Dataquest tracks three countries: South Korea, Taiwan, and Singapore. (South Korea has been included since February 1995). These brief analyses are the summation of notes made each month for the months of February through December. The 21 devices that we tracked in 1995 are:

- Standard logic (74AC244 and 4F244)
- Analog (7805-T092 and RS-232C-422)
- DRAM (1Mbx1, 4Mbx1, 1Mbx4, 512Kx8, 4Mbx4, 1Mbx16, and SIMM 4Mbx8)
- VRAM (128Kbx8)
- SRAM (128Kbx8-20/70 and 64Kbx4)
- EPROM (2Mb)
- Flash (2Mb, 4Mb)
- Microprocessors (486DX-33, 486DX2-60, Pentium, and PowerPC)

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Dataquest does not release company-specific information. The pricing data reported, in U.S. dollars, is collected during the previous month and averaged to reflect a country's semiconductor pricing for that month. Lead times for these devices are also provided. The Asia/Pacific data appears with other regional pricing (North America, Europe, and Japan) under the Semiconductor Supply and Pricing Worldwide service (SPSG-WW). Tables 1 through 4 show historical contract prices for Taiwan, Korea, Singapore, and Asia/Pacific.

The Memory-Intensive Market

The main semiconductor devices, such as flash, DRAM, SRAM, and microprocessors, play a dominant role in the Asia/Pacific market, as they do in the other regions of the world.

Asia/Pacific experienced tight supplies of DRAM and flash in the middle of the year, pushing up and sustaining prices.

Telecommunications, personal computers, and consumer electronics equipment are the main applications that supported growth of semiconductor device sales in 1995. The aggressiveness of Taiwanese suppliers contributed to the competitive environment in Asia/Pacific.

Memory

South Korea showed an overall increase, albeit gradual, keeping pace with the tight supply overseas.

1Mb DRAM

Pricing for 1Mbx1 DRAM showed slight fluctuations, following major applications in electronic games and, in some cases, CD-ROM drives (see Figure 1). During the launch of Windows 95 in the third quarter of 1995, Dataquest saw small price spikes in Singapore and Taiwan, while South Korea showed steady increases until November. Pricing was also affected by the swings of yen-dollar exchange rates. During August, Taiwan hit a high, with a 13 percent increase in prices. Singapore and Korea rose between 2 and 5 percent.

4Mb DRAM

The second quarter was a good season for 4Mb DRAM suppliers, with firm prices seen in Singapore and Taiwan. South Korea was the only country that showed a steady increase in pricing for the 1Mbx4 and 4Mbx1 devices.

The Taiwanese 4Mb DRAM market began to show signs of weakness as PC manufacturers began to switch to 16Mb devices in the third quarter. Singapore and South Korea, however, managed to maintain fairly firm pricing for the 1Mbx4 and 4Mbx1 devices in view of tight supplies of 16Mb (see Figures 2 and 3). High summer inventory (in response to a shortage in previous months) in Taiwan and Singapore could have been to blame for any sharp decrease in pricing.

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Table 1
Taiwan: Regional Historical Contract Prices, 1995 (U.S. Dollars)

Device Family	Feb. 20	Mar. 20	Apr. 17	May 15	Jun. 19	Jul. 17	Aug. 14	Sep. 18	Oct. 16	Nov. 13	Dec. 12
74AC244	0.28	0.27	0.28	0.29	0.29	0.28	0.27	0.28	0.46	0.46	0.46
Lead Time (Weeks)	4	4	4	4	4	4	4	3	4	4	4
386DX-40 CPGA	28.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	-
Lead Time (Weeks)	2	2	3	2	2	2	2	2	2	2	-
4F244	0.21	0.21	0.22	0.23	0.23	0.22	0.21	0.21	0.21	0.22	0.22
Lead Time (Weeks)	4	4	4	4	4	4	4	5	5	5	5
7805-TO92	0.22	0.21	0.22	0.23	0.23	0.23	0.21	0.21	0.21	0.22	0.22
RS-232C-422	0.17	0.17	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.18
Lead Time (Weeks)	5	5	6	4	4	4	4	4	4	4	3
DRAM 1Mbx1-70	3.90	3.90	3.76	3.76	3.76	3.45	3.90	3.53	3.55		-
DRAM 1Mbx16-60	53.50	53.50	53.50	56.50	56.50	56.50	56.50	57.50	56.50	57.50	53.50
DRAM 1Mbx4-60	15.76	15.26	15.26	15.76	15.76	15.40	14.26	14.26	12.76	13.76	13.10
DRAM 4Mbx1-60	15.76	15.90	15.26	15.90	15.90	15.70	13.76	14.60	13.10	13.26	12.76
DRAM 4Mbx4-70	58.50	58.50	57.00	55.00	55.00	53.00	53.00	55.50	54.50	53.00	52.50
DRAM 512Kbx8-70	-	-	-	-	-	-	-	-	-	-	-
DRAM SIMM 4Mbx8	127.00	127.00	128.00	129.50	129.50	126.50	127.00	127.00	113.50	121.00	110.00
EPROM 2Mb 150n	3.45	3.45	3.55	3.60	3.60	4.48	4.60	4.60	4.60	3.80	4.20
Flash 2Mb	6.35	6.35	6.35	6.30	6.30	6.10	8.35	9.26	7.76	8.26	8.26
Flash 4Mb	16.76	16.76	16.76	16.76	16.76	16.76	16.76	17.50	16.50	16.50	-
SRAM 128Kbx8-20	15.00	14.76	15.26	15.76	15.76	17.00	15.50	15.50	13.76	13.76	15.50
SRAM 128Kbx8-70	11.00	11.51	11.50	11.76	11.76	11.45	11.50	10.76	7.26	7.76	7.76
SRAM 64Kbx4-25	-	-	-	-	-	-	-	-	-	-	-
VRAM 128Kbx8-8	5.50	5.70	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.70	5.70
Lead Time (Weeks)	-	4	5	5	5	5	5	5	5	4	4
486DX-33 CPGA	96.50	91.50	91.50	91.00	91.00	86.00	86.00	86.00	86.00	-	-
486DX2-66	156.50	152.50	152.50	151.50	151.50	131.50	131.50	131.50	131.50	130.00	-
Pentium P5-60	275.50	282.50	282.50	282.50	282.50	257.50	257.50	257.50	257.50	257.00	-
PowerPC 601-66	-	-	-	-	-	-	-	-	-	-	-

Source: Dataquest (February 1996)

SAMM-AP-MA-9507 ©1996 Dataquest March 11, 1996

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Table 2
Korea: Regional Historical Contract Prices, 1995 (U.S. Dollars)

Device Family	Feb. 20	Mar. 20	Apr. 17	May 15	Jun. 19	Jul. 17	Aug. 14	Sep. 18	Oct. 16	Nov. 13	Dec. 12
74AC244	0.40	0.40	0.40	0.40	0.40	0.38	0.38	0.38	0.38	0.39	0.39
Lead Time (Weeks)	8	8	8	8	12	8	8	8	8	8	8
386DX-40 CPGA	21.00	21.00	21.00	21.00	21.00	19.50	19.50	19.50	19.50	19.50	19.50
Lead Time (Weeks)	6	6	6	6	6	6	6	6	6	6	6
4F244	0.24	0.24	0.23	0.22	0.23	0.24	0.24	0.24	0.24	0.24	0.24
Lead Time (Weeks)	8	8	8	8	16	8	8	8	8	8	8
7805-TO92	0.20	0.20	0.20	0.20	0.21	0.21	0.22	0.22	0.22	0.22	0.22
RS-232C-422	0.34	0.34	0.34	0.34	0.34	0.34	0.36	0.36	0.36	0.36	0.36
Lead Time (Weeks)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
DRAM 1Mbx1-70	3.76	3.76	3.55	3.55	3.53	3.60	3.70	3.78	3.78	3.65	3.65
DRAM 1Mbx16-60	55.50	55.50	50.00	50.00	50.00	51.50	53.00	53.50	53.50	52.00	48.50
DRAM 1Mbx4-60	11.80	11.80	11.60	11.60	12.40	12.50	13.00	13.00	13.00	12.76	12.50
DRAM 4Mbx1-60	12.00	12.00	11.60	11.60	12.40	12.50	13.00	13.00	13.00	12.50	12.50
DRAM 4Mbx4-70	45.26	44.26	44.26	44.26	43.50	46.00	47.00	47.50	47.50	47.50	45.50
DRAM 512Kbx8-70	13.76	13.76	13.26	13.26	13.00	13.00	13.77	13.50	13.50	13.50	13.50
DRAM SIMM 4Mbx8	106.00	106.00	106.00	106.00	106.00	106.50	109.50	112.00	115.00	115.00	107.50
EPROM 2Mb 150n	4.45	4.45	4.45	4.45	4.10	4.15	4.15	4.15	4.40	4.60	4.60
Flash 2Mb	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.20	8.00	8.00
Flash 4Mb	15.00	15.00	15.00	15.00	15.00	14.85	14.85	14.85	15.10	15.70	15.70
SRAM 128Kbx8-20	14.05	14.05	14.05	14.05	14.05	14.05	14.05	14.05	14.35	15.26	15.26
SRAM 128Kbx8-70	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.60	7.60	7.60
SRAM 64Kbx4-25	3.05	3.15	3.15	3.15	3.15	3.15	3.15	3.05	3.26	3.26	3.26
VRAM 128Kbx8-8	7.26	7.26	7.26	7.26	7.26	7.26	7.26	7.26	7.26	6.76	6.76
Lead Time (Weeks)	8	8	8	8	8	8	8	8	8	8	8
486DX-33 CPGA	95.00	95.00	95.00	95.00	95.00	91.00	92.50	92.50	70.00	70.00	70.00
486DX2-66	144.50	144.00	164.00	124.41	130.00	153.50	154.00	154.00	117.50	117.50	117.50
Pentium P5-60	275.00	273.50	245.00	245.00	245.00	235.00	235.00	192.50	215.00	215.00	175.00
PowerPC 601-66	175.00	175.00	175.00	189.50	189.50	187.50	187.38	187.38	205.00	175.00	170.00
Lead Time (Weeks)	6	6	6	6	6	6	6	6	6	6	6

Source: Dataquest (February 1996)

Table 3
Singapore: Regional Historical Contract Prices, 1995 (U.S. Dollars)

Device Family	Feb. 20	Mar. 20	Apr. 17	May 15	Jun. 19	Jul. 17	Aug. 14	Sep. 18	Oct. 16	Nov. 13	Dec. 12
74AC244	0.44	0.44	0.38	0.37	0.42	0.42	0.42	0.42	0.41	0.41	0.41
Lead Time (Weeks)		8	8	10	10	10	10	10	6	6	6
386DX-40 CPGA	22.50	16.00	16.00	20.00	18.00	14.50	-	-	-	-	-
Lead Time (Weeks)	6	4	6	8	8	6	-	-	-	-	-
4F244	0.21	0.24	0.24	0.26	0.28	0.26	0.26	0.28	0.28	0.28	0.28
Lead Time (Weeks)	4	4	8	12	12	10	8	10	6	6	6
7805-TO92	0.19	0.20	0.22	0.21	0.20	0.20	0.20	0.20	0.20	0.19	0.19
RS-232C-422	0.19	0.20	0.19	0.21	0.21	0.21	0.21	0.23	0.23	0.23	0.23
Lead Time (Weeks)	4	4	4	8	8	8	6	8	6	6	6
DRAM 1Mbx1-70	3.80	3.76	3.86	3.99	3.77	3.94	3.99	3.95	3.85	3.77	3.76
DRAM 1Mbx16-60	60.76	57.00	54.71	58.85	56.84	56.84	56.88	56.26	55.10	55.60	53.20
DRAM 1Mbx4-60	14.78	14.23	14.00	14.08	14.27	13.96	14.07	13.76	13.70	13.40	13.12
DRAM 4Mbx1-60	14.88	14.30	14.65	14.59	13.26	14.40	14.00	14.09	14.05	13.74	13.73
DRAM 4Mbx4-70	47.00	46.72	46.14	50.38	49.50	48.57	51.38	51.00	50.51	50.01	48.72
DRAM 512Kbx8-70	15.50	15.00	15.80	15.70	16.00	15.50	15.42	15.12	14.88	14.60	14.40
DRAM SIMM 4Mbx8	110.00	120.00	133.00	135.00	126.50	125.00	123.50	127.76	120.00	115.50	108.26
EPROM 2Mb 150n	5.23	4.65	4.34	5.80	5.80	4.70	4.70	5.20	5.20	5.20	4.93
Flash 2Mb	7.26	7.26	10.50	8.50	8.00	7.26	7.76	8.76	9.26	8.76	8.20
Flash 4Mb	16.28	16.33	18.20	17.50	16.55	15.70	15.83	16.89	15.88	15.64	15.35
SRAM 128Kbx8-20	14.60	14.30	15.26	14.74	14.50	14.26	17.37	17.26	16.76	16.33	16.53
SRAM 128Kbx8-70	8.98	8.20	9.63	8.37	8.14	8.49	8.35	8.39	7.80	7.48	7.08
SRAM 64Kbx4-25	3.10	3.10	3.55	3.16	3.78	3.80	3.38	3.38	3.80	3.15	2.88
VRAM 128Kbx8-8	6.30	6.00	6.50	6.15	6.30	7.20	7.28	7.35	7.45	6.71	6.71
Lead Time (Weeks)	-	-	-	10	10	-	8	10	8	8	8
486DX-33 CPGA	125.50	112.00	90.50	75.00	65.00	65.00	-	-	-	-	-
486DX2-66	146.50	111.50	98.76	103.00	102.00	100.00	68.26	57.00	54.50	46.50	45.00
Pentium P5-60	465.00	395.00	322.50	320.00	285.03	270.00	260.00	220.00	207.50	185.00	157.50
PowerPC 601-66	-	-	-	-	-	-	-	-	-	-	-
Lead Time (Weeks)	-	-	-	-	-	-	-	-	-	-	-

Source: Dataquest (February 1996)

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Table 4
Asia/Pacific: Regional Historical Contract Prices, 1995 (U.S. Dollars)

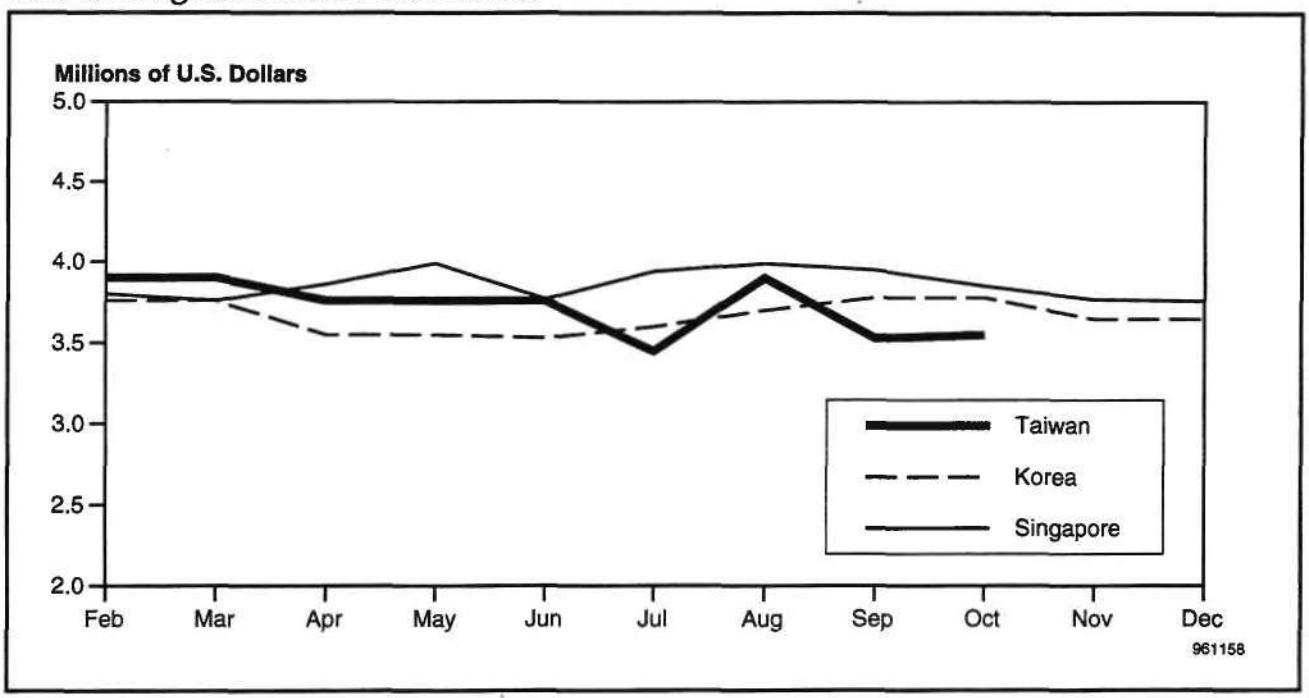
Device Family	Feb. 20	Mar. 20	Apr. 17	May 15	Jun. 19	Jul. 17	Aug. 14	Sep. 18	Oct. 16	Nov. 13	Dec. 12
74AC244	0.37	0.37	0.35	0.35	0.37	0.36	0.36	0.36	0.42	0.42	0.42
Lead Time (Weeks)	6	7	7	7	9	7	7	7	6	6	6
386DX-40 CPGA	23.83	19.33	19.33	20.67	20.00	18.33	20.25	20.25	20.25	20.25	19.50
Lead Time (Weeks)	5	4	5	5	5	5	4	4	4	4	6
4F244	0.22	0.23	0.23	0.24	0.25	0.24	0.24	0.24	0.24	0.25	0.25
Lead Time (Weeks)	5	5	7	8	11	7	7	8	6	6	6
7805-TO92	0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
RS-232C-422	0.23	0.24	0.24	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26
Lead Time (Weeks)	5	5	5	6	6	6	5	6	5	5	5
DRAM 1Mbx1-70	3.82	3.81	3.72	3.77	3.69	3.66	3.86	3.75	3.73	3.71	3.71
DRAM 1Mbx16-60	56.59	55.33	52.74	55.12	54.45	54.95	55.46	55.75	55.03	55.03	51.73
DRAM 1Mbx4-60	14.11	13.76	13.62	13.81	14.14	13.95	13.78	13.67	13.15	13.31	12.91
DRAM 4Mbx1-60	14.21	14.07	13.84	14.03	13.85	14.20	13.59	13.90	13.38	13.17	13.00
DRAM 4Mbx4-70	50.25	49.83	49.13	49.88	49.33	49.19	50.46	51.33	50.84	50.17	48.91
DRAM 512Kbx8-70	14.63	14.38	14.53	14.48	14.50	14.25	14.60	14.31	14.19	14.05	13.95
DRAM SIMM 4Mbx8	114.33	117.67	122.33	123.50	120.67	119.33	120.00	122.25	116.17	117.17	108.59
EPROM 2Mb 150n	4.38	4.18	4.11	4.62	4.50	4.44	4.48	4.65	4.73	4.53	4.58
Flash 2Mb	6.87	6.87	7.95	7.27	7.10	6.79	7.70	8.34	8.07	8.34	8.15
Flash 4Mb	16.01	16.03	16.65	16.42	16.10	15.77	15.81	16.41	15.83	15.95	15.53
SRAM 128Kbx8-20	14.55	14.37	14.86	14.85	14.77	15.10	15.64	15.60	14.96	15.12	15.76
SRAM 128Kbx8-70	9.13	9.04	9.51	9.18	9.10	9.11	9.08	8.85	7.55	7.61	7.48
SRAM 64Kbx4-25	3.08	3.13	3.35	3.16	3.47	3.48	3.27	3.22	3.53	3.21	3.07
VRAM 128Kbx8-8	6.35	6.32	6.51	6.39	6.44	6.74	6.77	6.79	6.82	6.39	6.39
Lead Time (Weeks)	8	6	7	8	8	7	7	8	7	7	7
486DX-33 CPGA	105.67	99.50	92.33	87.00	83.67	80.67	89.25	89.25	78.00	70.00	70.00
486DX2-66	149.17	136.00	138.42	126.30	127.83	128.33	117.92	114.17	101.17	98.00	81.25
Pentium P5-60	338.50	317.00	283.33	282.50	270.84	254.17	250.83	223.33	226.67	219.00	166.25
PowerPC 601-66	175.00	175.00	175.00	189.50	189.50	187.50	187.38	187.38	205.00	175.00	170.00
Lead Time (Weeks)	6	6	6	6	6	6	6	6	6	6	6

Source: Dataquest (February 1996)

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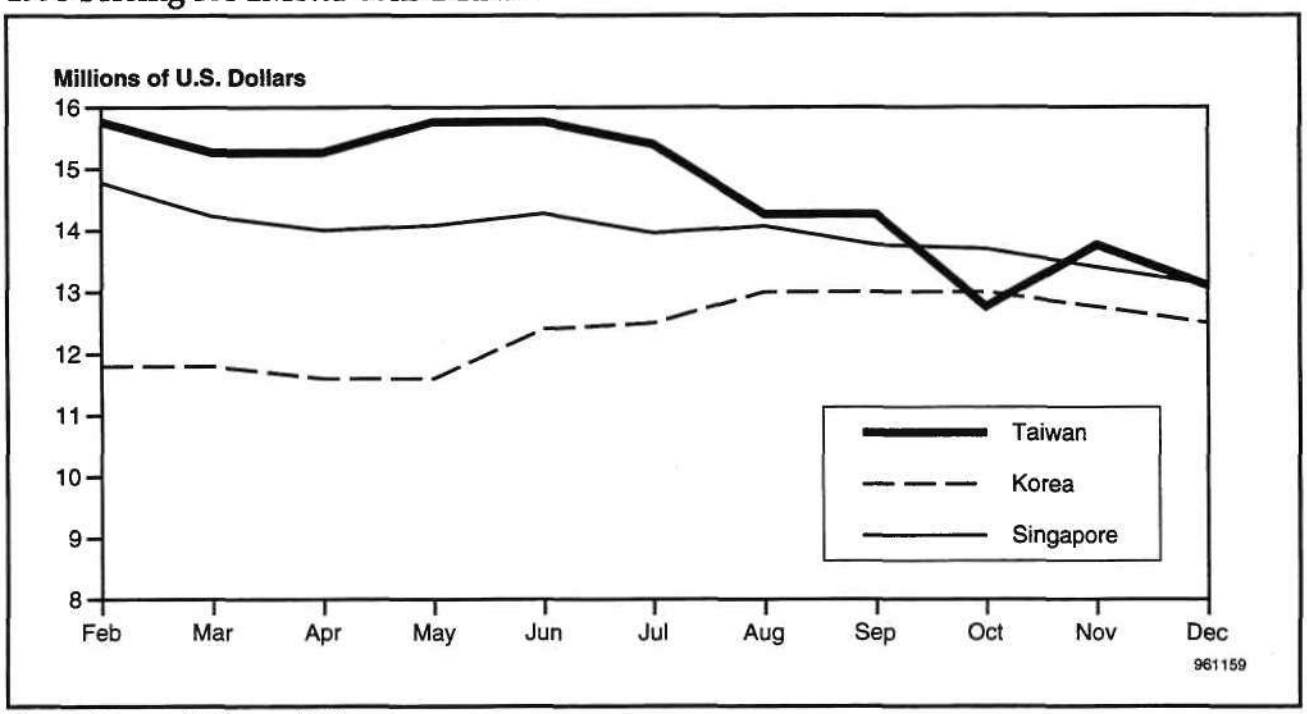
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Figure 1
1995 Pricing for 1Mbx1-70ns DRAM



Source: Dataquest (February 1996)

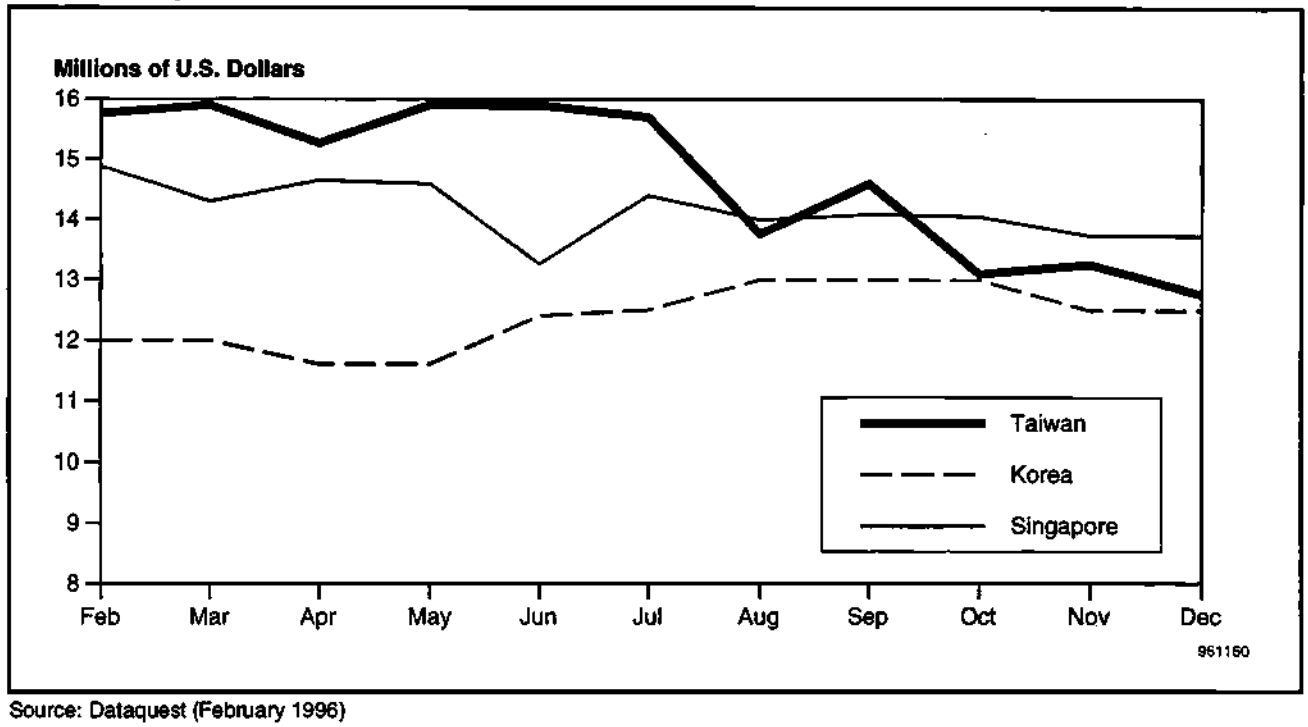
Figure 2
1995 Pricing for 1Mbx4-60ns DRAM



Source: Dataquest (February 1996)

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Figure 3
1995 Pricing for 4Mbx1-60ns DRAM



Source: Dataquest (February 1996)

August saw a temporary emotional response to the launch of Windows 95, with an overall increase in DRAM prices. Windows 95, heralded as the next major software, will help to multiply demand for 16Mb DRAM devices once the operating system becomes more widespread in desktops. Dataquest believes that memory requirements could double to 16MB per PC, the amount needed to run Windows 95 well, compared with the current average of 8MB per system.

Taiwan is the only country that did not track 512Kbx8 DRAM, which could reflect the lackluster interest in the wider-bit device. This wider-bit device experienced shortages during the second and early third quarters in Singapore, which saw firm pricing. However, pricing began a gentle slide as inventory levels improved (see Figure 4).

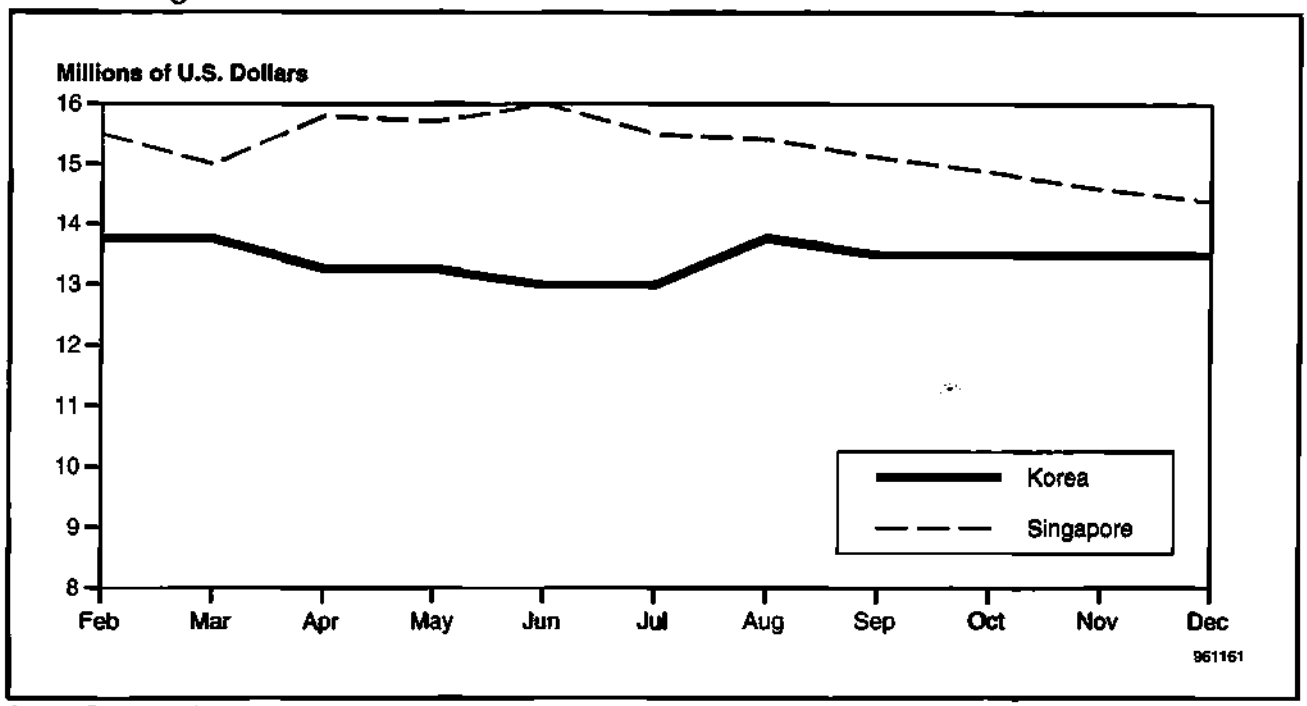
With a tight supply of 16Mb DRAM (particularly because of unsatisfactory yields from 1Mbx16 DRAM), the life cycle of the 4Mb DRAM will be lengthened somewhat.

16Mb DRAM

Pricing for 4Mbx4 DRAM softened slightly in Singapore in the middle of the year, mainly because of a shortage of PC peripherals such as rigid disk drives and CD-ROM drives. The Taiwanese market was soft until the end of the third quarter, when prices firmed because of high demand as the PC players geared up to sell off their stock before the end of the year. In South Korea, 4Mbx4 and 1Mbx16 DRAM pricing began to increase gradually before leveling off in anticipation of new systems loaded with Windows 95.

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Figure 4
1995 Pricing for 512Kbx8-70ns DRAM



Source: Dataquest (February 1996)

Pricing for 1Mbx16 DRAM devices decreased slightly in South Korea for November as users switched to a cheaper alternative, 4Mbx4. All three countries saw a maximum of a $5 drop in 1Mbx16 pricing in April. Figures 5 and 6 show pricing for 4Mbx4 and 1Mbx16 DRAM.

4Mbx8 SIMM

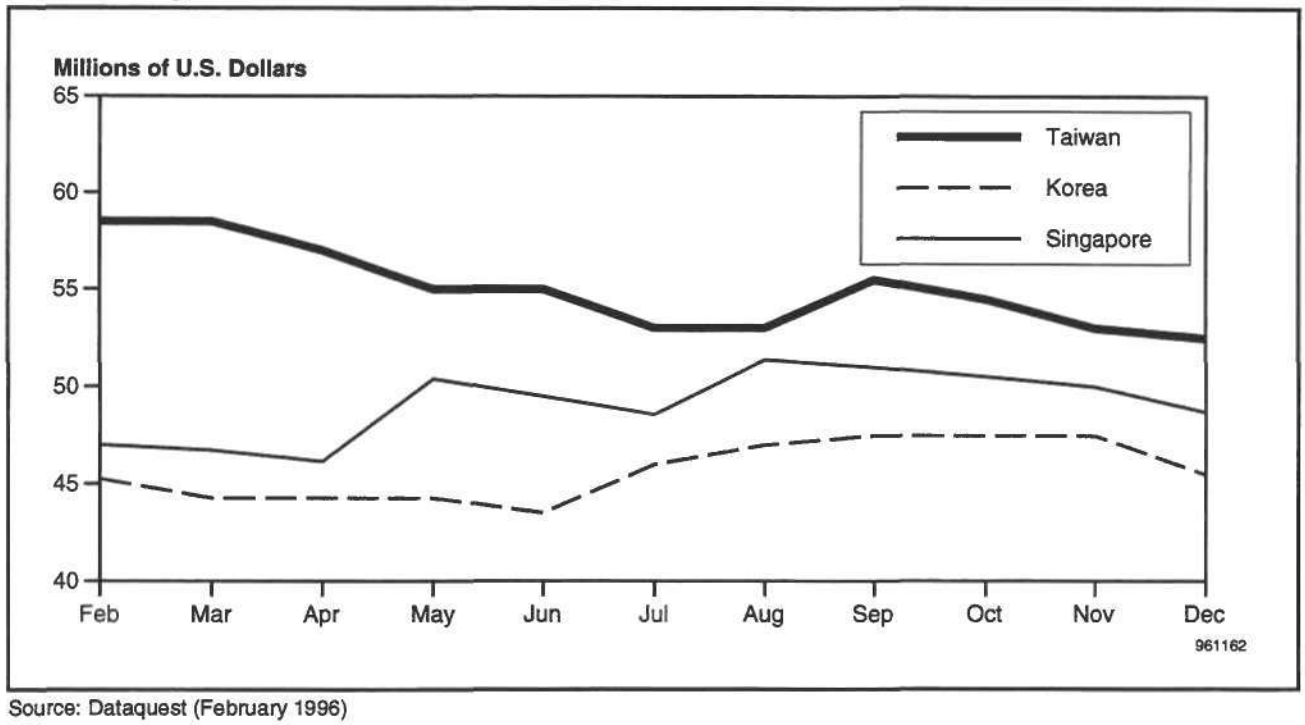
Singapore PC manufacturers chased after supplies of 4Mb(1Mbx4)x8 SIMMs, pushing up prices during the second quarter. However, the market softened from the third quarter toward the end of the year as suppliers tried to minimize or kill inventory. South Korea bucked the trend with a gentle increase in memory module pricing. Figure 7 shows 1995 4Mb(1Mbx4)x8 SIMMs pricing.

2Mb-150ns EPROM

EPROM pricing declined or remained low in Singapore and Taiwan because of oversupply during the first quarter of 1995. Singapore saw a sharp rise in EPROM pricing at the end of the second quarter resulting from extremely tight supply, which immediately eased with recovering inventory levels. Even though the communications and data processing industries were ready to switch to the favored flash device, pricing for EPROMs improved and remained firm as the supply of flash devices remained strained (see Figure 8).

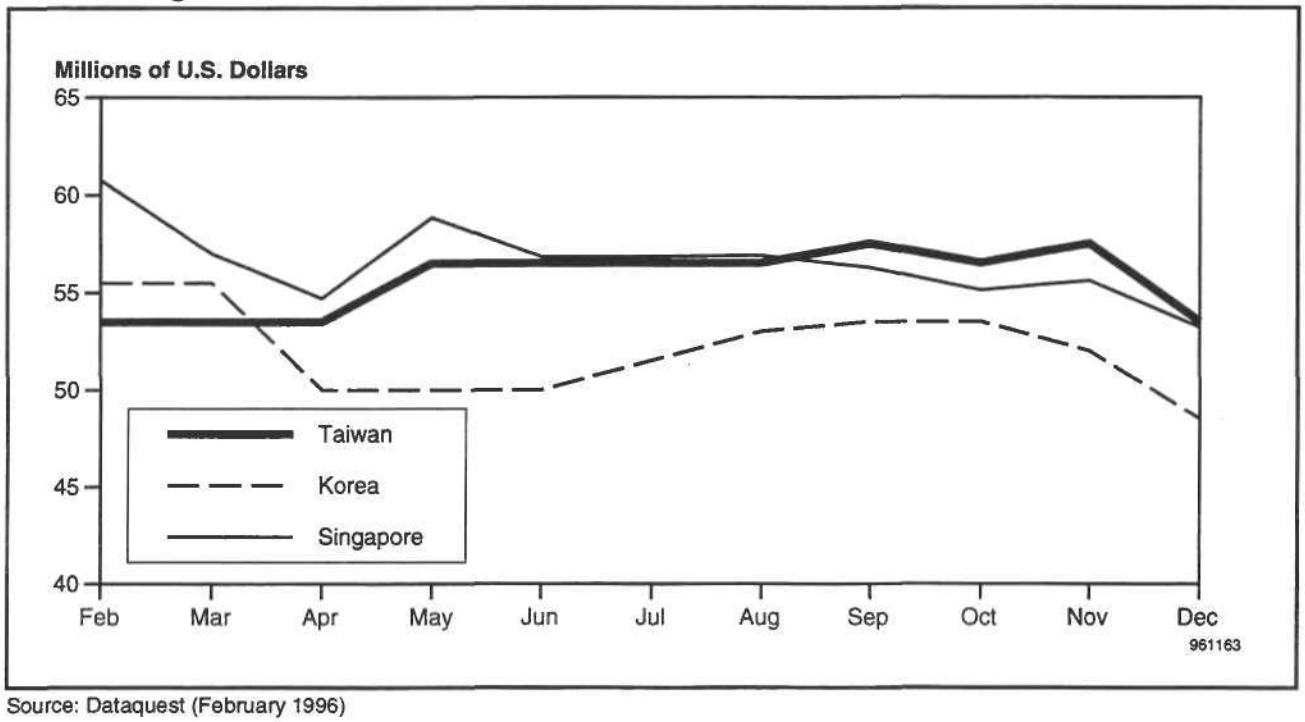
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Figure 5
1995 Pricing for 4Mbx4-70ns DRAM



Source: Dataquest (February 1996)

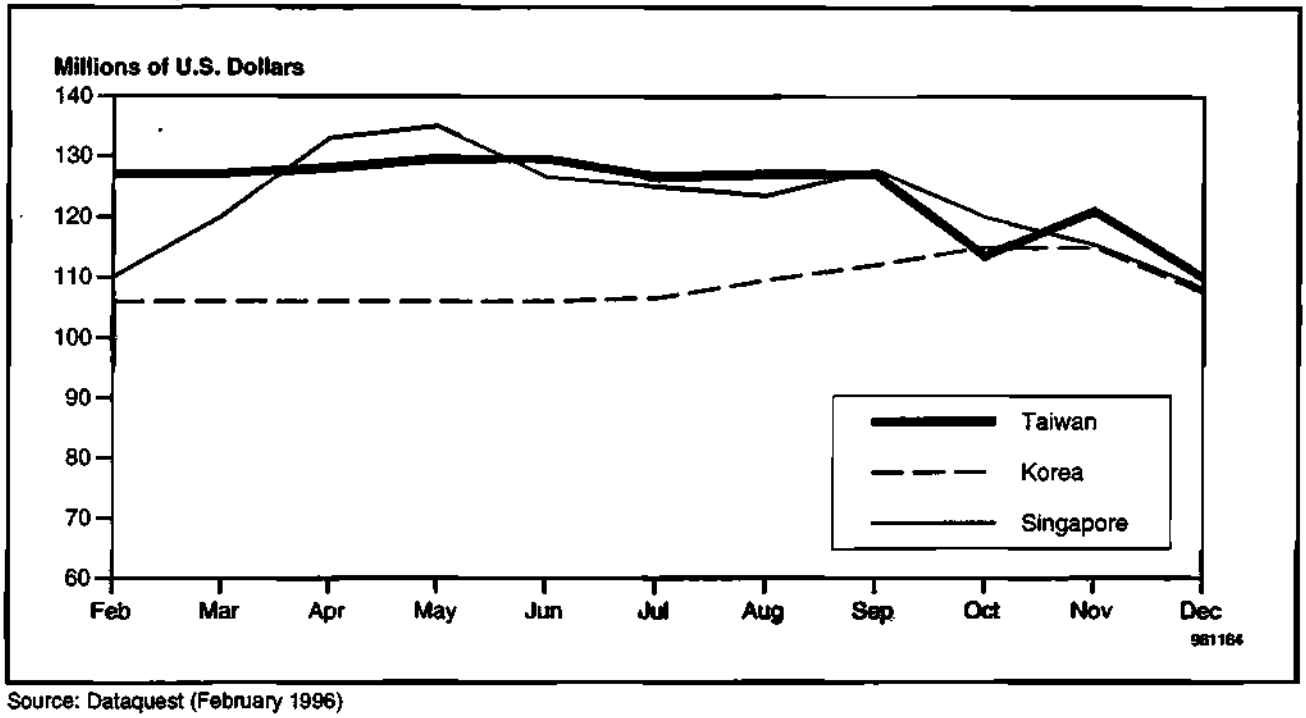
Figure 6
1995 Pricing for 1Mbx16-60ns DRAM



Source: Dataquest (February 1996)

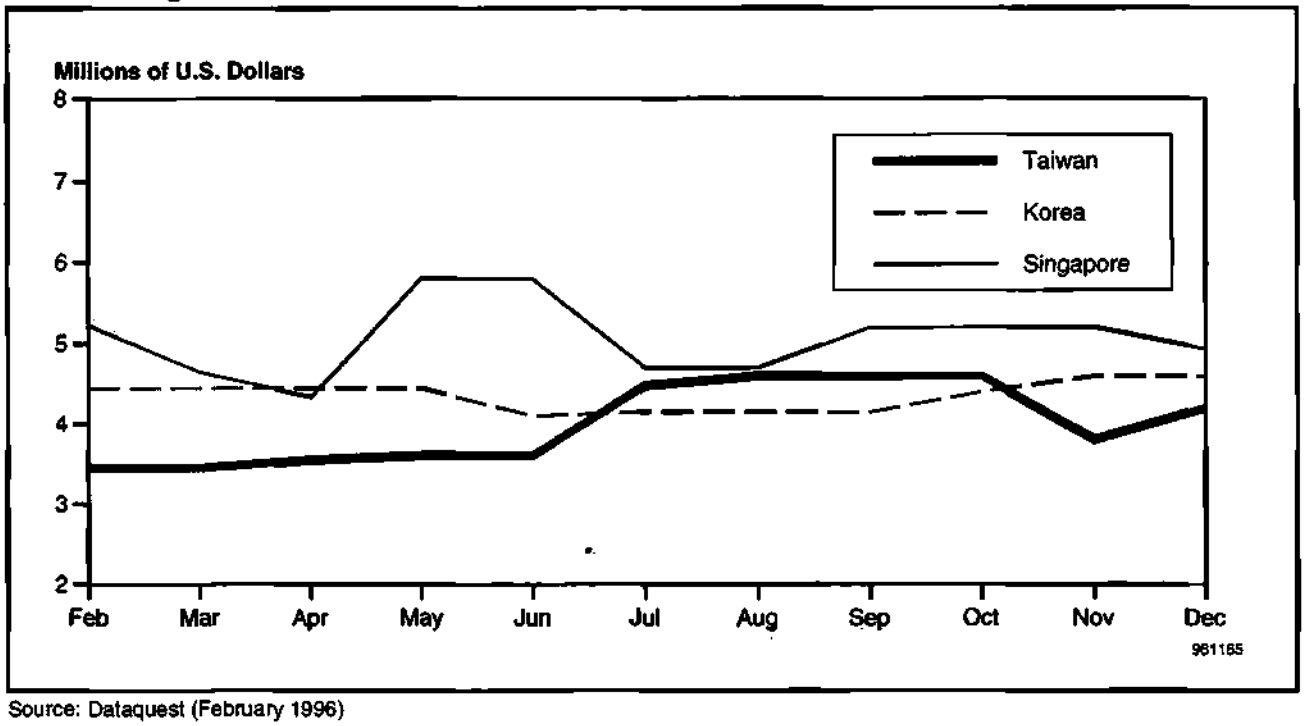
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Figure 7
1995 Pricing for 4Mb(1Mbx4)x8 DRAM SIMMs



Source: Dataquest (February 1996)

Figure 8
1995 Pricing for 2Mb-150ns EPROM



Source: Dataquest (February 1996)

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Flash

The constant change in inventory levels and supplies of flash devices resulted in active pricing movement in Singapore (for both the 2Mb and 4Mb, throughout the year) and Taiwan (for the 2Mb, but only after July). Overall, countries such as Singapore faced a shortage in the early part of the year, indicated by the great increases in price over the previous months (see Figures 9 and 10). Price hikes were being supported by telecommunications and PC players.

128Kbx8-20ns/70ns and 64Kbx4-25ns SRAM

Rigid disk drive manufacturers in Singapore began to favor fast SRAM, which experienced low inventory levels, beginning in the third quarter. South Korea's supply of SRAM was tight but was loaded with backlogs; however, pricing remained stable (see Figures 11 through 13). Taiwan saw a sharp price plunge in October, particularly in slow SRAM, because the SRAM shortage of late 1994 had been relieved. Both SRAM suppliers and PC makers tried to minimize or kill inventory, which also pulled the price down, and they forecast that prices would continue to decrease.

South Korea, Singapore, and Taiwan all started with the same price (a little over $3) for 64Kbx4-25ns SRAM, but South Korea managed to maintain pricing throughout the year. After October, 256Kb SRAM began to lose out to the more favored device, DRAM. In Taiwan, 256Kb SRAM was not popular, and low supply and demand kept the price more stable than in the other two countries. From December 1995, two local vendors, United Microelectronics Corporation and Winbond, began to mass-produce 32Kbx32 SRAM. The price, which was falling because of their aggressive production, made most PC makers move their procurement to this device.

1Mb VRAM

Singapore was the only country that showed price movement for 1Mb VRAM (see Figure 14). Pricing was stable in the South Korean and Taiwanese markets, with the former showing a dip in November (as in Singapore). Singapore was able to sustain firm pricing during the third quarter as some vendors made an exit to a higher bit type, leaving 1Mb VRAM supply levels low but still of interest among users. The trend, however, switched to 2Mb and 4Mb VRAM as 1Mb supply started to decrease.

Microprocessors

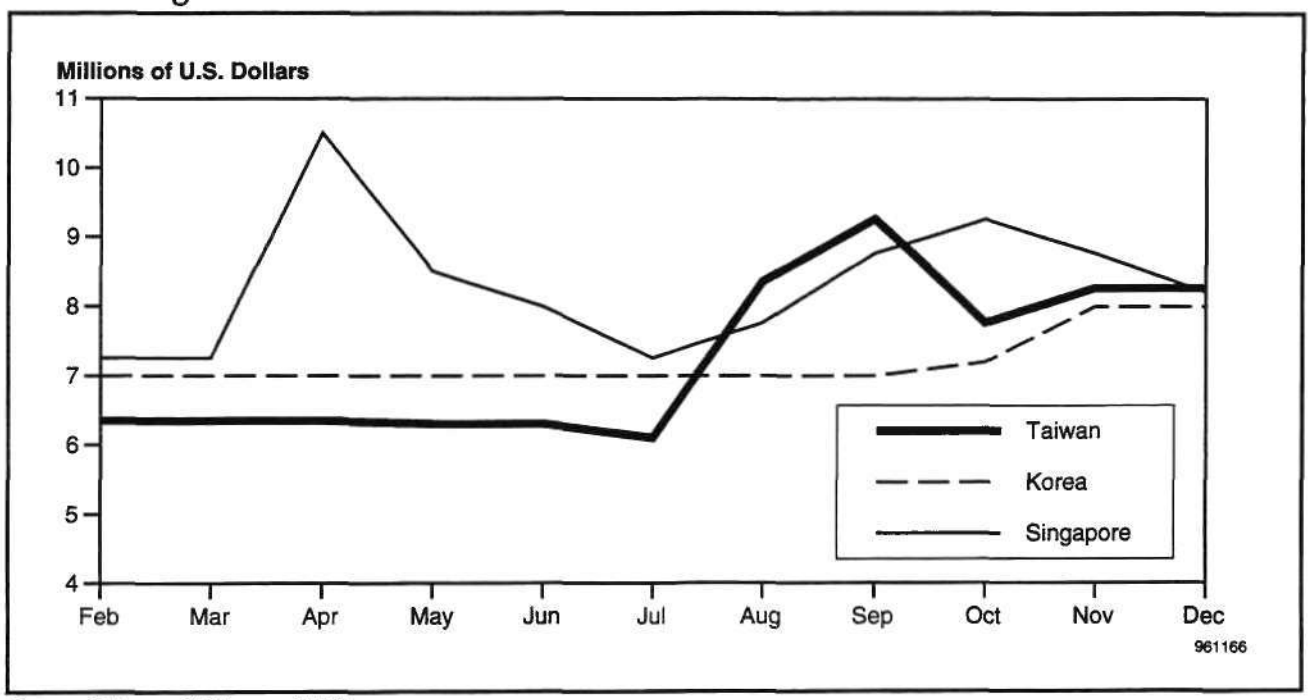
486

Following the demise of 386 microprocessors, the 486 class dominated the PC markets. The price of the 486DX-33 for Taiwan and South Korea hovered between $90 and $100 until September, when prices plunged in response to price cutting by rival Intel's Pentium chip (see Figure 15). Singapore was selling at the highest price at the beginning of the year, but slid below the other countries' price level. We stopped tracking the 386 after July, when it lost popularity.

The downturn of the 486 market is just around the corner. The 486DX2-66 continued to command the market, although the 486DX2-66 was sliding at faster rate than the Pentium P5-60 chip. The main factor that favored the

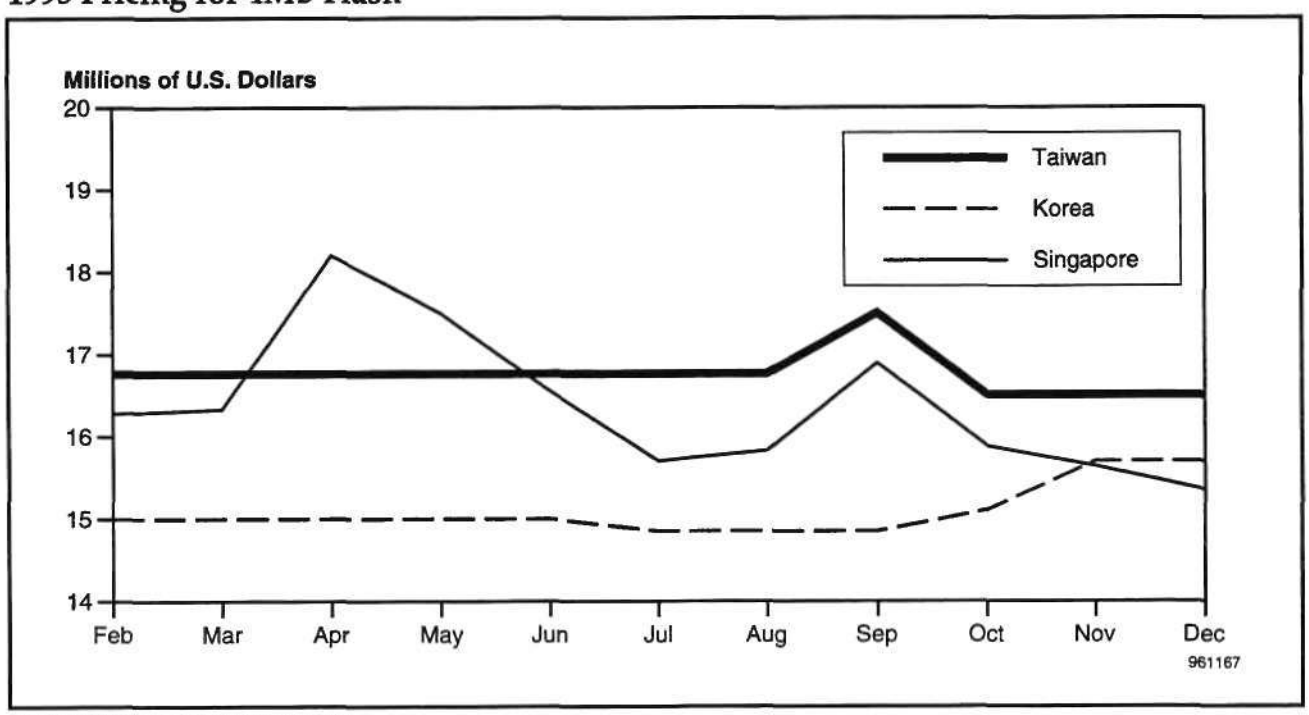
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Figure 9
1995 Pricing for 2Mb Flash



Source: Dataquest (February 1996)

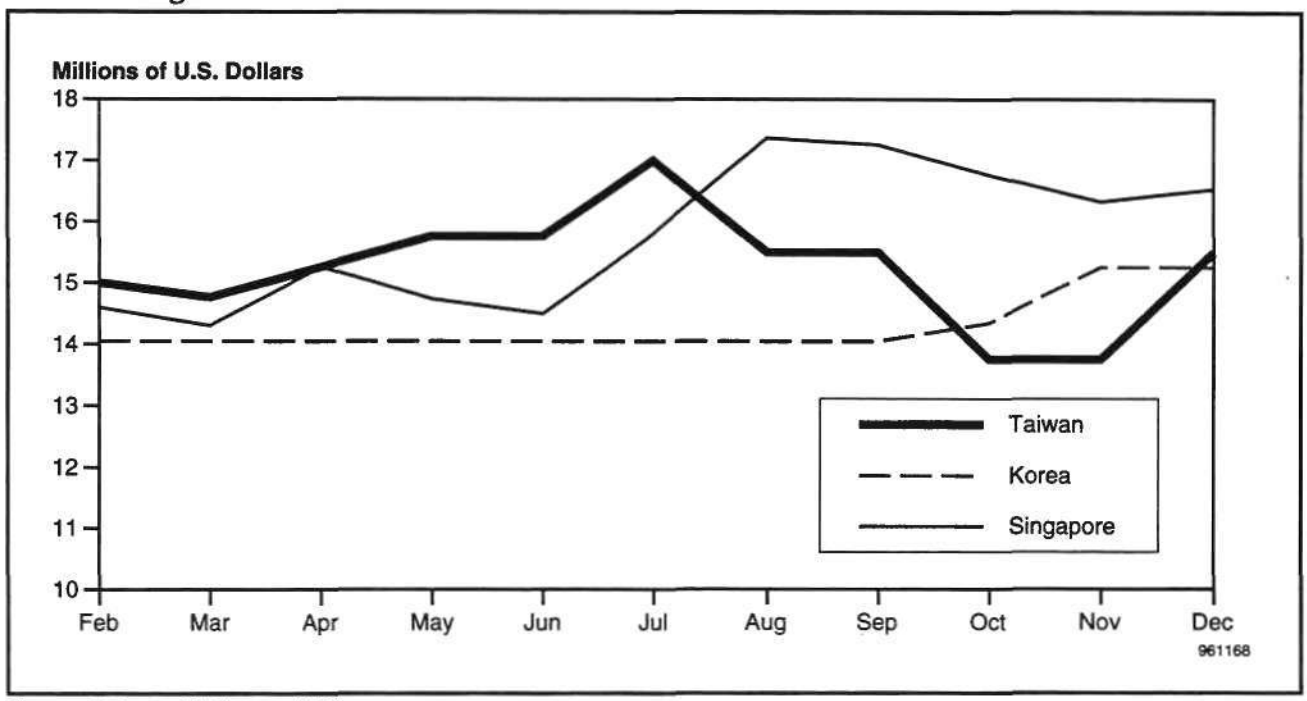
Figure 10
1995 Pricing for 4Mb Flash



Source: Dataquest (February 1996)

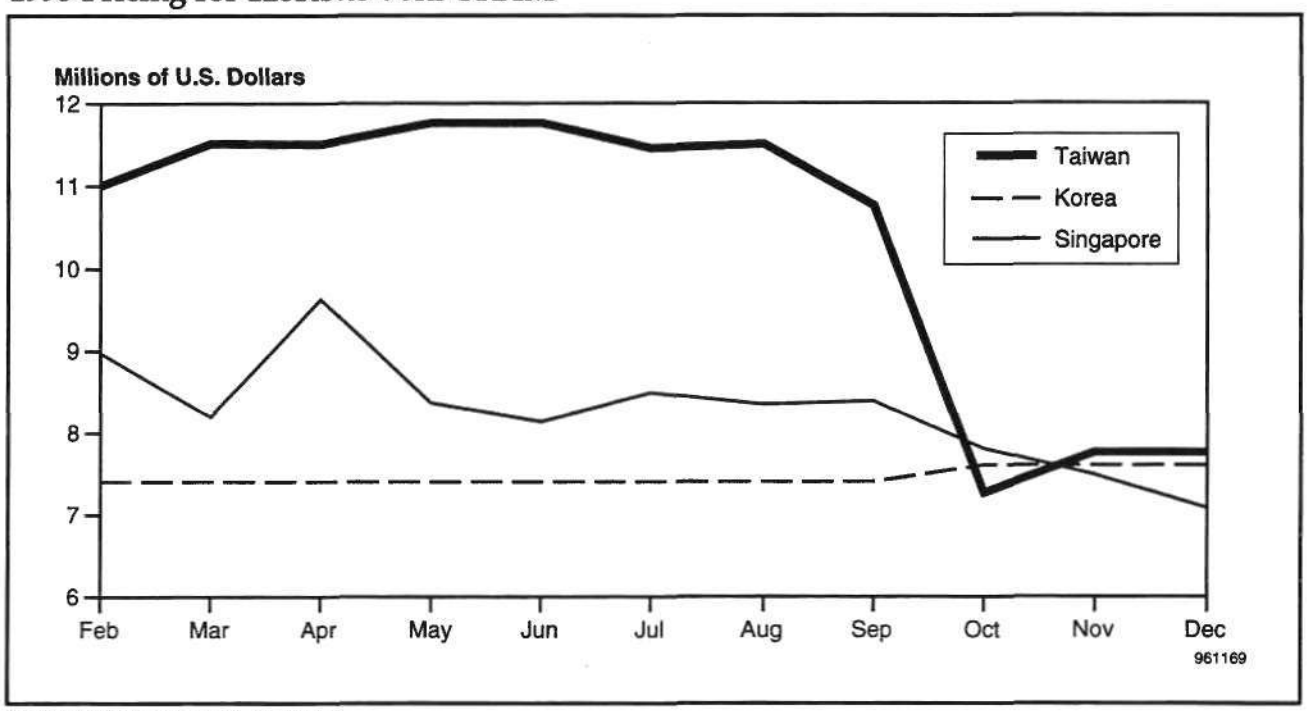
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Figure 11
1995 Pricing for 128Kbx8-20ns SRAM



Source: Dataquest (February 1996)

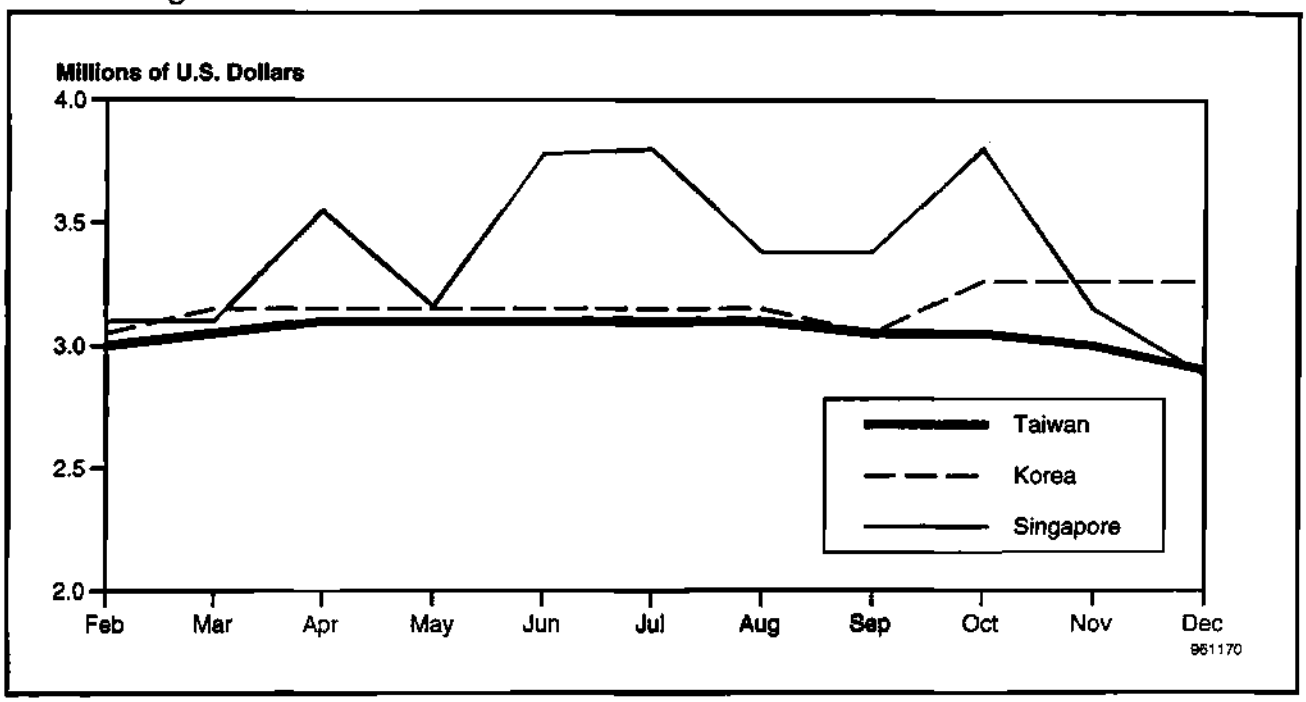
Figure 12
1995 Pricing for 128Kbx8-70ns SRAM



Source: Dataquest (February 1996)

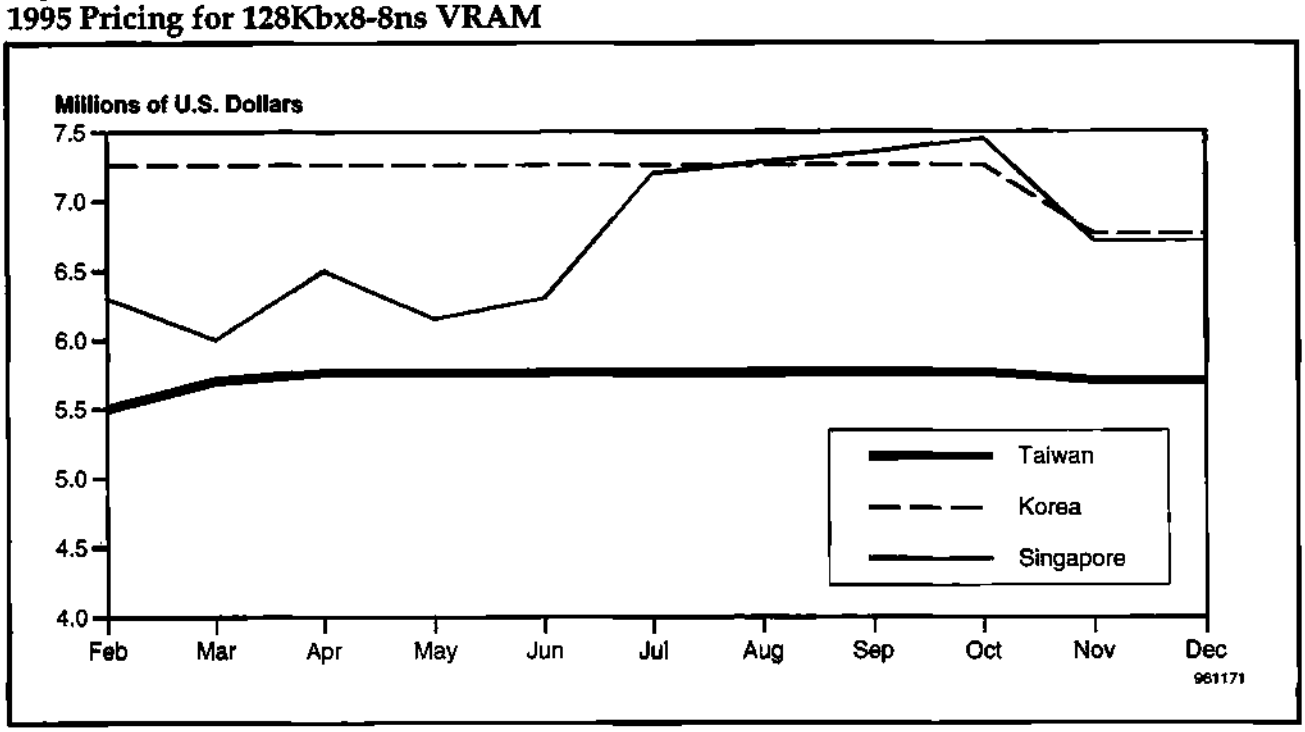
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Figure 13
1995 Pricing for 64Kbx4-25ns SRAM



Source: Dataquest (February 1996)

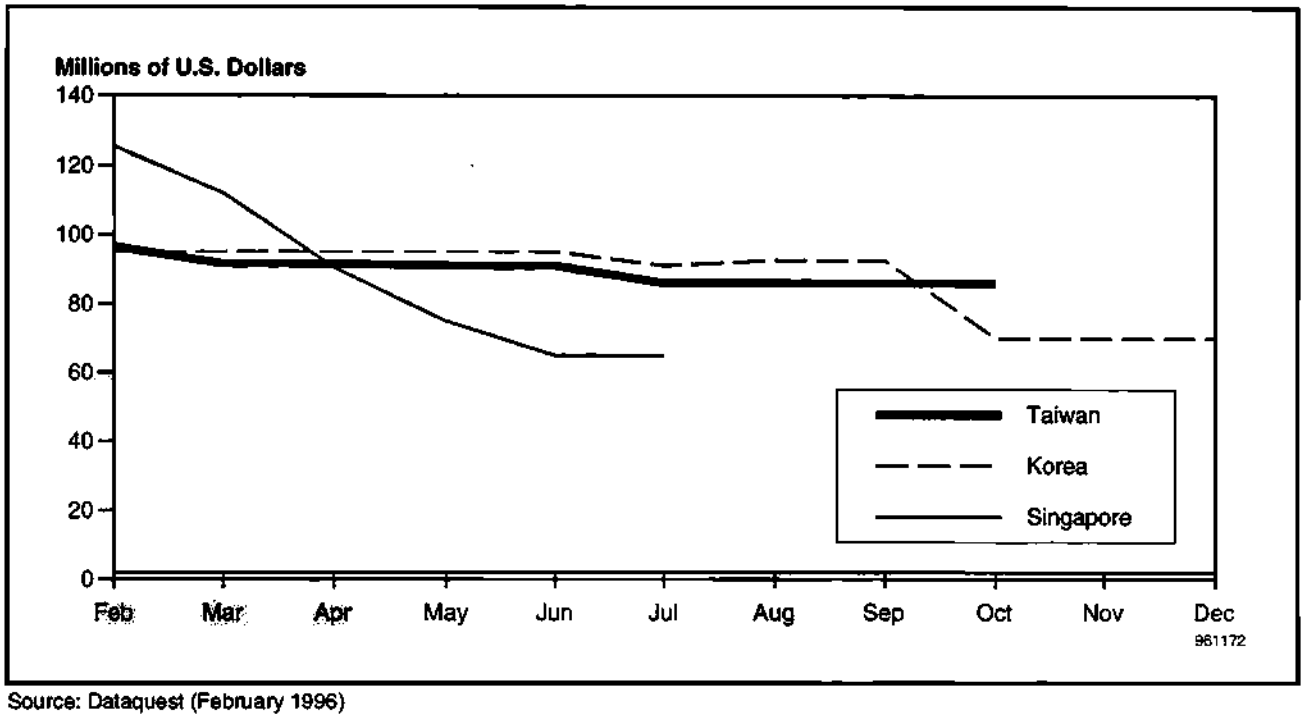
Figure 14
1995 Pricing for 128Kbx8-8ns VRAM



Source: Dataquest (February 1996)

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Figure 15
1995 Pricing for the 486DX-33 CPGA



Source: Dataquest (February 1996)

486DX2-66 over Pentium-based PCs was a big price difference (about $318.50 at the beginning of the year) because of fierce price cuts by PC players seeking to attract home users. Singapore showed the fastest decline in August, about 32 percent, as suppliers tried to kill off their inventory of 486DX2-66-based PCs faster. Singapore closed 1995 with the lowest pricing in the region, $45. The price difference observed between the P5-60 and 486DX2-66 chips was $112.50 in December.

The 486DX2-66 market in South Korea oscillated more this year than the Singapore and Taiwan markets (see Figure 16). This was mainly owing to slower demand at the end of the second quarter and users' deviation to Pentium-based PCs in the fourth quarter.

Pentium P5

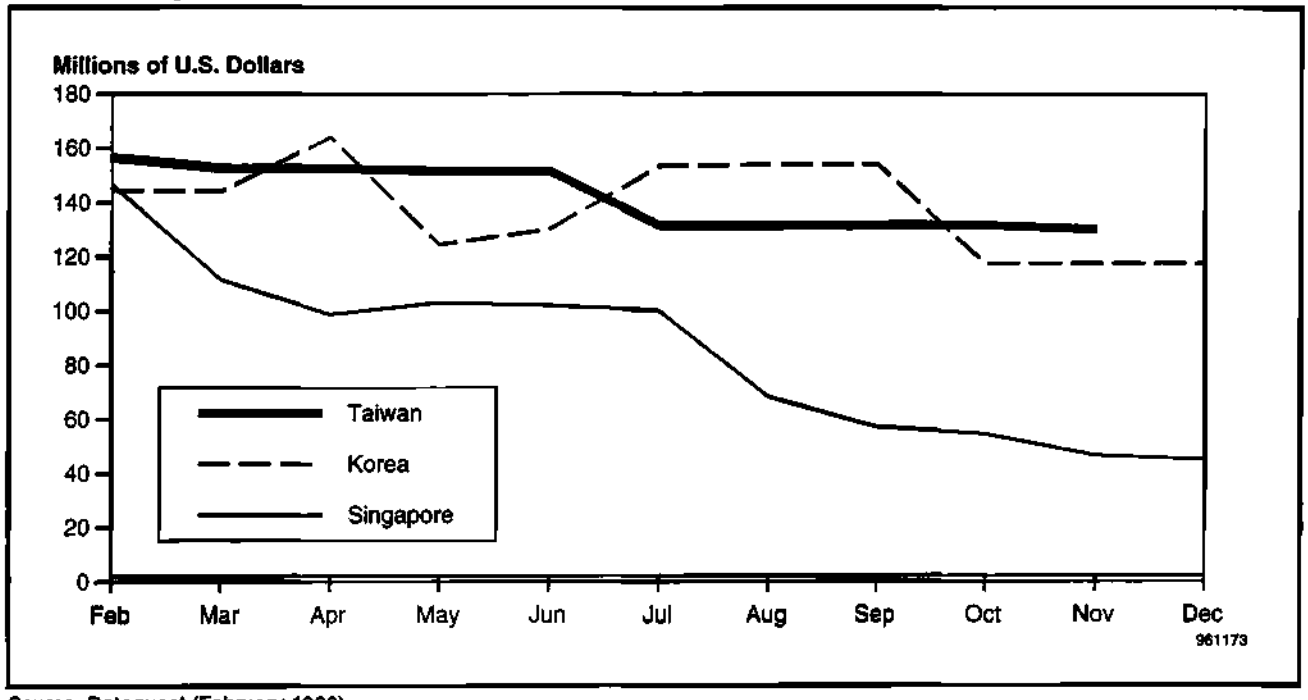
Pricing in Singapore for the Pentium P5-60 was higher than in the Taiwan and South Korea markets in the beginning of 1995 (see Figure 17). It crossed over the South Korea price level in August and the Taiwan price level before October. The Singapore Pentium P5-60 market closed at $157.50 in December, only about 7 percent higher than the 486DX2-66 price at the beginning of the year.

The Pentium P5-60 market showed little activity in Taiwan until early in the third quarter. This was mainly because the Pentium-75, Pentium-100, and Pentium-125 were gaining popularity over the Pentium-60, forcing its price down.

In South Korea, stable pricing in the first half of 1995 was disrupted by the Windows 95 introduction, which made the P5-75 more popular than the P5-60.

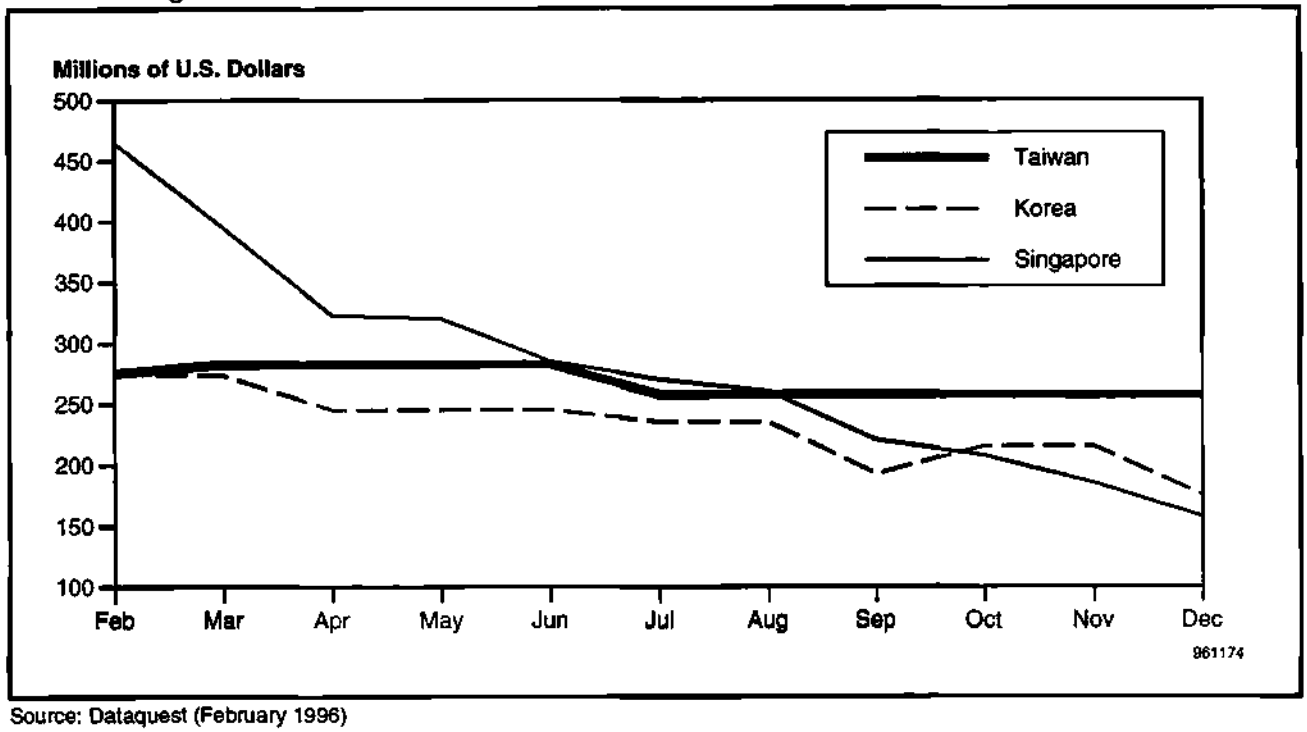
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Figure 16
1995 Pricing for the 486DX2-66



Source: Dataquest (February 1996)

Figure 17
1995 Pricing for the Pentium P5-60



Source: Dataquest (February 1996)

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PowerPC

Taiwan and Singapore do not have Power PC pricing available.

We observed constant pricing in Korean market, with some strong demand toward the end of the year (see Figure 18). This was mostly because of IBM's aggressiveness in promoting its Power PC-based computers.

Standard Logic and Analog

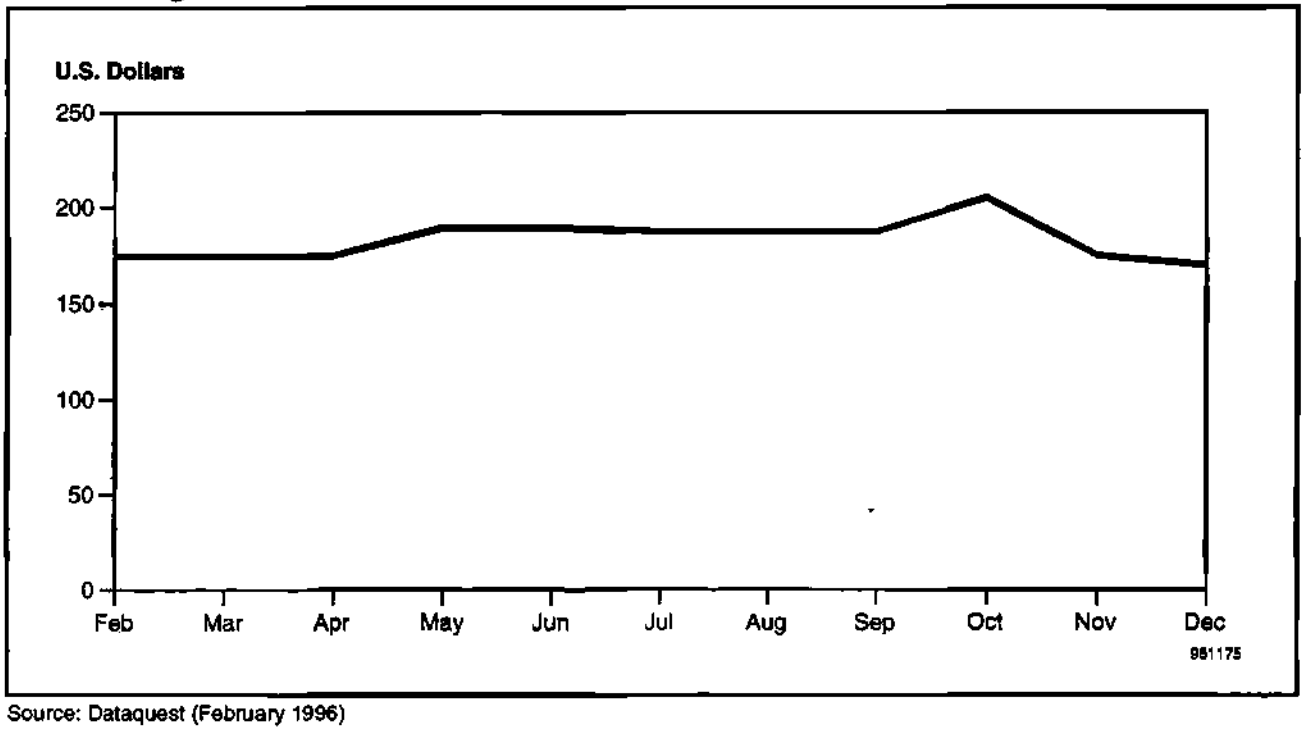
Two analog devices were followed in 1995. Generally, Dataquest saw strong demand for analog devices, especially in Singapore, with very tight inventory levels. Long and fluctuating lead times for May to September were noted for both analog devices observed. A balance of demand and supply was finally reached; we detected improvements in lead times and stabilization of prices in South Korea and Singapore over the past three months.

As with analog devices, suppliers of standard logic had difficulty meeting demand in Singapore at the same time. The strong growth of telecommunications was the main reason for this shortage. Suppliers surveyed confirmed the easing of logic availability recently, which was followed by softer pricing.

In contrary, Taiwan had a comfortable level of inventory for the past eight months. In April, lead times caused the price to rise marginally in anticipation of mild demand, primarily from telecommunications manufacturers.

Standard logic devices in South Korea were firm, and prices were stable most of the time (see Figures 19 through 22).

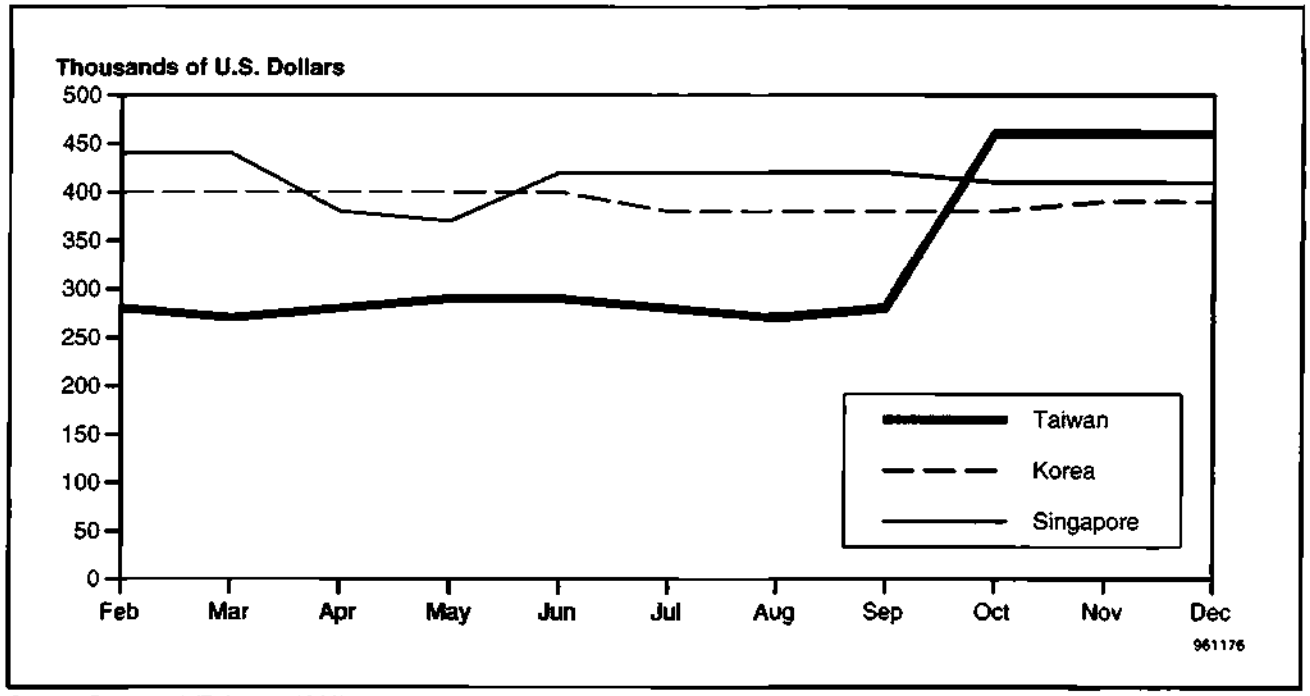
Figure 18
1995 Pricing for the PowerPC 601-66



Source: Dataquest (February 1996)

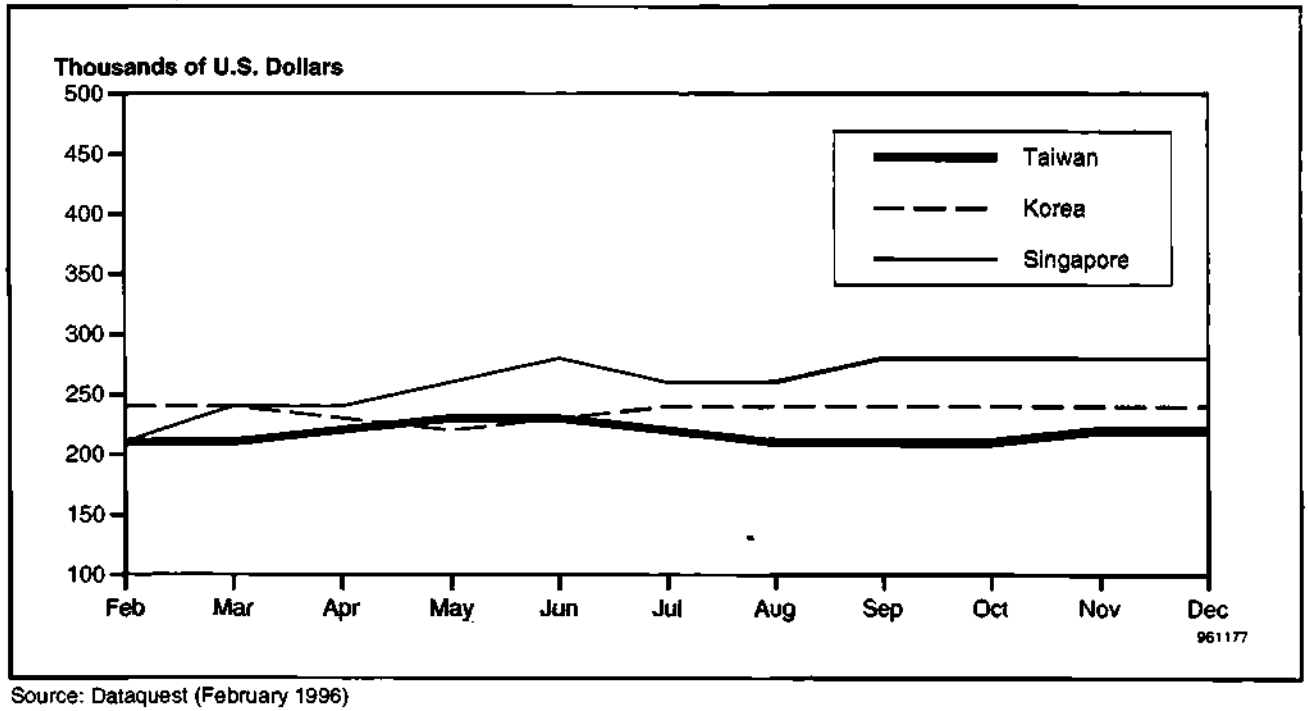
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Figure 19
1995 Pricing for the 74AC244



Source: Dataquest (February 1996)

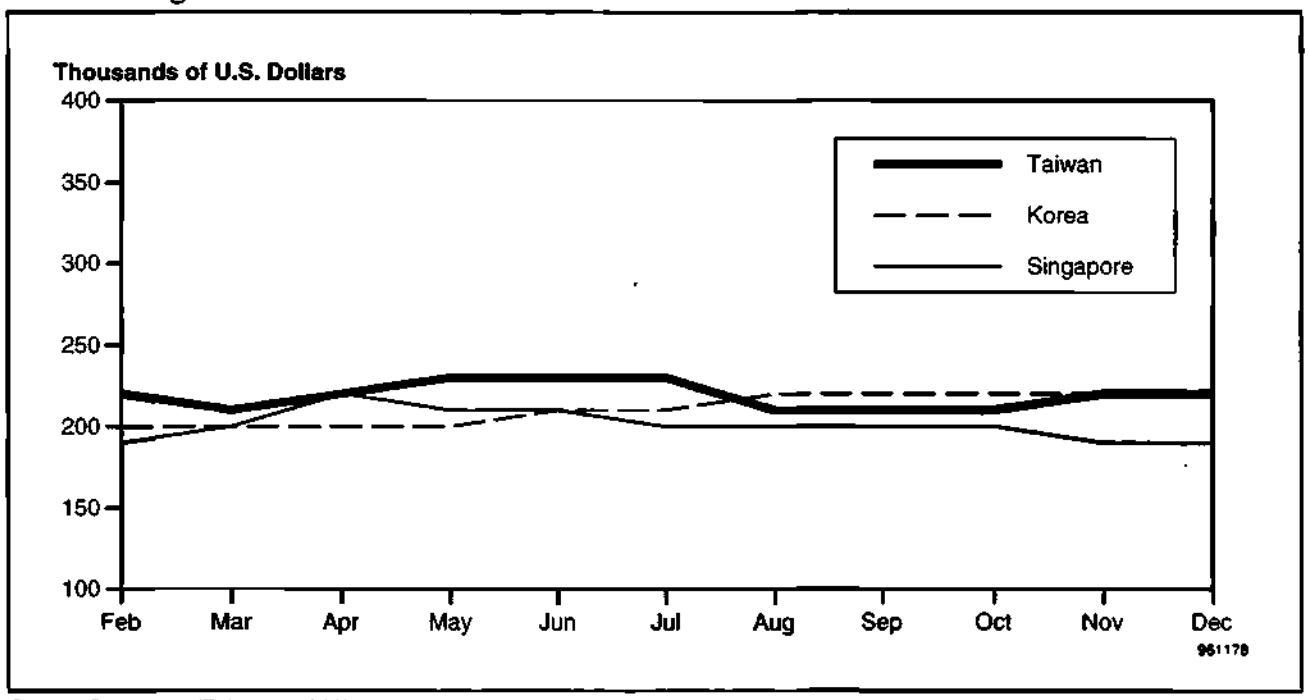
Figure 20
1995 Pricing for the 4F244



Source: Dataquest (February 1996)

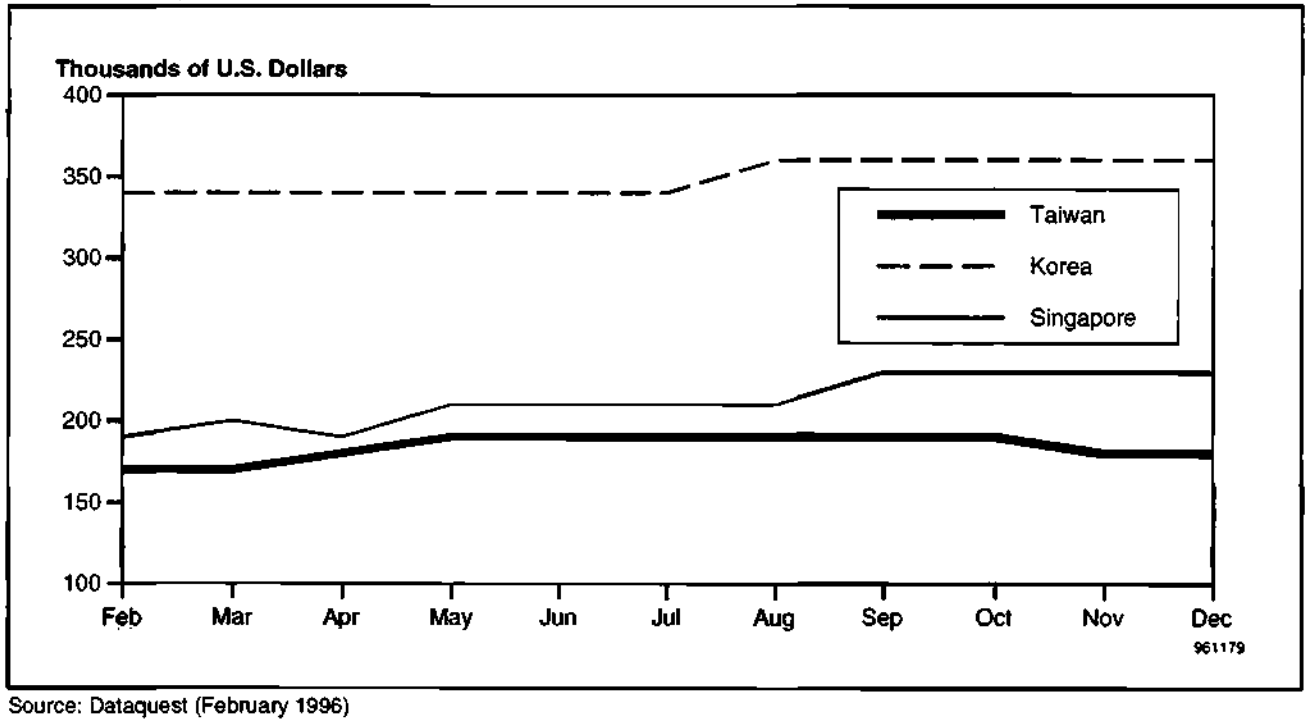
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Figure 21
1995 Pricing for the 7805-TO92



Source: Dataquest (February 1996)

Figure 22
1995 Pricing for the RS-232C-422



Source: Dataquest (February 1996)

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Dataquest Perspective

Asia/Pacific has become the center of world attention as plans are drawn to invest in more and more wafer fabs, particularly in Singapore.

Further development is expected in devices such as DRAM and SRAM. Nonstandard DRAM such as extended data out (EDO) DRAM is becoming more popular in the PC market. This is mainly to support the more sophisticated requirements of Pentium-based PCs. The main DRAM players are planning to invest in more 16Mb capacity.

We are going to see the P5 flourish even more in 1996, balancing the growth of the devices that support it. Intel has been reasonably aggressive, with its involvement in motherboard manufacturing in the Asia/Pacific region (Malaysia), carrying Pentium processors, including its Pentium Pro, on its boards. This move has been seen as its strategy to get closer to the PC vendors planning to set up manufacturing plants in Malaysia. Intel is also taking advantage of the fast-growing PC and telecommunications markets in the Asia/Pacific region.

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Via fax..... 886-2-756-2663

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Market Analysis



Semiconductor Application Markets Asia/Pacific

Preliminary Market Look

Asia/Pacific 1994 January Market Share Report

Abstract: *On January 4, Dataquest released a Dataquest Alert containing our preliminary 1994 Asia/Pacific top 20 semiconductor supplier ranking. Our Alert summarized key market developments, and this newsletter further explains our numbers by providing a by-company analysis for the top 10 companies. Detailed product information will be published in March when the complete Asia/Pacific market share database is shipped to clients of our Asia/Pacific regional services.*

By Daniel Heyler (Hong Kong) and Eddy Tan (Singapore)

Asia/Pacific without Rest of World (ROW)

It should come as no surprise that we have discarded ROW from Asia/Pacific service coverage, because clients have had almost no interest in Latin America or the Middle East. In 1995 and hereafter, we will publish only Asia/Pacific and respective country information.

Although these ROW markets have in fact been growing, capturing these regions has remained difficult because they are too small to warrant separate coverage.

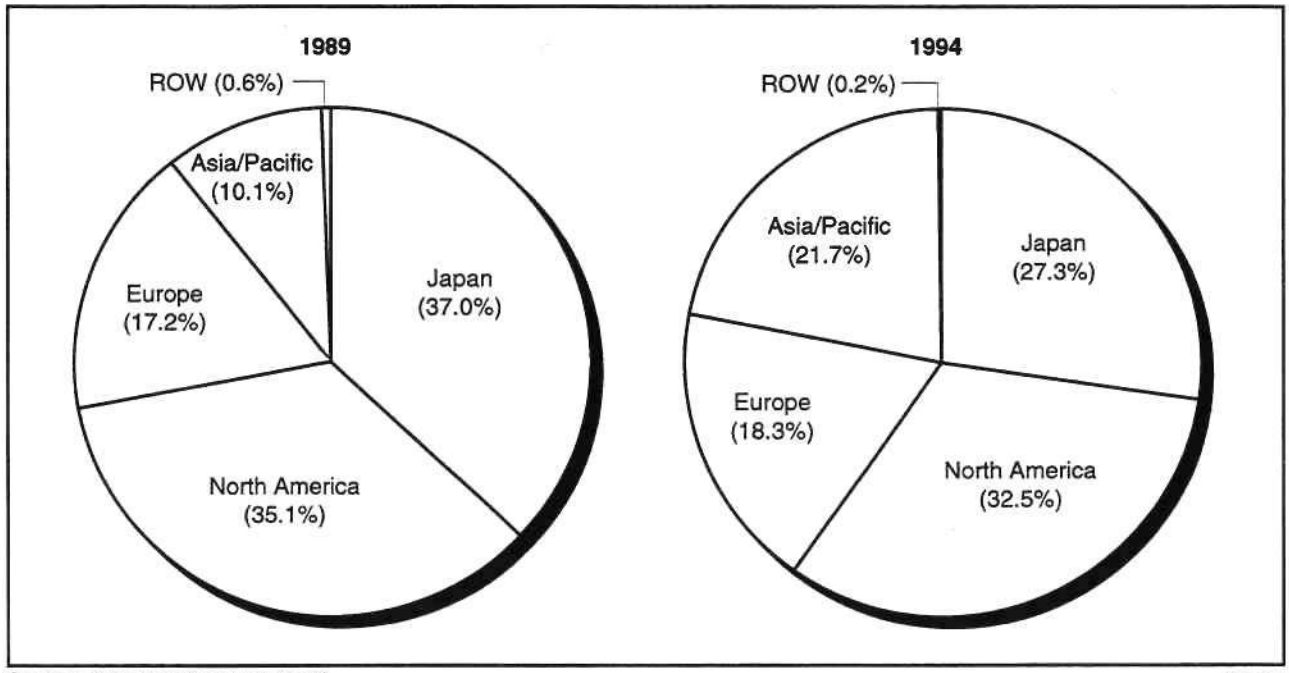
Dataquest is moving away from the concept of ROW as a catchall term. Instead, regional and country-level coverage are more essential to business planners. For example, eastern Europe and the Russian republics used to be included in ROW and now are tracked from our European offices. The bottom line is that we will continue to redefine regions and products to best reflect the current markets and, presumably, the needs of our clients.

Figure 1 compares the worldwide market share survey results of 1989 and 1994. Both years show ROW as less than 1 percent of the worldwide market (numbers rounded to the nearest percentage). We have chosen to not report this as a separate region because of its small size, but the importance of Asia/Pacific warrants the exclusion of ROW.

Dataquest

Program: Semiconductor Application Markets Asia/Pacific
Product Code: SAMM-AP-ML-9501
Publication Date: January 30, 1995
Filing: Market Analysis

Figure 1
Worldwide Semiconductor Consumption by Region, 1989 and Preliminary 1994



Source: Dataquest (January 1995)

9500553

Major Market Trends

The Asia/Pacific region, which was the high-growth region of the 1980s, is proving to be the market of the 1990s. Asia/Pacific had a little more than half of Japan's total semiconductor consumption in 1992 (see Figure 2). But the two are nearly equal when 1994 revenue is compared with Japan's 1993 revenue. That means that Asia/Pacific is now within one year of surpassing the Japanese market in terms of semiconductor consumption.

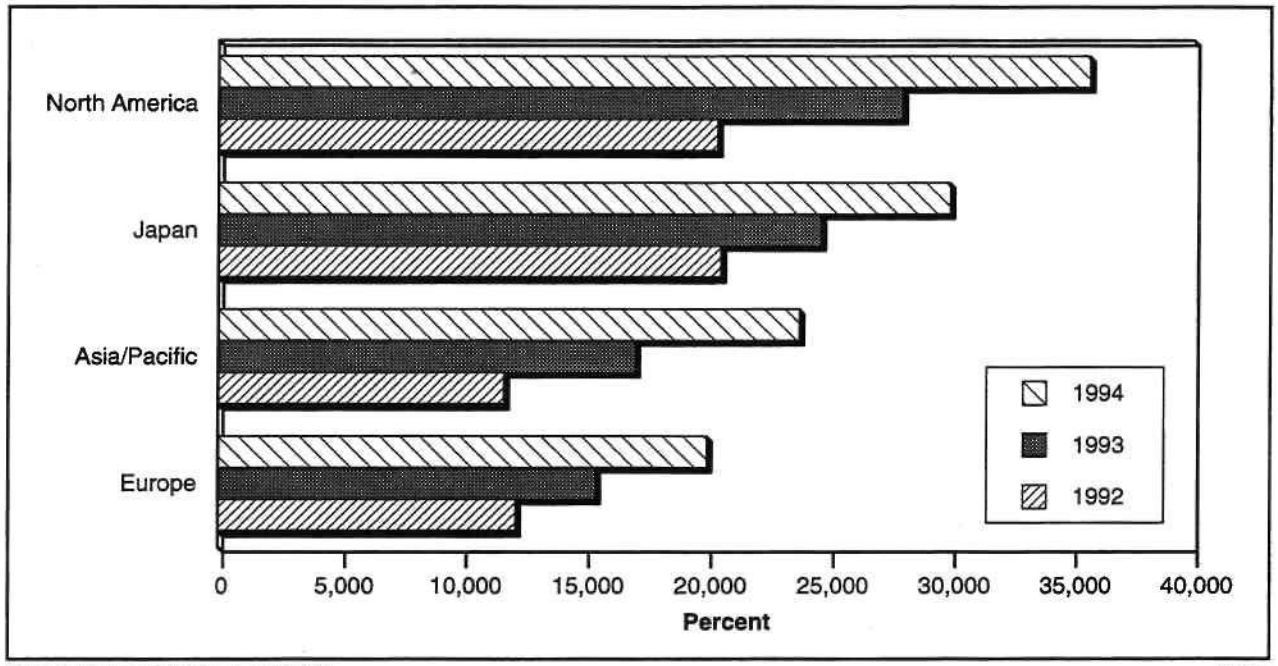
Although PCs are the most important market driver of 1994, a plethora of consumer and communications applications contributed to the region's rapid growth. This section discusses some of the key products and applications in 1994.

The relentless migration to higher-performance PCs by demanding users was catalyzed by aggressive system pricing. Although PC and disk-drive companies suffered at the bottom line (although the number of units shipped accelerated), semiconductor companies were the benefactors in the PC-oriented Asia/Pacific.

The twin evils of DRAM supply constraints and PC demand acceleration aggravated PC companies but propped prices for about two quarters beyond our previous year's forecast. Cache SRAMs were in short supply later in the year, further frustrating PC exporters. The lack of key components resulted in further consolidation of the PC industry. DRAM-dependent Taiwanese PC companies are facing the same frenzy experienced in the late 1980s, which resulted in the Texas Instruments (TI)-Acer joint venture. PowerChip, Vanguard, Nan Ya, MOSel/Vitelic, and TSMC (foundry)

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Figure 2
Worldwide Semiconductor Consumption by Region, 1992 to Preliminary 1994



Source: Dataquest (January 1995) 9500554

have jointed TI-Acer in producing DRAMs locally. Japanese companies, short of capital and weary of overbuilding, are transferring technology to Taiwanese semiconductor companies. These moves by Oki, Toshiba, Mitsubishi, and others help Japan temper Taiwan's long-standing complaints about Japan's huge DRAM imports and its trade surplus.

As we have mentioned during the past two years, microprocessor demand is increasingly driven by local consumption of PCs in Asia/Pacific. The movement to modularized PCs in both desktop and, more recently, notebook form is enabling PC companies to purchase their CPUs at the last possible moment in order to obtain the best price or volume discounts (the difference between profit and loss in the cutthroat PC industry). Furthermore, PC exporters to the United States can reduce tariff costs by 3.9 percent by shipping a motherboard without its microprocessor (0 percent tariff with a microprocessor and 3.9 percent with it). As for exports to Europe, the tariff margin is negligible, so the issue is related more to inventory costs, delivery time, and pricing.

The greatest long-term microprocessor opportunities lie in the markets beginning to consume PCs in Asia/Pacific. In particular, Pentium system demand in Korea, Taiwan, and Australia further contributed to Intel's impressive 6.6 percent market share. These countries' PC trends lagged worldwide product trends by about two quarters, but the lag time is decreasing to one quarter in 1995. Consistent with Advanced Micro Devices (AMD) and Intel is the view from PC companies that positioned their Asia/Pacific facilities to prepare for Asia/Pacific systems demand.

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But production expansion by these six DRAM producers did not alone account for a strong microprocessor market. The increased reliance on subcontract manufacturing within Asia/Pacific contributed to the high PC production and CPU consumption within the region. We have referred to this trend several times, and nowhere is it more important than in PCs, where we see increased original equipment manufacturer/original design manufacturing (OEM/ODM) activity in Taiwan.

The thirst for enhanced computing power is felt even in mainland China. By the middle of 1994, China's interest in 386-based machines began to die and the fourth quarter saw a surge in 486DX2 demand. However, official statistics in China show that sales in Indonesia and Malaysia are much higher than in China, but most companies, including Intel, admit that the "gray market" in China/Hong Kong is "very active." At the same time, we see Taiwanese motherboards being built in China with the help of Hong Kong systems integrators. Some motherboards are exported (with CPU), and others are sold within Asia/Pacific.

We expect downward growth pressure in the latter half of 1995 for microprocessors. The main reason is Intel's worldwide pricing strategy for CPUs. Although we saw $400 prices for DXs in the beginning of 1994, Pentiums will be less than $300 during the first quarter, according to Intel. Intel's goal is to make the 486 obsolete as quickly as possible. Another factor negatively affecting CPU growth is the fact that notebook computers are increasingly shipped in modular kit form and will suffer the same fate as desktops. The surge in notebook production and export in Asia/Pacific will not be directly translated into high CPU growth because some exporters will wait to buy the CPU in Europe, North America, or Japan.

Malaysia: Asia/Pacific's Fastest-Growing Market

More than 20 years of hard selling to foreign investors has earned Malaysia the reputation of amassing a significant number of major manufacturing facilities in the region. This is particularly true in the area of consumer electronic equipment, which is dominated by the Japanese. The consumer equipment industry seemed to have defied the last fourth-quarter and possible first-quarter slowdown. Production shifts from Japan, mostly in consumer electronics equipment, have been cited as the major suspect in supporting semiconductor revenue growth in Malaysia. Semiconductor components that benefited from the shift include (mostly low-end) audio and video ICs and analogs, and to some extent, microcontrollers. Some chip manufacturers are concerned about whether they can even cope with supply for 1995.

Among other Japanese manufacturers, Aiwa and Pioneer plan to move a portion of their capacity to Malaysia. In Singapore, Mitsubishi Electronics Manufacturing is relocating its car audio operation to Malaysia because of a tight labor situation and escalating manufacturing costs. The company has also cited another motive—improved access to the southeast Asian market under the Brand-to-Brand Complementation Scheme, an incentive that halves tariffs on automobile parts traded among members. Singapore is not part of that scheme.

Concerns over the expiration of Malaysia's Generalized System of (trade) Preferences (GSP) status have also been flying around. A natural reaction for equipment manufacturers is to consider greener pastures in the region. Even without the GSP extension, Malaysia will still sell well because of its

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low production costs, good supporting infrastructure, and capable and English-speaking labor. Many manufacturers are already wary of Malaysia's continuing shortage of manpower and rising production costs relative to other opening markets in the region. Matsushita, which has been a partner with Indian consumer electronics company Videocon Group, is now studying the possibility of using Malaysia as a launching pad to produce additional air-conditioning units in India.

Malaysia could expect a fairly bullish first half in 1995 and may show slowdowns in the second half. (This service will publish a Focus Report on Malaysia's emerging semiconductor market and electronic equipment industry in August 1995.)

Company Performances: Top 10 in 1994

Companies whose market share did not increase should not be dismayed, unless they are in the DRAM business—wait until our product-level information is released in March to compare. North American companies lost market share to the three other regions, which is a reversal of 1993 trends. DRAM demand was the single most important revenue driver among the region's leading suppliers. As shown in Table 1, every major DRAM supplier in Asia/Pacific exhibited more than 40 percent growth in 1994. Hyundai was the biggest winner. Because of its aggressive surge in DRAM sales, Hyundai's total revenue increased 123 percent to $721 million, and it climbed four positions to No. 12 in the region. The top DRAM suppliers concur that their two biggest surprises were the volume of demand for 4Mb parts during the first three quarters and the unexpected surge in low-voltage, wide-bit 16Mb DRAM demand starting in the third quarter. Toshiba was able to sustain its leadership in the region, not only because of its DRAM business but also because of its substantial discrete sales.

No 1: Toshiba

Toshiba topped the Asia/Pacific semiconductor suppliers club with great success in the areas of consumers (audio/video ICs) and data processing (memory). It experienced healthy growth in the southeast Asia region as a whole. Toshiba's "vertical business" or direct marketing has worked out well, giving the semiconductor giant a good sense of local demands. Toshiba already has an ongoing joint venture with a leading Chinese manufacturer, Huajin Electronics Group, in Wuxi, China. This signals the company's optimism about another successful year and confidence in other emerging markets such as China and Vietnam.

No 2: Samsung

Singapore turns out to be an important revenue generator for Samsung, with Apple, Compaq, Digital Equipment Corporation, and Hewlett-Packard as the major accounts. Its 4Mb and 16Mb DRAM products occupied a majority of the revenue pie. The higher-capacity memory was introduced only in mid-1994. Samsung plans to aggressively market its microcontrollers, particularly ASIC (with minimal contribution compared to memories), which grew 50 percent last year. Unlike the other companies, Samsung has not felt the "boom effect" from Malaysia. We expect Samsung to deliver yet another impressive performance in 1995.

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Table 1
Preliminary 1994 Asia/Pacific Market Share Ranking, Total Semiconductor, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank	1992 Rank	Company	1992 Revenue	1993 Revenue	1994* Revenue	Percentage Change	1994 Market Share (%)	Cumulative Market Share (%)
1	1	1	Toshiba	982	1,324	1,944	47	8.2	8.2
2	2	2	Samsung	821	1,188	1,706	44	7.2	15.4
3	4	4	Intel	856	1,170	1,566	34	6.6	21.9
4	3	3	Motorola	819	1,188	1,301	10	5.5	27.4
5	6	6	Hitachi	491	747	1,106	48	4.7	32.1
6	8	8	Texas Instruments	446	696	1,095	57	4.6	36.7
7	7	7	NEC	471	713	1,063	49	4.5	41.1
8	5	5	Sanyo	436	749	994	33	4.2	45.3
9	9	9	Goldstar	312	590	847	44	3.6	48.9
10	10	10	Mitsubishi	370	529	762	44	3.2	52.1
11	11	11	Philips	424	517	761	47	3.2	55.3
12	16	16	Hyundai	248	323	721	123	3.0	58.3
13	14	14	Matsushita	236	424	589	39	2.5	60.8
14	13	13	SGS-Thomson	303	435	564	30	2.4	63.2
15	19	19	Sony	236	305	507	66	2.1	65.3
16	12	12	National Semiconductor	392	502	491	-2	2.1	67.4
17	17	17	Advanced Micro Devices	361	314	459	46	1.9	69.3
18	20	20	Fujitsu	221	270	431	60	1.8	71.1
19	18	18	Sharp	164	306	422	38	1.8	72.9
20	15	NA	IBM	NA	333	420	26	1.8	74.6
			All Others	3,155	4,472	6,029	35	25.4	100.0
			North American Companies	4,440	6,335	8,042	27	33.8	
			Japanese Companies	4,151	6,291	9,153	45	38.5	
			European Companies	1,028	1,377	1,938	41	8.2	
			Asia/Pacific Companies	2,125	3,092	4,645	50	19.5	
			Total Market	11,744	17,095	23,778	39	100.0	

*Preliminary
NA = Not available
Source: Dataquest (January 1995)

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No 3: Intel

Intel moved from a ranking of No. 4 in 1993 to No. 3 in 1994 and increased revenue by 34 percent to $1.6 billion. Microprocessor sales revenue, the lion's share of Intel Asia/Pacific business, accelerated during the second half of 1994 primarily because of increased DX2 demand and the higher average selling prices (ASPs) associated with this part. Singapore is Intel's largest microprocessor market because of major accounts such as Digital, Compaq, and HP. Other major accounts outside of Singapore include AST, AT&T, and Acer, which further accelerated their Asia/Pacific market presence. The surge in CD-ROM production and increasing use of flash caused this market to expand dramatically in 1994.

No 4: Motorola

Ranking fourth is Motorola, which met with success in the communications and consumer markets. However, Motorola's microprocessor business in Asia/Pacific suffered more than anyone's, as Apple Computer downsized its Singapore plant and shifted production back to North America. Motorola faced further semiconductor sales constraints because of production bottlenecks in its pager and mobile handset manufacturing in Asia/Pacific. The company's revenue was limited by not-too-strong sales in the data communications market. Motorola expects to perform better this year, with a projected growth rate of 30 percent (compared with the modest 10 percent rate posted in 1994).

No 5: Hitachi

Hitachi has continuously outperformed the market, and in 1994 it joined the ranks of the top five Asia/Pacific semiconductor suppliers. As for most DRAM suppliers, sustained 4Mb DRAM prices were good news, but what came as a surprise was the surge in 16Mb DRAM wide-bit, low-voltage demand, driven by notebook production. Hitachi's continued success in the DRAM business enabled its 48 percent revenue growth, but other areas proved successful as well. Singapore remains Hitachi's largest market in Asia/Pacific, but Malaysia and China showed rapid growth. Southeast Asia's Japanese consumer electronics and communications equipment markets were particularly active for Hitachi's 4-bit and 16-bit microcontrollers and there were shortages for certain products.

While a number of companies exited the diode market, Hitachi gained market share primarily because of increased activity from Japanese television and radio tuner manufacturers.

No 6: Texas Instruments

Texas Instruments was the fastest-growing company among the top 10 in Asia/Pacific. It leaped from a rank of No. 8 in 1993 to No. 6 in 1994. TI benefited from an increased supply of DRAMs from its joint ventures in Singapore (TECH) and Hsinchu (TI-Acer). The company was well positioned to service its major DRAM accounts within the region. But TI's breadth in PC products positions it ideally for Taiwan, which became the company's new Asia/Pacific headquarters (moved from Hong Kong). Furthermore, strong telecommunications demand enabled substantial growth in mixed-signal products.

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No 7: NEC

NEC has sustained its No. 7 position for the past three years. Like Sanyo, NEC saw explosive growth rates in the southeast Asian markets: 170 percent from 1992 to 1993, and 150 percent from 1993 to 1994. Hot products such as microcontrollers (more than 200 percent growth) and DRAM (more than 150 percent growth) made 1994 a memorable year for NEC. Again, consumers and data processing markets are supporting healthy sales in the region. NEC expects its revenue to grow a minimum of 130 percent in 1995.

No 8: Sanyo

After a strong 1993, Sanyo dropped three positions from No. 5 to No. 8 in the region. However, Sanyo's sales in southeast Asia grew twofold, thanks to strong demand in consumer products and production shift from Japan to the southeast Asia region. Semiconductor devices that enjoyed healthy growth included audio/video ICs. One of the top consumer manufacturers in the southeast Asia region, Sanyo expects to maintain its growth rate throughout 1995. The company expects to run into problems coping with demand.

No 9: Goldstar

Goldstar has sustained its No. 9 position in Asia/Pacific for the past three years. Sales growth matched Samsung's at 44 percent, but revenue was less than half of its Korean rival. Similar to Samsung, Goldstar focused on its large customers in North America, which enabled Hyundai to grab market share in Asia/Pacific. Hyundai jumped from a rank of No. 16 to No. 12 in 1994 because of its phenomenal revenue growth of 123 percent. If Hyundai is able to sustain this momentum in Asia/Pacific, it could surpass Goldstar and move into the top nine.

No: 10 Mitsubishi

Mitsubishi clinched the No. 10 position in Asia/Pacific because of success in controllers and gate arrays and to a lesser extent in 16Mb memories. Its Singapore market grew by 50 percent. The Taiwanese market would have experienced similar growth if not for DRAM constraints that kept the growth rate to about 20 percent. Mitsubishi's Malaysian market performed well in the areas of microcontrollers and linear ICs. Through Hong Kong, Mitsubishi plans to set up a stronger foothold in China, which the company expects to become a major market in five years. The company is upbeat concerning its overall performance for 1995, but it expects a slowdown in DRAM growth (20 percent) because of 1x16Mb constraints.

Asia/Pacific Companies Surpass Europe

As shown in Table 2, Korean DRAM manufacturers represent the largest share of Asia/Pacific's worldwide shipments. Because Dataquest does not count foundry and OEM business performed, Taiwan's total production is substantially higher than its shipments. Nevertheless, Taiwan's worldwide shipment revenue increased 38.7 percent to $1.5 billion, which represented 1.41 percent of the worldwide market. Korea semiconductor manufacturers expanded 69.7 percent to almost $8.6 billion, which represented 7.81 percent of the worldwide market. Combined Taiwanese and Korean shipments of $10.1 billion surpassed all European shipments ($9.8 billion) for the first time (see Table 3).

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Table 2
Preliminary 1994 Asia/Pacific Companies' Worldwide Market Share Ranking, Total Semiconductor, Including Hybrid (Millions of U.S. Dollars)

1994 Rank	1993 Rank	1992 Rank	Company	1992 Revenue	1993 Revenue	1994* Revenue	Percentage Change	Percentage Share of World (%)
1	1	1	Samsung	1,900	3,044	4,893	60.7	4.46
2	2	2	Goldstar	642	946	1,797	90.0	1.64
3	3	3	Hyundai	556	853	1,621	90.0	1.48
4	4	4	United Microelectronics	198	309	399	29.1	0.36
5	7	6	Winbond Electronics	117	184	308	67.4	0.28
6	5	5	MOSel/Vitelic	161	223	269	20.6	0.25
7	6	7	Korean Electronic Co.	148	177	225	27.1	0.21
8	9	9	Macronix	69	144	221	53.5	0.20
9	8	8	Hualon Microelectronics Corporation	75	83	113	36.1	0.10
10	10	10	Silicon Integrated Systems	40	71	99	39.4	0.09
11	11	NM	Holtek	NM	53	70	32.1	0.06
12	12	NM	Acer Labs	NM	50	70	40.0	0.06
13	11	11	Daewoo	24	31	38	22.6	0.03
			Korean Companies	3,270	5,051	8,574	69.7	7.81
			Taiwanese Companies	660	1,117	1,549	38.7	1.41
			Asia/Pacific Companies		6,168	10,123	64.1	9.23

*Preliminary
NM = Not meaningful
Source: Dataquest (January 1995)

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Asia/Pacific companies have more than doubled their share of the worldwide semiconductor market since 1990. Japanese and European companies' shares of worldwide revenue have decreased, while North American and Asia/Pacific companies' shares have increased. Asia/Pacific has been viewed primarily as an importer of key components, but the breakneck investments in manufacturing have made it a major global supplier (see Table 4).

Table 5 contains the exchange rates for the major Asia/Pacific markets used in this 1994 market share survey.

Table 3
Preliminary 1994 Worldwide Semiconductor Market Share Estimates by Regional Supplier (Billions of U.S. Dollars)

	1993 Revenue	1993-1994 Growth (%)	1994 Revenue	1994 Market Share (%)
North American Companies	37.1	22	45.4	41.4
Japanese Companies	34.6	28	44.4	40.5
Asia/Pacific Companies	6.2	63	10.1	9.2
European Companies	7.7	27	9.8	8.9
Total Revenue	85.6	28	109.7	100

Source: Dataquest (January 1995)

Table 4
Preliminary 1994 Worldwide Semiconductor Market Share by Region (Percentage of Worldwide Revenue)

Year	North American Companies	Japanese Companies	Asia/Pacific Companies	European Companies
1990	38.6	46.3	3.9	11.2
1991	38.4	46.4	4.6	10.6
1992	41.5	42.3	6.0	10.2
1993	43.4	40.4	7.2	9.0
1994	41.4	40.5	9.2	8.9

Source: Dataquest (January 1995)

Table 5
Asia/Pacific Preliminary 1994 Average Exchange Rates by Country, Foreign Currency per U.S. Dollar

Country	Annual Average 1994	U.S. Dollar Appreciation 1994 (%)
China (Renminbi)	8.54	48.28
Hong Kong (Dollar)	7.73	-0.10
India (Rupee)	31.15	1.00
Malaysia (Ringgit)	2.50	-3.04
Singapore (Dollar)	1.53	-5.54
South Korea (Won)	802.84	0.42
Taiwan (Dollar)	26.45	1.13
Thailand (Baht)	25.36	0.19

Source: The Dun & Bradstreet Corporation

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Dataquest Perspective

The 1994 Asia/Pacific semiconductor market reached a remarkable $23.8 billion in revenue for the year and increased its share of worldwide consumption to an unprecedented 22 percent, according to Dataquest's preliminary 1994 worldwide semiconductor market share results. The market outpaced the world market, which expanded by 28 percent.

Asia/Pacific's exceptional semiconductor market performance in 1994 is attributed to the accelerated evolution of its world-class computer and peripherals industries, the rapid emergence of communications markets, and a continuous increase in foreign expansion and investments in local manufacturing, especially among the Japanese consumer electronics manufacturers.

Asia/Pacific companies benefited from the region's growth but also made gains in foreign markets, which was most evident among the Korean DRAM manufacturers. Consequently, total worldwide revenue for Asia/Pacific companies led all regions with a 63 percent growth rate and surpassed European suppliers for the first time.

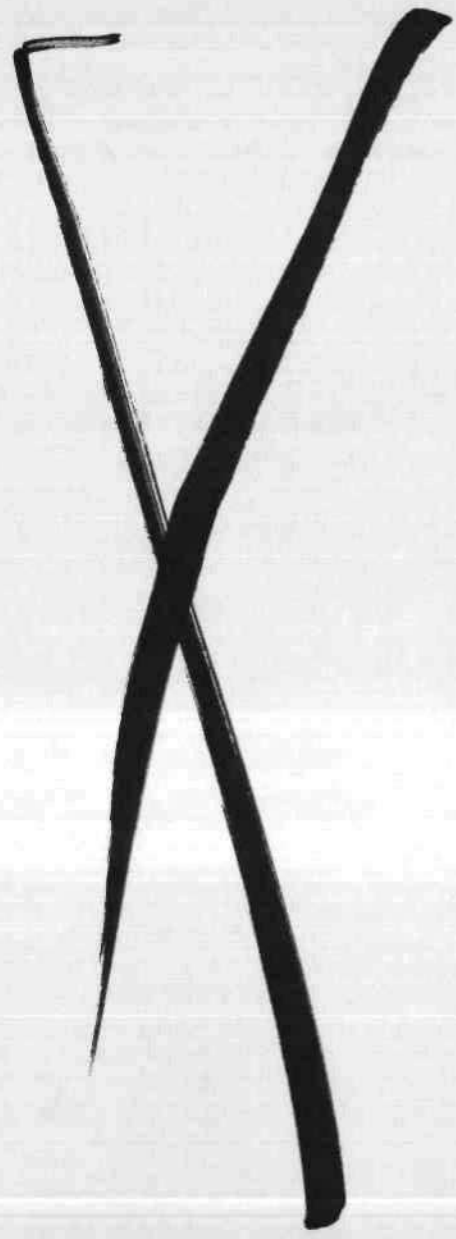
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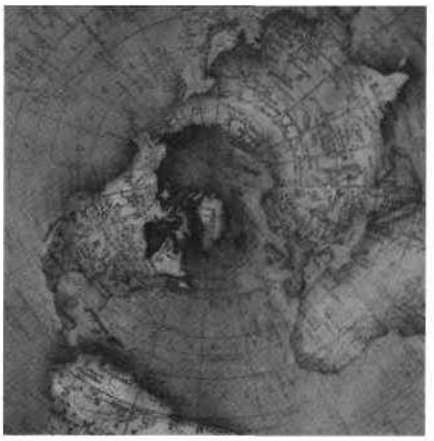
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Malaysian Equipment Production and Semiconductor Consumption



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Chapter 1
Historical Perspective

Malaysia has emerged as one of the fastest-growing countries in Asia/Pacific. As with other Asia/Pacific countries, foreign seed funds have provided a powerful impetus to the country's economic growth, which has been averaging 8 percent per year for the last seven years. Manufacturing spearheaded the country's consistent growth, which, in turn, is dominated by the electronics industry. The country's strategy of substituting an import-dependent economy with export-oriented, electronics-focused industry is paying off. Malaysia shifted focus from commodity products to electronics, which today is the country's key export and continues to enjoy robust growth.

The postindependence period of the 1960s was marked by high unemployment. Rescue came in the form of initial investments from Matsushita and Sanyo, which sparked droves of other Japanese consumer electronics equipment manufacturers to establish large bases in Malaysia in the 1980s. The availability of cheap labor and easy access to a market of 300 million people in Southeast Asia was simply irresistible. European companies came in smaller numbers, bringing in semiconductor assembly and test and consumer equipment manufacturing. The American companies, too, joined the investment fray, scrambling to introduce large semiconductor assembly and test facilities during the "second wave" in the 1970s. Thanks to U.S. companies, this decade will usher in increased production of rigid disk drives and PCs. Other East Asian companies have established telecommunications and PC peripherals (Taiwan) and consumer equipment (Korea) assembly facilities. After three decades of aggressive development, Malaysia has evolved into a respectable base for consumer equipment manufacturing and semiconductor packaging.

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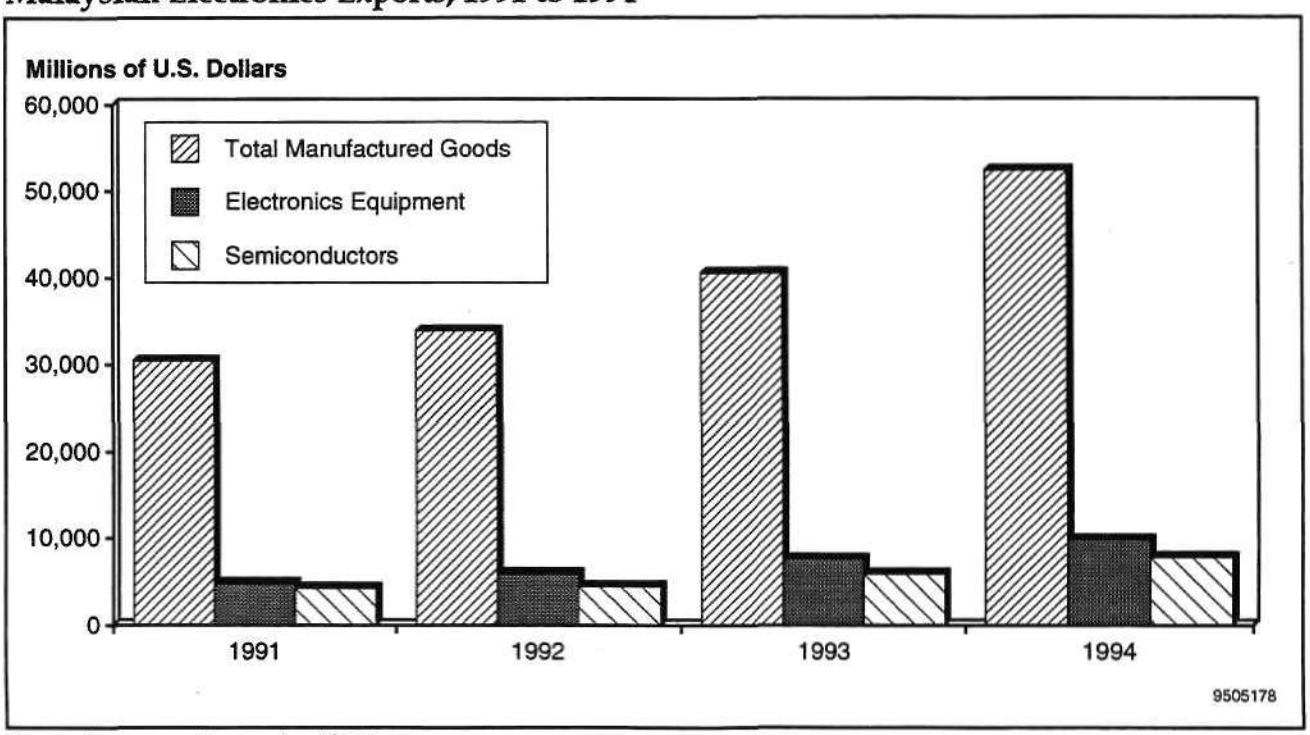
Chapter 2
Electronic Equipment: Exports, Domestic Market, and Production

In this chapter, Dataquest provides a historical overview of Malaysian export trends, followed by a chapter giving a view of domestic equipment markets. The last chapter provides the electronics equipment production history and forecast.

Malaysia's Export Market Trends

Malaysia's strategy in invigorating manufacturing industries has resulted in robust growth in its export revenue, particularly in the electronics industry. Figure 2-1 and Table 2-1 demonstrate the rising importance of exports of semiconductors and electronics equipment vis-à-vis total manufactured goods. Total exports grew by 29.1 percent to $52.3 billion in 1994, making Malaysia the 19th largest exporter in the world. Following a brief deceleration in 1992, exports of packaged semiconductors grew consistently at 31 percent in 1993 and 1994. Semiconductor exports reached $7.8 billion last year, with an export share of 14.9 percent. In comparison, electronics equipment exports doubled within three years to $9.8 billion in 1994, boosting the total export share to 18.7 percent. Malaysia's concern about being too dependent on semiconductor exports has been allayed somewhat, as the export share of equipment (consumer and data processing) began dominating over semiconductors beginning this decade. We have estimated equipment exports by six categories in Figure 2-2. Export trends by equipment type will be discussed in the last section.

Figure 2-1
Malaysian Electronics Exports, 1991 to 1994



Source: Dataquest (September 1995)

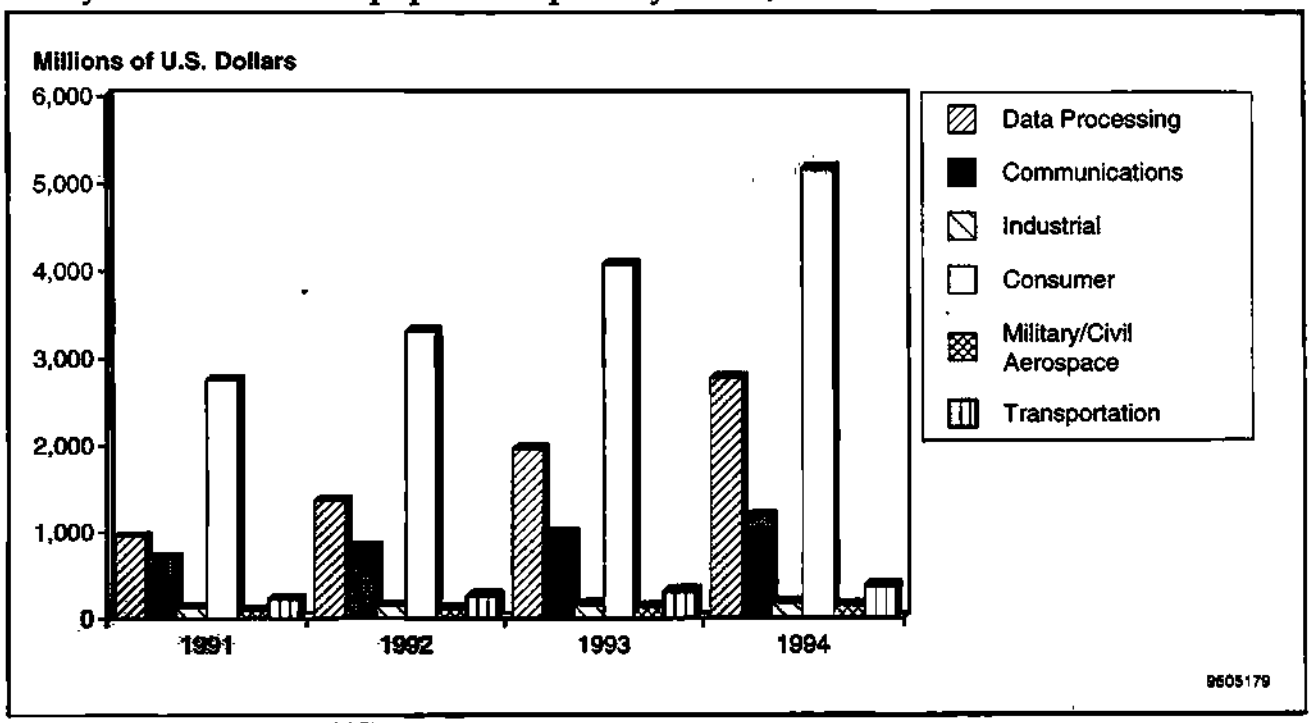
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Table 2-1
Malaysian Exports, 1991 to 1994 (Millions of U.S. Dollars)

	1991	1992	1993	1994
Total Manufactured Goods	30,419	33,900	40,521	52,313
Electronics Equipment	4,830	5,989	7,585	9,804
Semiconductors	4,282	4,484	5,910	7,792

Source: Malaysian Industry Development Authority

Figure 2-2
Malaysian Electronics Equipment Exports by Sector, 1991 to 1994



Source: Dataquest (September 1995)

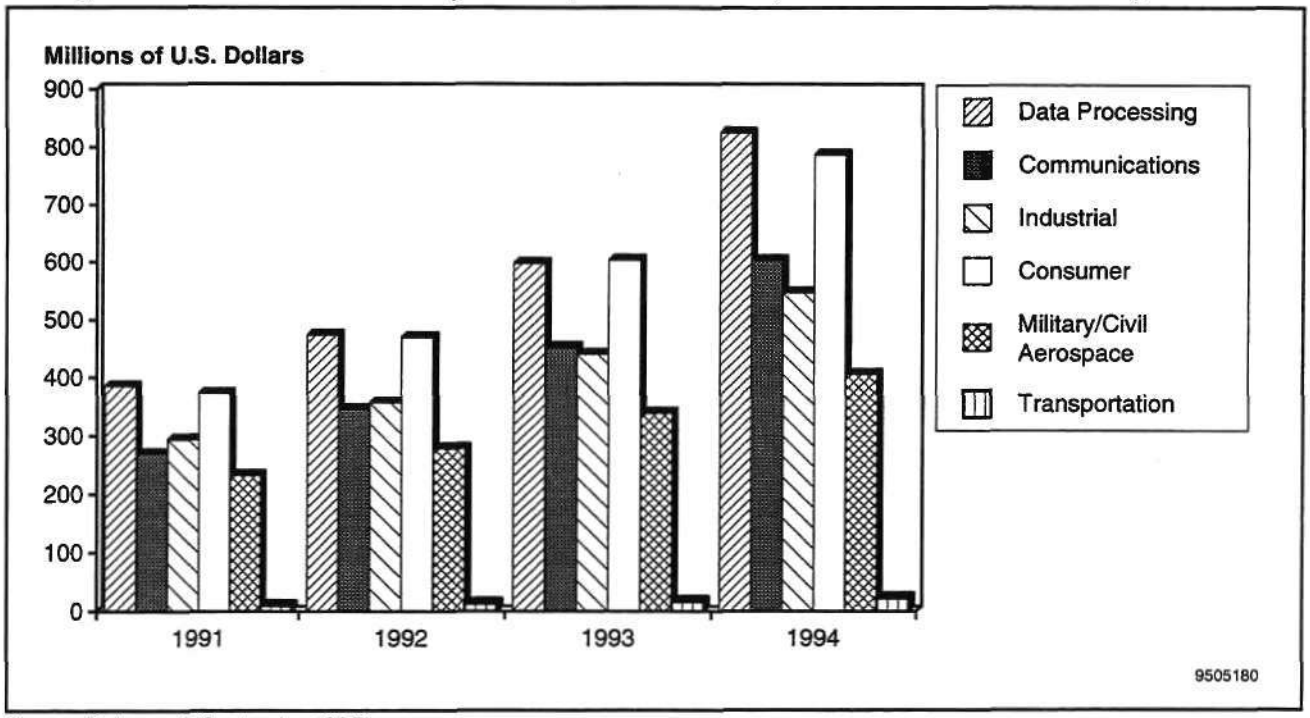
Malaysia's Domestic End Market

Dataquest estimates that Malaysia's 1994 total electronics equipment domestic market surged by 31 percent to $3.2 billion. Data processing led the way, capturing 26.7 percent of the domestic market, followed by consumer equipment (24 percent), communications (19 percent), industrial (17 percent), military/aerospace (13 percent), and transportation (1 percent), as shown in Figure 2-3.

Malaysia's aggressive computerization program has resulted in robust growth for the data processing market in the last few years. Overtaking the consumer equipment market, data processing recorded the highest growth—38 percent—to attain $825 million in 1994. This can be attributed mostly to computers (predominantly PCs), which expanded by 47 percent to $516 million. Corporate users have begun linking PCs through networks (LAN and WAN) to enhance computing power. The input/output devices market, predominantly printers, climbed by 35 percent to $120 million.

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Figure 2-3
Malaysian Domestic Market by Sector, 1991 to 1994 (Millions of U.S. Dollars)



Source: Dataquest (September 1995)

Dataquest estimates that Malaysia's consumer equipment domestic market, the second largest, at $787 million, was up by 30 percent in 1994. That growth accelerated as an increasing number of households purchased and upgraded video and audio equipment, followed by electrical appliances. Video equipment's share of 31 percent of the consumer market in 1994 exceeded that of audio (27 percent), appliances (27 percent), and personal electronics/others (16 percent). The video equipment market overtook previous market leader audio equipment in dollar terms in 1992.

Like data processing, communications is a high-growth market, given Malaysia's relatively low penetration of communications devices. The country's determination to improve its overall infrastructure and achieve its "Vision 2020" has been driving this high-growth market. The market has been growing consistently at over 30 percent for the last three years. Malaysia consumed $603 million worth of telecommunications devices in 1994, an increase of 33 percent. Mobile communications, a newcomer, is being widely used by the business community, which regards mobile devices as both business enhancement tools and status symbols.

Dataquest estimates the 1994 industrial market at $548 million, a growth of 24 percent. Manufacturing systems/instruments accounted for 48 percent of the industrial equipment market, with most of the remainder accounted for by medical equipment. The $407 million military/aerospace market was dominated by radar and navigational equipment. Transportation, a $23 million market primarily in the form of automobile stereo, grew in tandem with the country's domestic car assembly industry.

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Trends and Forecast of Malaysia's Equipment Production by Sector

Dataquest projects healthy growth in all electronics sectors as the country's high economic growth momentum continues to roll forward throughout the decade. The following section discusses trends and outlook by sector. Production historical estimates are summarized in Table 2-2. Figure 2-4 demonstrates the importance of consumer equipment manufacturing, followed by data processing and communications.

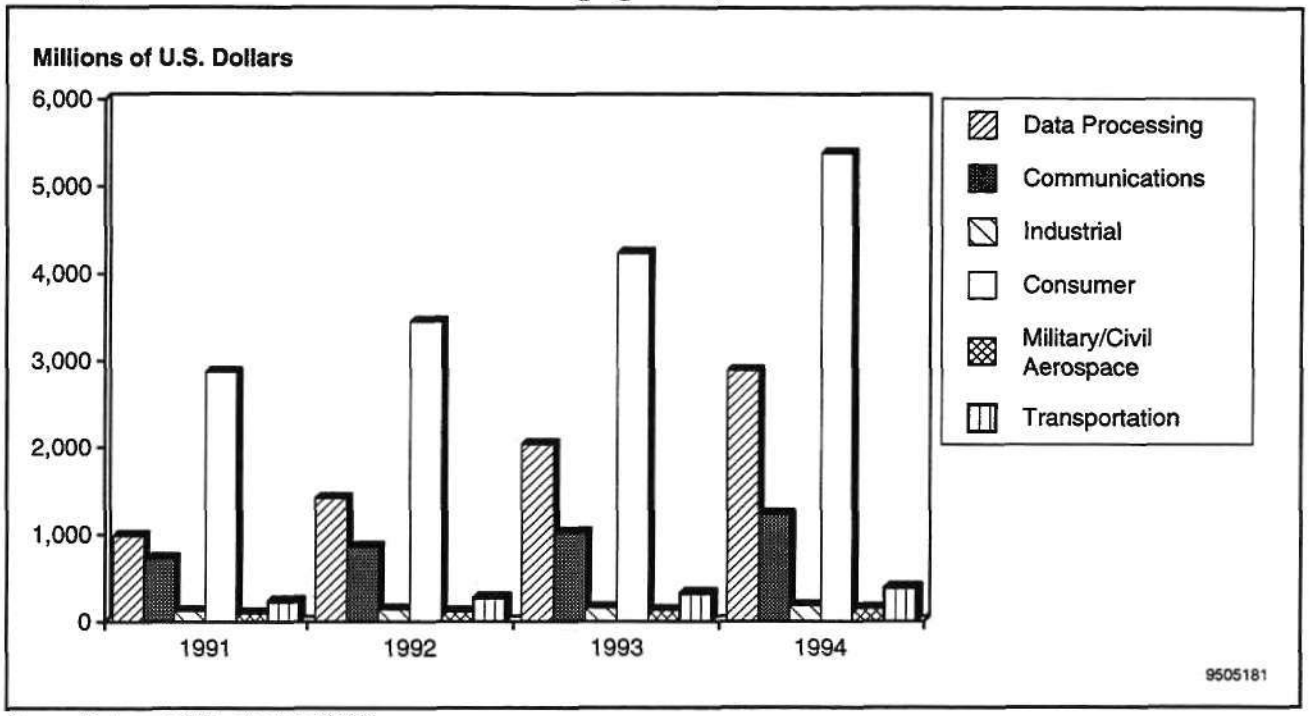
Table 2-2
Malaysian Equipment Production by Sector, 1991 to 1994
(Millions of U.S. Dollars)

	1991	1992	1993	1994
Total Equipment	5,031	6,239	7,573	9,976
Data Processing	984	1,412	1,709	2,650
Computers	161	211	289	429
Data Storage	450	750	890	1,590
Input/Output	185	221	257	306
Dedicated Systems	101	129	155	188
Other Data Processing	87	101	118	137
Communications	728	857	1,017	1,229
Premise Telecom	567	670	798	960
Public Telecom	14	16	19	24
Mobile Communications	122	142	166	205
Broadcast and Studio	11	13	15	17
Other Communications	14	16	19	23
Industrial	123	141	159	182
Security and Energy Management	3	4	4	5
Manufacturing Systems/Instruments	96	111	124	139
Medical Equipment	17	19	22	27
Other Industrial	6	8	9	11
Consumer	2,869	3,446	4,238	5,380
Audio	1,280	1,515	1,787	2,210
Video	1,113	1,377	1,789	2,370
Personal Electronics	158	189	229	281
Appliances	312	358	425	509
Other Consumer	6	7	8	10
Military/Civil Aerospace	100	114	130	152
Transportation	227	269	319	384

Source: Dataquest (September 1995)

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Figure 2-4
Malaysian Production of Electronics Equipment, 1991 to 1994



Source: Dataquest (September 1995)

Table 2-3 shows the production forecast throughout 1999 by category. Data processing is experiencing strong growth with a compound annual growth rate (CAGR) of 27.1 percent, while consumer equipment continues to maintain its large revenue base. The forecast is represented graphically in Figure 2-5.

Consumer Equipment

Japan, with its labor cost-cutting and its yearning to be closer to the local markets, has poured further investment into Malaysia. The latter is now blessed with a consumer equipment market that is its largest electronics manufacturing sector. Dataquest estimates that consumer production grew by 27 percent to $5.4 billion in 1994. Overall growth was strongly led by video products (mostly televisions and videocassette recorders), which began to overtake audio equipment as the leading sector in revenue.

The mighty yen has continued to force further production flow from Japan to Malaysia. The trend has extended even to the moving of some of Japanese facilities from Singapore to Malaysia—by Sanyo, among others. Dataquest believes that video manufacturing will grow from 1994 through 1999 at a CAGR of 32 percent to $9 billion in 1999. Sony and Matsushita plan to increase video capacity by as much 100 percent. Audio equipment manufacturing has recently experienced some demand-driven production hiccups. Malaysia's labor crunch and rising wages, coupled with the rising importance of other, cheaper manufacturing sites in Asia/Pacific with even larger potential appetites, particularly China, are looking more and more like real threats. Audio manufacturing will see sustained growth rates of 20 percent. We foresee digitalization in consumer equipment manufacturing becoming more widespread after the second half of 1996. Overall, we project consumer manufacturing to grow by a CAGR of 26 percent to $16.8 billion.

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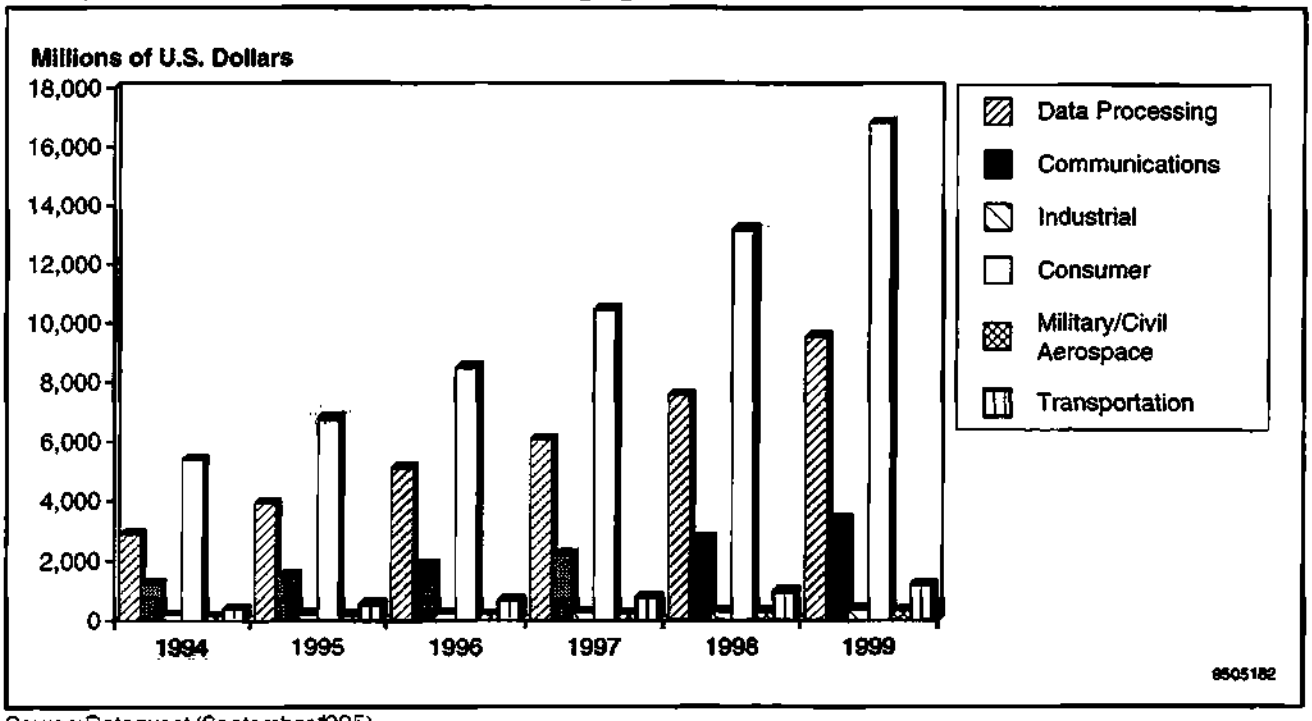
Table 2-3
Malaysian Equipment Production by Sector, 1994 to 1999 (Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Equipment	9,976	12,292	15,233	18,273	22,679	28,342	23.2
Data Processing	2,650	3,148	3,823	4,307	5,203	6,193	18.5
Computers	429	525	638	770	1,108	1,694	31.6
Data Storage	1,590	1,870	2,280	2,470	2,830	2,990	13.5
Input/Output	306	368	444	524	641	789	20.9
Dedicated Systems	188	226	272	321	388	478	20.5
Other Data Processing	137	159	189	222	236	242	12.1
Communications	1,229	1,507	1,859	2,226	2,738	3,390	22.5
Premise Telecom	960	1,176	1,445	1,725	2,105	2,584	21.9
Public Telecom	24	30	38	46	58	74	25.3
Mobile Communications	205	253	318	387	493	631	25.2
Broadcast and Studio	17	20	24	28	34	43	20.4
Other Communications	23	28	34	40	48	58	20.3
Industrial	182	209	240	270	316	375	15.6
Security and Energy Management	5	6	8	9	11	13	20.8
Manufacturing Systems/Instruments	139	157	178	197	228	267	13.9
Medical Equipment	27	33	40	47	57	70	21.0
Other Industrial	11	12	15	17	21	25	18.5
Consumer	5,380	6,766	8,493	10,474	13,185	16,833	25.6
Audio	2,210	2,689	3,218	3,795	4,515	5,438	19.7
Video	2,370	3,111	4,109	5,288	6,989	9,355	31.6
Personal Electronics	281	345	423	509	626	775	22.5
Appliances	509	610	730	867	1,038	1,245	19.6
Other Consumer	10	11	13	15	17	20	15.7
Military/Civil Aerospace	152	177	207	237	278	329	16.7
Transportation	384	485	611	759	958	1,222	26.1

Source: Dataquest (September 1995)

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Figure 2-5
Malaysian Production of Electronics Equipment, 1994 to 1999



Source: Dataquest (September 1995)

Data Processing

Dataquest estimates that Malaysia's data processing production grew by 55 percent to $2.7 billion in 1994. Growth was led by production of disk drives and PCs. Dataquest believes that Malaysia's data processing industry will grow to $6.2 billion, a CAGR of 27.1 percent, again, driven by U.S. rigid disk drive and PC manufacturers. Conner, the trailblazer in rigid disk drives and now merging with Seagate, will continue to increase its capacity in Penang, which accounts for 60 percent of Conner's 3.5-inch global output. Hewlett-Packard, which started out with optoelectronics packaging in Penang, recently relocated its high-end gigabyte disk drive operation from England to Penang. Penang will ultimately account for half of HP's global production and is packaging optoelectronics. Quantum Penang's jump-start from acquisition of Digital's component facilities will also propel Malaysia's disk drive capacity this year. Western Digital in Selangor expects quick ramp-up as early as this year, after it finishes constructing its second building. Dell, Malaysia's first major PC manufacturer, targets production at the end of this year. Dell will also pave the way for other PC manufacturers and create more opportunities for contract manufacturers and component suppliers. The recent multimedia hype is generating interest among several Japanese consumer equipment manufacturers in manufacturing quad-speed CD-ROM drives. Mitsumi, TEAC, Sony, and newcomer Acer are already in the game and have plans to increase capacity. Taiwanese and Korean companies are also stepping up their peripherals (color monitors and keyboards).

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Telecommunications

Telecommunications is Malaysia's third-largest electronics equipment manufacturing industry. Dataquest values the country's production at $1.2 billion, or growth of 21 percent in 1994. Major telecommunications equipment manufacturers include Japan's Sony and Matsushita, Taiwan's Inventech and Formula, and North America's Motorola. In view of the low penetration of telecommunications equipment in the region, these manufacturers are set to expand their capacities to meet growing regional demand. We project telecommunications equipment production to grow at a CAGR of 22.5 percent from 1994 to 1999, to reach $3.4 billion.

Others

Industrial manufacturing, valued at $182 million, consists predominantly of instruments and medical equipment. We expect production revenue to double by 1999. We forecast production of military/aerospace equipment worth $152 million in 1994 to double to $329 million in 1999. Transportation growth is due mainly to automobile stereo equipment. We project that production of $384 million in 1994 will surge to $1.2 billion. Robert Bosch's established manufacturing operation, for example, will see expansion this year as demand for automobile stereo from regional automotive assembly plants increases.

Dataquest Perspective

Electronics equipment manufacturers will continue to expand manufacturing capacities, given the increasing size of the market in this region. As in other Asia/Pacific countries, the Japanese were among the first to establish assembly plants in Malaysia. Malaysia's "Look East" policy of the mid-1980s (in the period of high Japanese domestic manufacturing costs and a strong yen) forced a further production shift to Malaysia, consolidating Malaysia's strength as an important consumer equipment manufacturer. Simultaneously, American disk drive manufacturers such as Hewlett-Packard, Western Digital, and Quantum are following in Conner Peripherals' footsteps to turn Malaysia into another rigid disk drive manufacturing center. This will also be the decade of PC manufacturing, to be spearheaded by Dell.

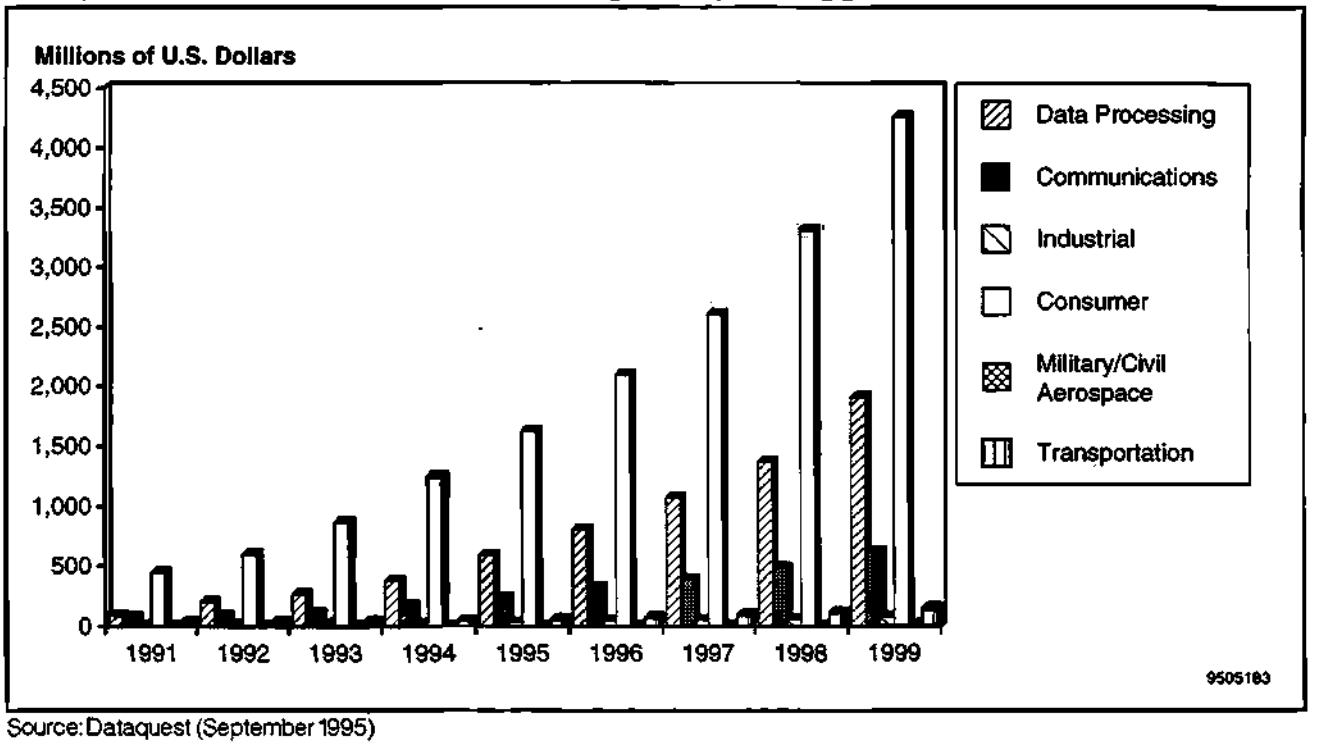
Malaysia's domestic demand for electronic equipment is dwarfed by its export-oriented production revenue. However, increasing affluence in households and corporations and an increasing need to computerize both public and private operations promise high growth in this market. Malaysia still requires further infrastructure development, for example, in the form of telecommunications equipment and services, thus assuring opportunities in this market.

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Chapter 3
Malaysia's Semiconductor Consumption Outlook and Forecast

Malaysia's total semiconductor consumption tripled in three years, reaching $2.0 billion in 1994. Figure 3-1 shows the history and forecast of semiconductor consumption. Total consumption for all six applications will more than triple to $6.6 billion by 1999. Consumer equipment will dominate semiconductor consumption, representing between 60 percent and 70 percent of the market throughout this decade. Video equipment manufacturers will, at a minimum, maintain their high manufacturing capacities throughout the decade. Data processing's consumption share will rise steadily from 20 percent in 1994 to 23 percent in 1999 as rigid disk drive and PC manufacturing capacities start pouring into the country beginning this year. Telecommunications will sustain its 9 percent share of semiconductor consumption.

Figure 3-1
Malaysian Total Semiconductor Consumption by Six Applications, 1991 to 1999



Source: Dataquest (September 1995)

The Malaysian semiconductor market is occupied predominantly by analog and discrete devices, with a combined share of 49 percent (see Table 3-1 and Figure 3-2) in 1994. This is not surprising, given the dominance of Japanese (followed by European) consumer equipment manufacturing. Dataquest expects strong growth from the memory and microprocessor markets in view of Malaysia's enhanced focus on data processing beginning this decade (see Table 3-2 and Figure 3-3). Dell's lead in manufacturing PCs will soon encourage other PC manufacturers to follow suit. At the same time, Conner, Western Digital, Quantum, and HP are expected to show substantially high production numbers, contributing to the overall strong growth in MOS digital devices.

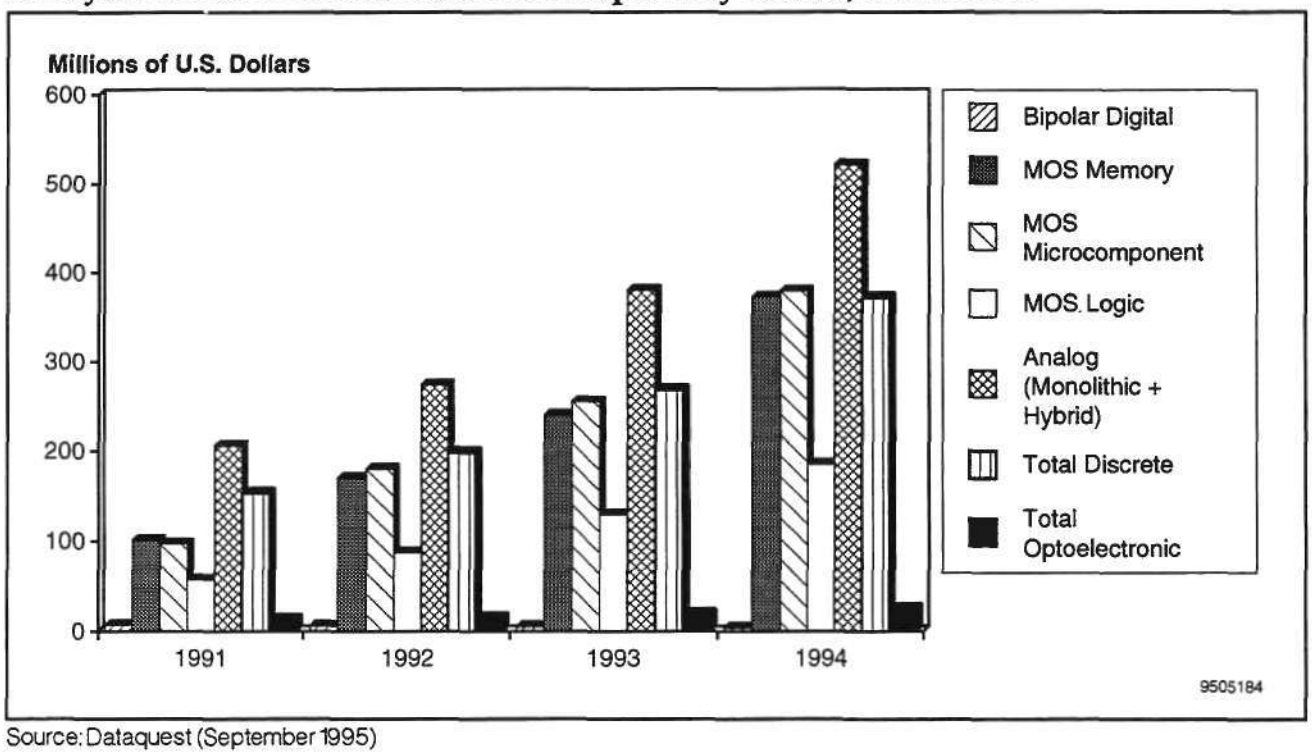
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Table 3-1
Malaysian Total Semiconductor Consumption by Device, 1991 to 1994
(Millions of U.S. Dollars)

	1991	1992	1993	1994
Total Semiconductor	638	886	1,441	1,975
Total IC	471	674	1,100	1,551
Bipolar Digital	7	5	5	4
MOS Digital	256	393	641	984
MOS Memory	102	149	240	390
MOS Microcomponents	97	165	274	401
MOS Logic	57	79	127	193
Analog (Monolithic + Hybrid)	208	276	454	563
Total Discrete	154	198	319	398
Total Optoelectronic	13	14	22	26

Source: Dataquest (September 1995)

Figure 3-2
Malaysian Total Semiconductor Consumption by Device, 1991 to 1994



Source: Dataquest (September 1995)

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Table 3-2
Malaysian Total Semiconductor Consumption by Device, 1994 to 1999
(Millions of U.S. Dollars)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	1,976	2,663	3,413	4,109	5,126	6,612	27.3
Total IC	1,552	2,154	2,795	3,383	4,256	5,545	29.0
Bipolar Digital	4	3	2	2	1	1	-24.2
MOS Digital	985	1,483	2, 014	2,482	3,111	4,099	33.0
MOS Memory	390	698	1,019	1,298	1,627	2,094	40.0
MOS Microcomponents	401	603	768	915	1,134	1,517	30.5
MOS Logic	193	183	227	269	350	488	20.4
Analog (Monolithic + Hybrid)	563	667	779	899	1,144	1,445	20.7
Total Discrete	398	471	570	666	789	960	19.3
Total Optoelectronic	26	38	48	60	81	107	32.7

Source: Dataquest (September 1995)

Figures 3-4 through 3-6 show the historical consumption by device of Malaysia's three major applications: data processing, communications, and consumer equipment. Figures 3-7 through 3-9 forecast consumption by device for these applications.

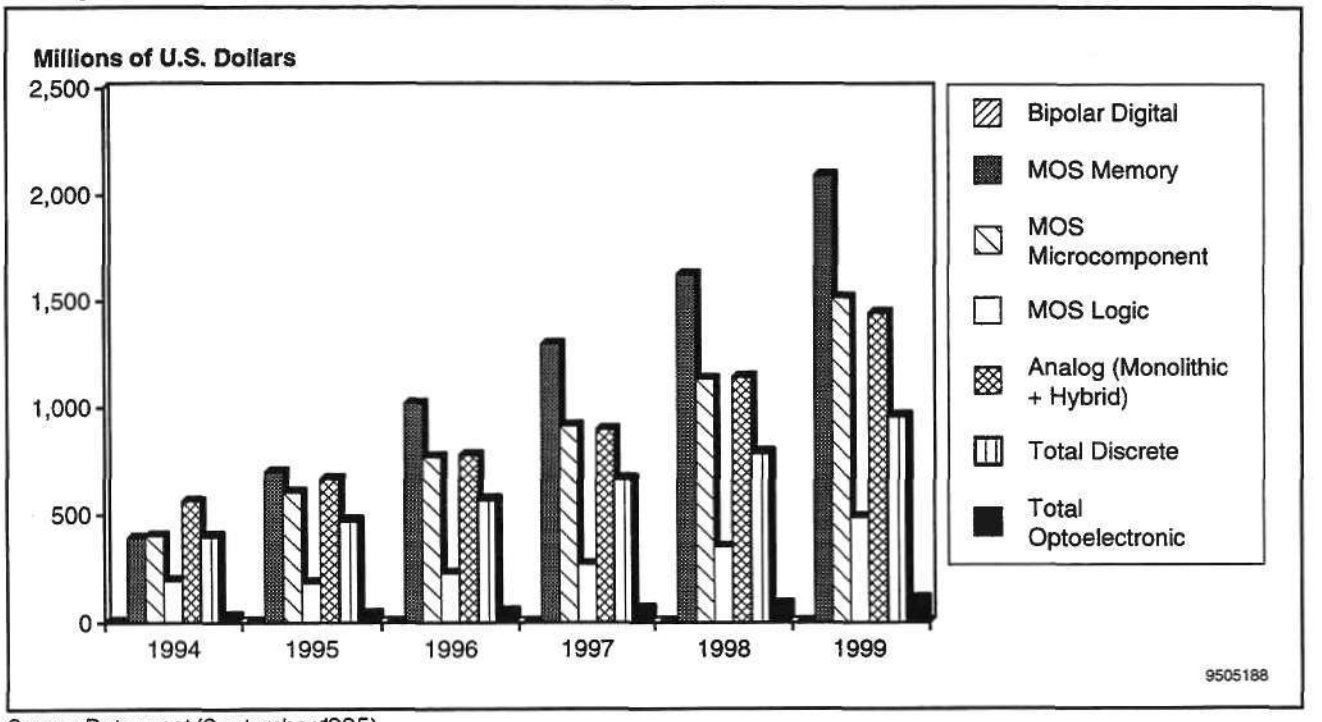
Dataquest Perspective

In a recent market share report, Dataquest showed the combined Singapore/Malaysia subregion as being the largest semiconductor market in Asia/Pacific. Singapore has stolen from Hong Kong the job of being the chief semiconductor supplier to Malaysian equipment manufacturers. That scenario will continue, although more semiconductor suppliers have begun to set up sales offices in Malaysia to provide better customer service to local equipment manufacturers.

Analogs, discretes, and microcontrollers have long dominated the semiconductor consumption scene, given Malaysia's significantly large manufacturing of consumer equipment. From the middle of this decade, Malaysia will see a rapid increase in consumption memories and microprocessors as the country moves toward manufacturing of data processing equipment. Semiconductor consumption, as a whole, will rise with increased equipment production.

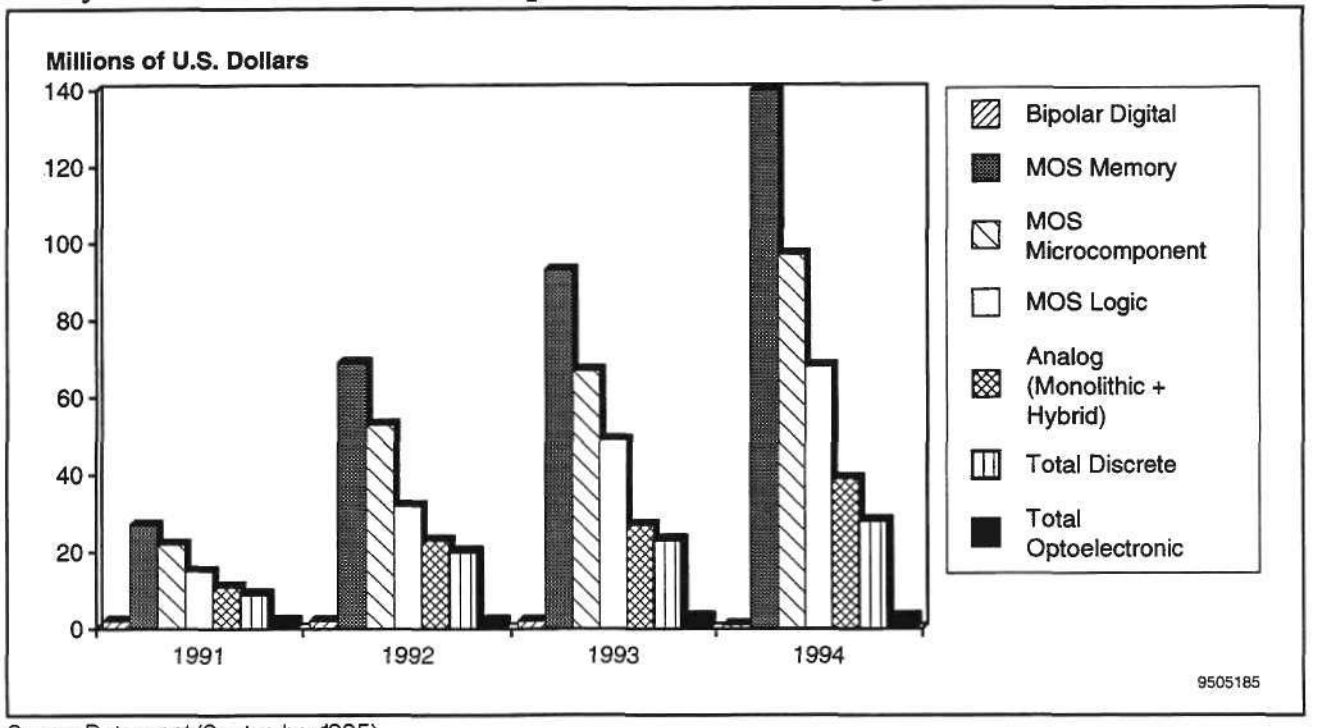
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Figure 3-3
Malaysian Total Semiconductor Consumption by Device, 1994-1999



Source: Dataquest (September 1995)

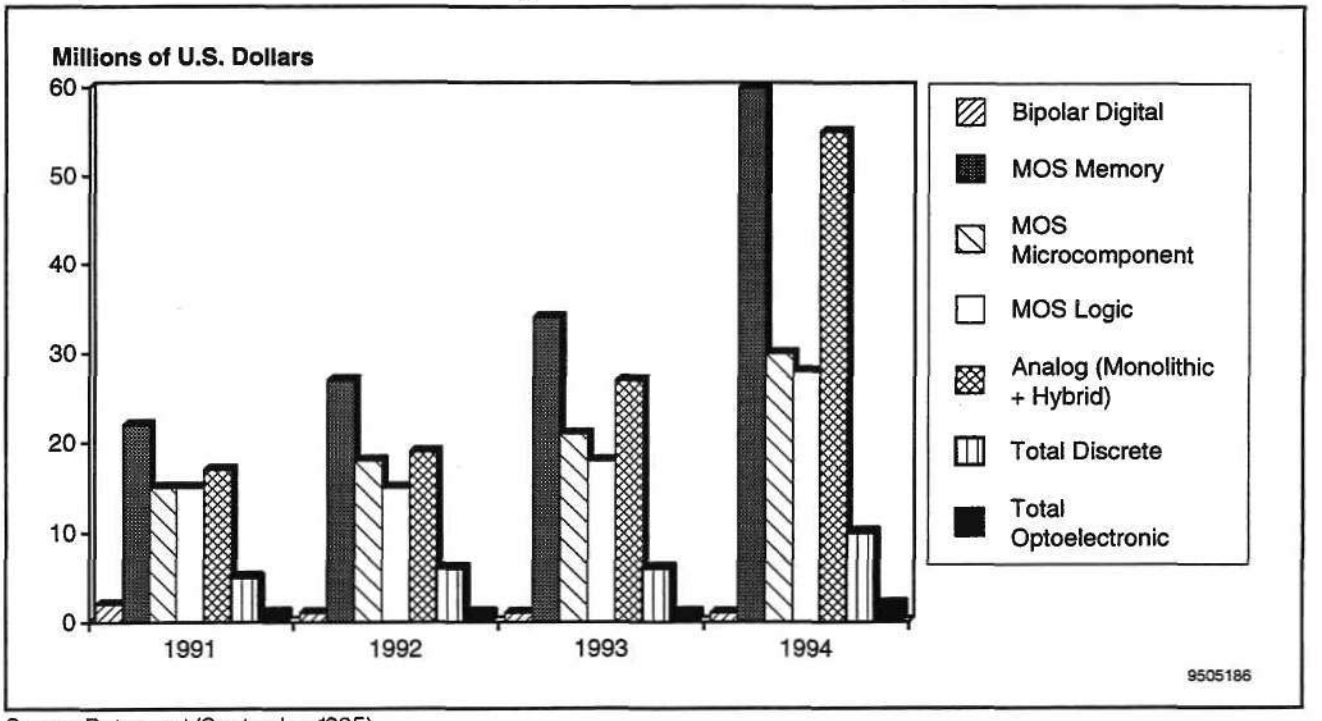
Figure 3-4
Malaysian Semiconductor Consumption in Data Processing, 1991-1994



Source: Dataquest (September 1995)

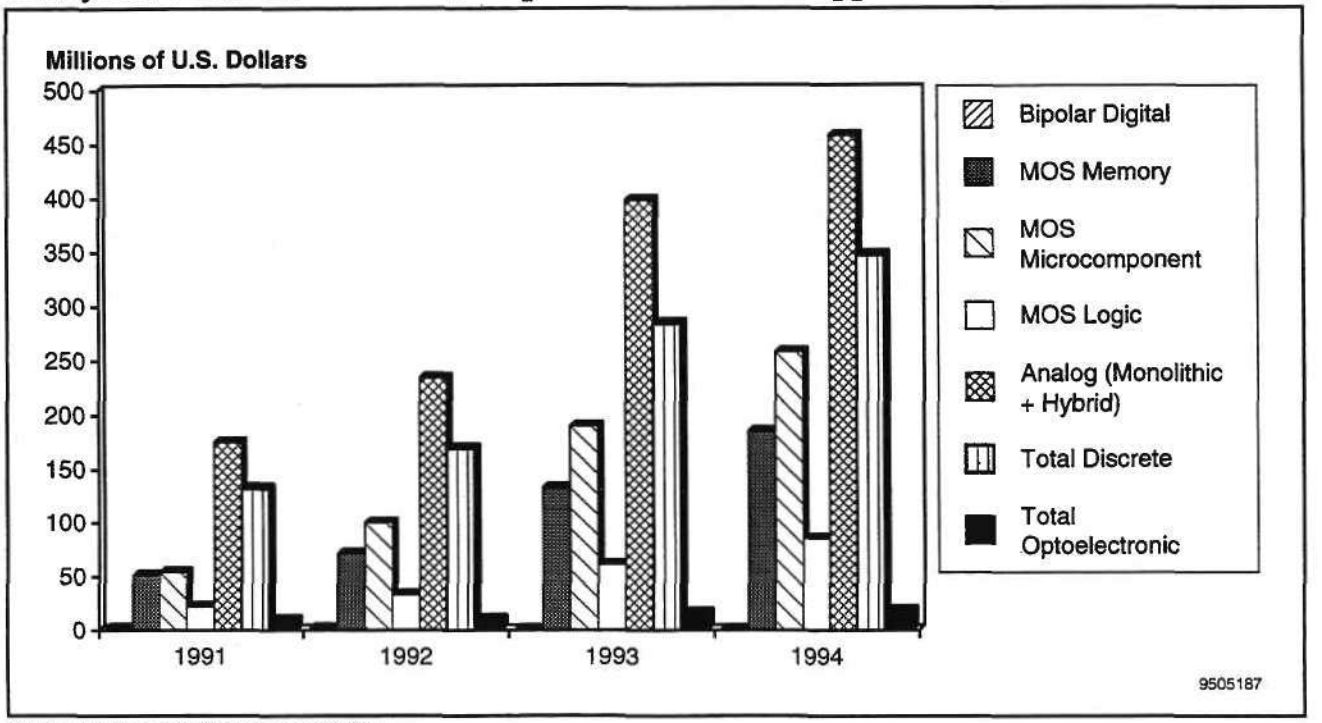
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Figure 3-5
Malaysian Semiconductor Consumption in Communications, 1991 to 1994



Source: Dataquest (September 1995)

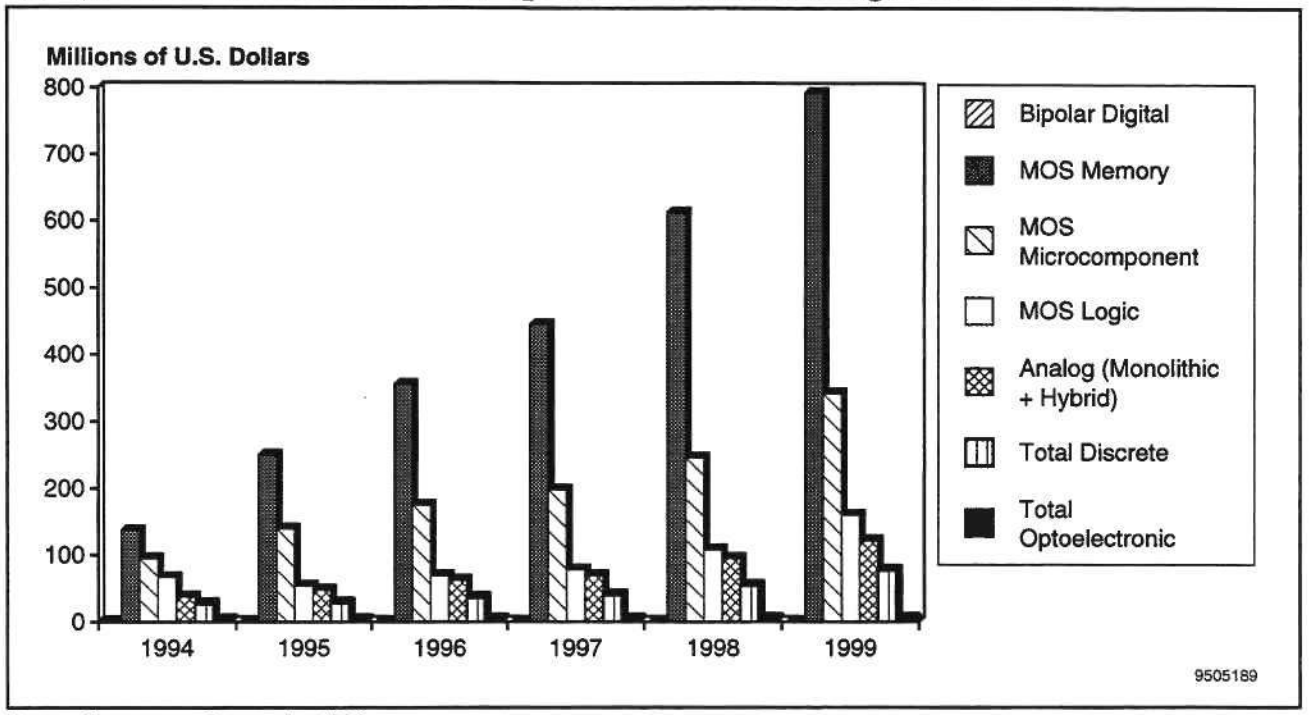
Figure 3-6
Malaysian Semiconductor Consumption in Consumer Applications, 1991 to 1994



Source: Dataquest (September 1995)

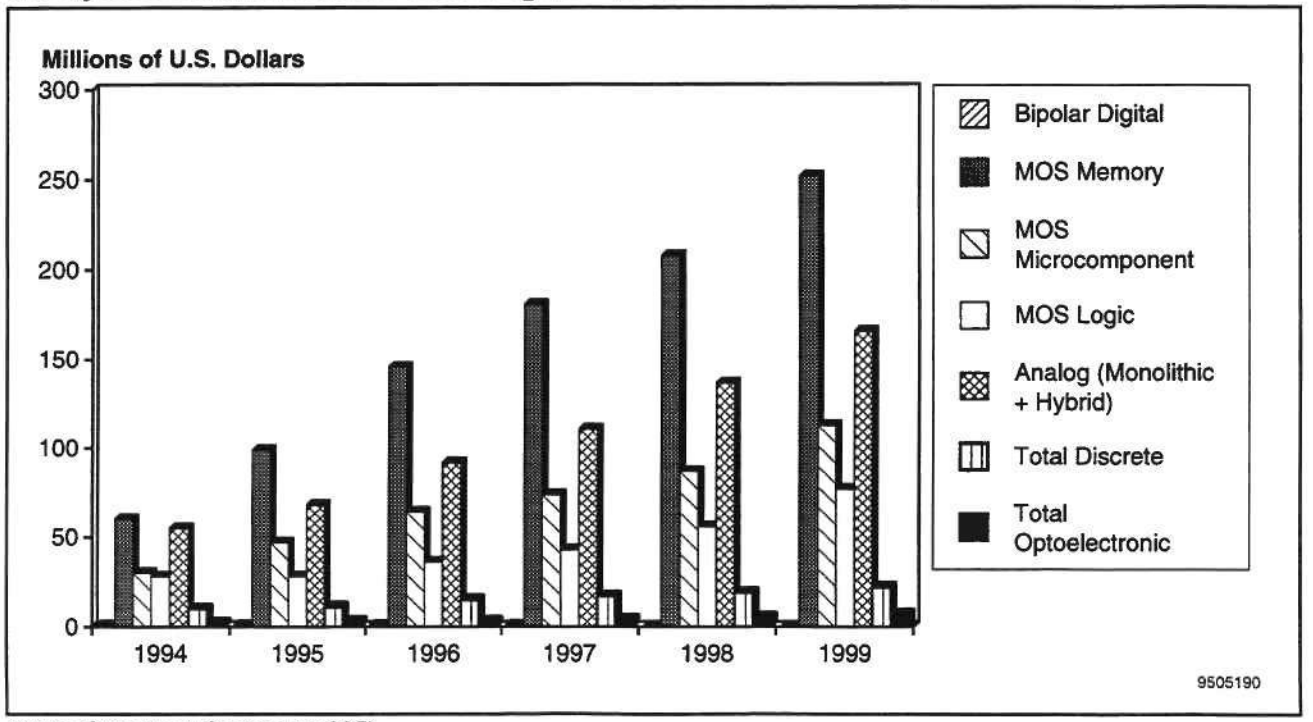
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Figure 3-7
Malaysian Semiconductor Consumption in Data Processing, 1994 to 1999



Source: Dataquest (September 1990

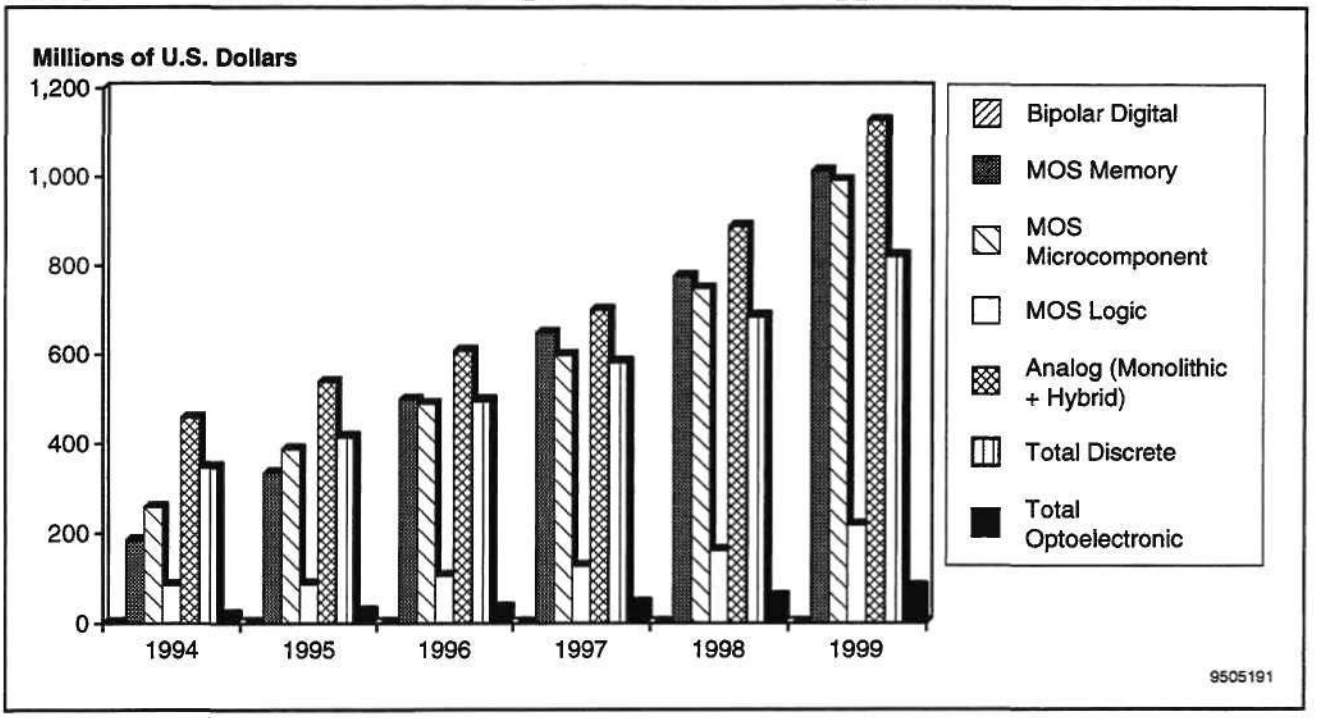
Figure 3-8
Malaysian Semiconductor Consumption in Communications, 1994 to 1999



Source: Dataquest (September 1995)

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Figure 3-9
Malaysian Semiconductor Consumption in Consumer Applications, 1994 to 1999



Source: Dataquest (September 1995)

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Chapter 4
Malaysia's Electronics Industry: Equipment Assembly and Semiconductor Packaging

This first section of this chapter will look at some of the multinationals that have contributed to the growth of Malaysia. The second section will highlight Malaysia's home-grown companies that serve as models to other aspiring local companies, while the third gives an update on Malaysia's semiconductor manufacturing. Companies not mentioned in these sections are included in a summary of major companies in Table 4-1.

Foreign Companies

Foreign companies have continued to drive Malaysian exports, thanks to the country's relatively low-cost labor pool and its location within the burgeoning Asia/Pacific markets. The next sections highlight some of the major foreign and local companies in Malaysia.

Japanese Companies

Japanese companies without question dominate consumer equipment manufacturing, which is Malaysia's largest electronics manufacturing sector. Video and audio equipment are the key products. Most of the Japanese manufacturers began congregating in Selangor, which contains the country's capital city and port/transportation facilities. Japanese companies then spread their wings to Johor, where they could enjoy Singapore's free port facilities. Other states with a Japanese presence include Malacca, Penang, and Kedah. Malaysia, like Thailand, is a favorite manufacturing base for floppy disk drives companies such as TEAC, Mitsumi, and Sony. We believe that the strong value of the yen will continue to push production flow to Malaysia. Japanese companies, including Toshiba, Fujitsu, NEC, and Hitachi, have several semiconductor assembly and test facilities in Malaysia.

Matsushita

Matsushita is the oldest consumer equipment manufacturer in Malaysia. It has manufactured household electrical appliances since 1965. Matsushita's 40 percent stake in National Panasonic allows efficient marketing and distribution. The Matsushita Group is the largest manufacturer in the consumer and industrial sector in Malaysia. The group comprises 16 factories, which also manufacture other household appliances, air conditioners, consumer electronics, and key components. For fiscal year 1994, ending March 1995, Matsushita expected to produce 600,000 units of VCRs per quarter. During this period, all overseas facilities were to produce 3.6 million units or 41 percent of its global output. The company hopes to double VCR output to 1.2 million units per quarter by 1996. During this year, overseas contributions will rise to 51 percent (5.7 million units) of the worldwide total. VCR production growth will also be supplemented by Matsushita's Chinese facility, from 39 percent in 1994 to 51 percent by 1996. Matsushita Electric is increasing its electrical appliance production by 40 percent. It recently built its largest overseas warehousing facility in Shah Alam, in reponse to the need to accommodate increasing export volumes.

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Sony

Sony established its five plants in Malaysia between 1987 and 1989. The three facilities in Prai, opposite Penang, under Sony Electronics, produce audio equipment, including the Walkman, and general products such as alarm clocks, floppy disk drives, and CD-ROM drives. Sony is estimated to produce 500,000 telephones per month. Sony Mechatronic churns out 1.2 million units of floppy disk drives per month, generating revenue of $23 million per month. The Prai facilities project revenue of $1.3 billion this year. Sony's other two Malaysian video equipment facilities boast of being the company's largest global manufacturing bases. Sony TV Industries in Bangi, Selangor, recorded revenue of $687 million, or 50 percent growth in 1994. It expects to produce 3 million television sets this year, a 20 percent increase. Sony TV expects revenue of $890 million for 1996. The Malaysian facility produces 25 percent of Sony's worldwide output. Its videocassette recorder counterpart, Sony Video, accumulated revenue of $607 million in 1994. It is targeting 3 million VCRs, a 50 percent increase in unit output this year. Sony Video forecasts revenue of $810 million for 1996. The Malaysian facility accounts for 60 percent of global output. Sony has 11 television and four video manufacturing facilities worldwide.

Hitachi

Hitachi Consumer Products started manufacturing TV components in 1980. It produces deflection yokes and flyback transformers for computers, televisions, and VCR tuners. Hitachi relocated its entire Japanese VCR operation to Penang, and the island is its center for marketing, manufacturing, and R&D. Ninety-five percent of its production of televisions and VCRs is for export. Malaysian engineers designed Hitachi's diode mounter machine, now being considered for patent registration. Hitachi Consumer Products expects to achieve revenue of $142 million this year. Hitachi Semiconductor, its sister semiconductor company, runs two IC assembly/test facilities. The major facility in Penang packages 16Mb DRAM, 4-bit and 8-bit microcontrollers, LCD drivers, diodes, transistors, and memory modules. The smaller facility in the nearby state of Kedah assembles small volumes of M-Pak transistors for audio/video applications.

North American Companies

North American companies are highly visible in semiconductor packaging and data storage manufacturing in Penang and Selangor. Following Conner's arrival in Penang, Quantum and HP began clustering their disk drive operations in the vicinity. Western Digital chose to be located in Selangor. Dell, a North American company, will be the first to introduce a global PC manufacturing facility in Penang.

Intel

Intel's 18-year-old Penang facility is its largest assembly and test facility worldwide, accounting for 80 percent of Pentium microprocessors. Intel designated the Penang facility as business headquarters for 8-bit microcontrollers, responsible for design (including 16-bit), marketing, assembly/test, and distribution. Intel is investing $157 million to construct its PG7.1, an extension of its seventh building, which assembles and tests Pentium chips. The 200,000-square-foot facility, scheduled for completion this year, will assemble both Pentium and P6 chips, with the former ranging from the 75-MHz to the 100-MHz type. Intel will add 300 employees to

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its total of 3,500 in this expansion. Elsewhere in the region, Intel will pump $358 million into the Philippines to assemble and test Pentium chips and other devices. Intel also plans to invest $150 million in Shanghai to assemble and test flash memories and embedded microcontrollers in 1997.

Motorola

Motorola, one of the pioneers in investing in Penang, opened its facility in 1972. The Penang facility designs, develops, and manufactures two-way mobile walkie-talkies for low-band/VHF/UHF. It also supports CT-2 product enhancement. Malaysia is Motorola's leading global semiconductor assembly and test facility. Motorola's wafer fab, which produces discretes, is integrated with an assembly/test facility in the state of Negri Sembilan (south of Kuala Lumpur). Its main semiconductor facility, located in the state of Selangor, assembles and tests DRAM, microprocessors, and analogs. Motorola also has established a joint-venture company with Philips to package surface-mount discretes for consumer electronic products.

Conner Peripherals

Conner, now merging with Seagate, carries the distinction of being Malaysia's first rigid disk drive company. It started out with head stack assembly in 1989, then converted to full manufacturing of disk drives in 1990. The Malaysian facility is the primary center for the manufacture of 3.5-inch 850MB and 1.2GB RDDs, accounting for 60 percent of its global manufacturing. The facility assembles 30,000 units a day; a majority of the 850MB product is supplied to Packard Bell. It plans to introduce the Cabo and Stingray series during the third quarter of 1995, followed by the La Paz series in the fourth quarter.

Dell

Dell is establishing its third global manufacturing base in Penang through its subsidiary, Computer Direct. This move earns Dell the title of first major PC manufacturer to arrive in Malaysia. Construction of the 22,000-square-meter facility began in March 1995. It is scheduled to begin production at the end of this year. The initial monthly output of 2,000 units will increase gradually to 10,000 units. The facility can achieve a maximum output of 100,000 units per month, which rivals its facility in Limerick, Ireland. Penang was chosen as Dell's Asian manufacturing base to be closer to its major regional clients in Japan and Australia and to target the burgeoning Chinese market. It is also a choice site because of the presence of component suppliers such as Intel Penang and Western Digital Selangor and a host of contract manufacturers.

European Companies

Robert Bosch and Siemens were the first two European companies to invest in Penang, in 1972. European companies also have several semiconductor assembly and test facilities (SGS-Thomson and Siemens) and audio/video equipment manufacturing (Thomson, Grundig, and Robert Bosch).

Siemens Components

Siemens owns two semiconductor assembly and test facilities in Penang and Malacca. The Penang facility, acquired from Litronix in 1981, specializes in intelligent displays, optocouplers, and OCD products. The Malacca

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plant focuses on 4Mb and 16Mb DRAM, transistors, diodes, and LEDs. Siemens plans to invest $200 million over the next few years to upgrade both facilities, which includes a fiber-optics project in Penang. To date, Siemens has invested $307 million. The two facilities employ 5,000 people and recorded revenue exceeding $1 billion in 1994.

Robert Bosch

This German company began manufacturing exposure meters for silent movie cameras in Penang in 1972. It added assembly of movie cameras and car signal flashes in 1973. The Penang facility is the largest producer of Blaupunkt (audio) products, controlling over 30 percent of its global production. Its local R&D team has designed automotive stereos, replacing cameras, since 1983.

Thomson

Thomson manufactures audio, video, and communications equipment under the brands General Electric, RCA, and ProScan in the United States and Fergusson, Telefunken, SABA, and Normandie in Europe. Thomson set up three manufacturing facilities in Malaysia in 1987. Its Asia/Pacific corporate headquarters in Singapore provides engineering, design, and technical support. The manufacturing facility in Kulim in the state of Kedah focuses on high-end consumer equipment such as CD players and cordless telephones, while the other two produce portable audio products and corded telephones. Thomson sold one of its Johor facilities to its Singapore-based subcontract manufacturer. Thomson has also ventured into Nantou to manufacture optical pickups, which will see expansion in Thomson's high-end consumer equipment manufacturing in China.

Asian Companies

Companies from Taiwan, South Korea, and Hong Kong are also starting to exploit the manufacturing cost advantages of Malaysia. Taiwanese companies came because of cultural and language affinities. In fact, they are the largest investors in Malacca, where they share a common dialect. Taiwanese companies such as Acer and Lite-on manufacture PC peripherals such as color monitors and keyboards. Inventech and Formula are also known for assembling telecommunications equipment. ASE Electronics, Rectron, and Golden Frontier Technology are Taiwanese IC subcontractors. Hualon has announced plans to construct a wafer fab in Malaysia's new Kulim High Technology Park in the state of Kedah, near Penang. Samsung is an icon of South Korea's PC and consumer peripherals manufacturing in Malaysia. Lucky Goldstar depends upon a local company, Setron, to provide contract manufacturing/assembly services for its electrical appliances.

Samsung Electron Devices

Samsung established its largest overseas manufacturing facility in Seremban, Malaysia, away from the "crowded" Shah Alam industrial zone. Samsung Electron Devices Malaysia (SEDM) was set up in Seremban in 1990 to produce color display tubes for PCs and electron guns for televisions and PCs. Sixty percent of its products are exported, with the remaining 40 percent sold to Funai, Matsushita, and Sharp. SEDM is targeting revenue of $266 million this year, or 72 percent growth. It employs 2,802 workers. SEDM expects to generate a total of 6.48 million color picture tubes and color display tubes in 1995, an increase of 86 percent. SEDM is constructing a second facility scheduled

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for completion in 1996. It will assemble PCBs and will add two color monitor lines. SEDM's related companies are Samsung Corning (color cathode ray tube glass bulbs) and Samsung Electronics (microwave ovens). All in all, Samsung has 35 overseas manufacturing facilities. As a sales group, Samsung captures over 10 percent of the Malaysian electrical appliance market. It projects revenue to reach $46 million this year.

Acer Technologies

Acer Technologies in Seberang Jaya, Prai (near Penang) is a full subsidiary of Taiwan-based Acer Peripherals Inc. The Malaysian facility accounts for more than two-thirds of Acer's total production volume of 14-inch and 15-inch color monitors and 100 percent of keyboard production. Acer Technologies is targeting a 60 percent increase in monitor output, or 3.2 million units this year. It expects to increase keyboard capacity to 4 million units this year. Acer plans to achieve a maximum capacity of 5 million monitors and 8 million keyboards by 1996. Revenue in 1994 was $344 million, for growth of 49 percent. Acer is investing $40.6 million over the next two years, half to go into construction of a second facility for the exclusive production of 1 million units of CD-ROM drives this year. Acer Technologies expects to churn out 1 million units per month by 1997.

Malaysia's Indigenous Electronics Companies

Malaysian companies tend to play the role of component supply and PCB assembly/contract manufacturing to multinationals. The supporting companies structure provides a powerful base from which multinationals can take root and expand their local operations. In addition to U.S.-based Solectron and newcomers such as Jabil, Zircom, and Dovatron, Malaysia has its own electronics equipment contract manufacturers such as Tong Kah. Malaysia has attracted Singapore-owned contract manufacturers such as NatSteel, which is trying to minimize the effects of rising manufacturing costs and labor shortages in Singapore. Malaysia's local semiconductor (subcontracting) assembly industry is represented by Carsem, Unisem (a spin-off of rival Carsem), and Globetronics.

Carsem

Carsen is Malaysia's oldest and largest semiconductor packaging subcontractor. Singapore's Hong Leong Group bought over 70 percent of the company in 1984; the remaining 30 percent is controlled by the Malaysian government. Carsem, which started out by providing electrical testing in 1972, has grown into an important semiconductor assembly facility for clients such as AMD, Linear Technology, and Unitrode. Most of the clients are from U.S. (55 percent) and European (35 percent) disk drive, telecommunications, and automotive industries. Carsem has invested in R&D facilities and is targeting testing to complement its current processes. Located in the state of Perak between Penang and Kuala Lumpur, the 6,000-strong company generated revenue of $41 million last year.

Sapura

Sapura is a classic example of a Malaysian contract manufacturer that has graduated from OEM for Siemens (then Matsushita and Thomson) to producing its own range of telecommunications equipment. The Sapura Group started out in 1975 as an OEM manufacturer of single-line telephones for Siemens. Today, the Malaysian group is worth $77 million and is well diversified in telecommunications equipment manufacturing and

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R&D, marketing, trading, and IT services. Under the Sapura group are two publicly traded companies: Uniphone Telecom (public telephones and telephone cards) and Sapura Telecom (manufacturing and marketing of telecommunications equipment, design, cable installation, and paging services). Sapura's R&D unit collaborates with an independent Canadian design house, Silent Signal, on radio-frequency products. It produces an average of 75,000 units of telephone products a year, mostly supplied to the local telecommunications authority, Telekom Malaysia.

Likom

Likom is another contract manufacturer with high hopes of producing its own brand-name products next year, starting with keyboards. Likom Corporation was incorporated in 1992 as the PC peripherals manufacturing arm of diversified conglomerate Lion Corporation. It was established by the former employees of a PC assembly company, Microcomputer Systems, which pioneered assembly of PCs in Malaysia in 1988. Likom purchased several Taiwanese and U.S. PC-related manufacturers to jump-start its manufacturing business. The company assembles color monitors (150,000 units per month), power supplies, keyboards (200,000 units per month), CD-ROMs (200,000 units per month), and PC assemblies (30,000 units per month) under OEM/ODM agreements.

Since 1994, Likom has operated in an 880,000-square-foot facility in Malacca's Cheng Industrial Zone, south of Kuala Lumpur. The nine-plant facility employs 3,800. Clients include Apple, Unisys, NEC, Compaq, and Olympia. Likom expects a minimum of a 20 percent increase in unit output for all its products. It aims to grow its business to $2 billion by 1997, and to $5 billion by 2000.

Table 4-1
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
IC Assembly/Test				
AMD	Penang	1972	United States	Assembly of program logic devices, flash memory, EPROM
ASE Electronics	Penang	1991	Taiwan	IC packaging subcontractor
Carsem	Perak	1972	Malaysia	IC packaging subcontractor
China Semiconductor	Malacca	1993	Taiwan	A/T LEDs
Fujitsu Microelectronics	Selangor	1988	Japan	A/T MOS memory, linear ICs
Harris Advanced Technology	Selangor	1974	United States	A/T power ICs
Hewlett-Packard	Penang	1972	United States	A/T LEDs, microwave diodes, rigid disk drives
Hitachi Semiconductor	Penang	1972	Japan	A/T 16Mb DRAM, microcontrollers (4-bit, 8-bit), LCD drivers, diodes, transistors
Hitachi Semiconductor	Kedah	1972	Japan	A/T M-Pak transistors

(Continued)

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Table 4-1 (Continued)
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
Globetronics	Penang	1991	Malaysia	IC packaging subcontractor
Golden Frontier Technology	Penang	1994	Taiwan	A/T rectifiers
Integrated Device Technology	Penang	1987	United States	A/T SRAM
Intel	Penang	1972	United States	A/T Pentiums; D/A/T 8-bit and 16-bit MCUs
Linear Technology	Penang	1994	United States	A/T analog devices
Motorola	Selangor	1974	United States	A/T MCUs, 6800 MPUs, PowerPCs, analog devices, 16Mb DRAM
Motorola	Negri Sembilan	1985	United States	A/T discretes; wafer fab (discretes)
National Semiconductor	Penang	1972	United States	A/T logic devices
National Semiconductor	Malacca	1972	United States	A/T analog devices
NEC	Selangor	1974	Japan	A/T transistors, consumer/ industrial linear ICs, light-emitting diodes
Quality Technology	Selangor	1979	United States	A/T optocouplers (telecom)
Rectron	Penang	1987	Taiwan	A/T diodes, bridges, rectifiers
Rohm-Wako	Selangor	1987	Japan	A/T LEDs (resistors)
Semiconductor Miniature Products	Negri Sembilan	1995	United States-Netherlands	A/T surface-mount discretes
SGS-Thomson	Johor	1974	France	A/T power ICs, transistors, diodes
Siemens (through Litronix)	Penang	1972	Germany	A/T optoelectronics
Siemens	Malacca	1973	Germany	A/T 1Mb, 4Mb, 16Mb DRAM, power transistors, opto-electronics, diodes
Texas Instruments	Selangor	1972	United States	A/T DRAM, thermostats, motor protectors
Toshiba Electronics	Selangor	1973	Japan	A/T DRAM, transistors
Unisem	Perak	1991	Malaysia	IC packaging subcontractor
RDD				
Applied Magnetics	Penang	1988	United States	Thin-film media
Conner	Penang	1989	United States	Rigid disk drives
Hewlett-Packard	Penang	1995	United States	Rigid disk drives
Komag	Penang	1992	United States	Rigid disk drive media
Quantum	Penang	1994	United States	Rigid disk drives
Read-Rite	Penang	1991	United States	Head stack assembly

(Continued)

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Table 4-1 (Continued)
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
Seagate	Penang	1990	United States	Head gimbal assembly, thin-film media
Western Digital	Selangor	1994	United States	Rigid disk drives
Video				
Action	Penang	1988	Taiwan	Color televisions
Aiwa	Johor	1989	Japan	Videocassette recorders, videocassette players
Asahi	Kedah	1988	Japan	LCD (televisions)
Funai	Johor	1989	Japan	Color televisions, television video
Hitachi (HEPM)	Selangor	1980	Japan	Videocassette recorders, televisions
Makonka	Selangor	1989	Japan	Color televisions
Matsushita Audio/Video	Johor	1990	Japan	Audio/video, radios, radio cassettes
Mitsubishi Electric	Johor	1989	Japan	Videocassette recorders
Matsushita Electronics	Selangor	1990	Japan	Color picture tubes
Matsushita TV	Selangor	1988	Japan	Televisions
Orion	Malacca	1988	Japan	Videocassette players, televisions
Philips-JVC	Selangor	1988	Netherlands-Japan	Videocassette recorders
Setron	Selangor	1992	Malaysia-Korea	Color televisions, video cassette recorders, stereo systems, CD players, washing machines
Sony Electronics	Penang	1987	Japan	Cassette players,stereo systems, CD players, floppy disk drives, CD-ROM drives
Sony TV Industries	Selangor	1988	Japan	Color televisions
Sony Video	Selangor	1989	Japan	Videocassette recorders
Sharp	Kedah	1974	Japan	Radios, cassette recorders, stereo systems, built-in CD players
Sharp	Johor	1989	Japan	Videocassette recorders
Sharp-Roxy Appliances	Selangor	1985	Japan	Videocassette recorders, refrigerators, washing machines, gas cookers, vacuum cleaners, televisions
Sharp-Roxy Electronics	Johor	1980	Japan	Televisions, picture tubes

(Continued)

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Table 4-1 (Continued)
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
Silver	Selangor	1988	Japan	Color televisions, videocassette players, CD players, stereo systems
Yupiteru	Penang	1990	Japan	Color televisions, cordless phones
Audio				
Asahi Industries	Johor	1988	Japan	Radio cassette CDs, stereo systems, cordless phones, phone answerers
Audio Electronics (Philips)	Penang	1979	Netherlands	Stereo systems
Clarion	Penang	1972	Japan	Car stereos
FMS	Penang	1991	United States-Japan	Car stereos
Grundig	Penang	1988	German	Headphones, radios, radio cassettes, CD players, stereo systems
Onkyo	Selangor	1989	Japan	Stereo systems
Pioneer	Johor	1991	Japan	Stereo systems, CD players, car stereos
Robert Bosch	Penang	1972	German	Car stereos
Sanshin	Kedah	1985	Japan	Car stereos
Santronics	Johor	1987	Japan	Headphones, radio cassettes, radio-cassette CDs, stereo systems, cordless phones
Thomson	Kedah	1987	France	CD players, speaker phones, cordless phones
Thomson	Johor	1979	France	Radios, cassette players, answering machines, corded phones
TKR	Malacca	1988	Japan	Car stereos, game machines
Toyo	Penang	1984	Japan	Headphones, radios, corded and cordless phones
Trio-Kenwood	Johor	1991	Japan	CD players, stereo systems, car stereos
Tru-Tech	Johor	1994	Singapore	Audio, CD players, stereo systems
Yamaha	Perak	1991	Japan	CD players, stereo systems
Telecom				
Bestec	Selangor	1990	Taiwan	Corded phones
Formula	Penang	1988	Taiwan	Corded and cordless phones

(Continued)

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Table 4-1 (Continued)
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
Huston	Perak	1988	Taiwan	Corded phones
Inventech	Penang	1989	Taiwan	Corded phones, answering machines, calculators
Iwatsu	Negri Sembilan	1990	Japan	Corded phones
Marconi	Kedah	1984	Italy	Telecom, military equipment
Meisei	Penang	1989	Japan	Corded phones
Motorola	Penang	1972	United States	Walkie-talkies/transceivers, cellular phones
Multitone	Malacca	1994	Taiwan	Beepers
Northern Telecom	Penang	1982	United States	Power conversion switches, PBX line cards
Northern Telecom	Kedah	1986	United States	Key phones
Nouveau Tech	Selangor	1991	Japan-Malaysia	Corded phones
RC Centronic	Selangor	1990	Taiwan	Phone answerers, cordless phones
S Megatel	Selangor	1994	Hong Kong-Malaysia	Cordless phones
Sapura	Selangor	1975	Malaysia	Phones, fax machines, cellular phones, beepers
Team Concept	Kedah	1989	Taiwan	Corded phones
PCs, Peripherals				
Acer	Penang	1985	Taiwan	Color monitors, keyboards, CD-ROM drives
Alps	Negri Sembilan	1989	Japan	Tuners
Brother Industries	Johor		Japan	Fax machines
Chinon	Johor	1972	Japan	Floppy disk drives
Dell	Penang	1995	United States	Personal computers
Fujitsu Components	Johor	1980	Japan	Keyboards
Gateway 2000	Malacca	1995	United States	Personal computers
Great	Penang	1990	Taiwan	Color monitors
Likom	Malacca	1992	Malaysia	Color monitors, keyboards, CD-ROM drives (OEM)
Lite-On	Penang	1991	Taiwan	Color monitors (OEM)
Mitsumi Electronic	Johor	1979	Japan	Floppy disk drives, micromotors, mice
Mitsumi Technology	Johor	1986	Japan	Keyboards, remote controls
NEC	Kedah	1983	Japan	Color monitors, CD-ROM drives
Samsung	Negri Sembilan	1989	South Korea	Color monitors, color picture tubes, microwave ovens

(Continued)

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Table 4-1 (Continued)
Electronics Equipment Manufacturers and Semiconductor Packaging Facilities in Malaysia

Company	Location (State)	Year Established	Country of Origin	Activities/Products
Sonica	Johor	1991	Singapore	Color monitors
TEAC	Malacca	1990	Japan	Floppy disk drives
Wearnes Electronics	Johor	1994	Singapore	Car stereos, CD players, floppy disk drives
Consumer, Others				
Black & Decker	Pahang	1974	United States	Car audio
Flextronics	Johor	1991	United States	Electrical appliances, fans
Goko Camera	Johor	1988	Japan	Cameras
Hitachi A/C	Selangor	1989	Japan	Air conditioners
Levitec Electric	Johor	1989	Switzerland	Industrial controls
Matsushita Compressor	Selangor	1987	Japan	Air conditioners, motors
Matsushita Electric	Selangor	1965	Japan	Color televisions, refrigerators, washing machines, cookers, fans, irons, vacuum cleaners
Matsushita Electronic	Selangor	1987	Japan	Ceramic condensers, tape resistors
Matsushita Electronic Component	Selangor	1972	Japan	Condensers, tuners, switches, remote controls
Matsushita Electronic Motor	Kedah	1990	Japan	Micromotors (office automation, audio/video)
Matsushita Industrial	Selangor	1972	Japan	Air conditioners
Matsushita Precision Capacitor	Malacca	1990	Japan	Capacitors (plastic film)
MEMC Electronic Materials	Selangor	1989	United States	Unetched silicon wafers
Minolta	Selangor	1973	Japan	Cameras
Nikko	Penang	1989	Japan	Toy remote controls
Samsung	Selangor	1987	South Korea	Microwaves
Sanden	Selangor	1985	Japan	Car air conditioners
Sanwa RC System	Johor	1989	Japan	Remote controls
Sanyo Industries	Perak	1967	Japan	Cookers, fans, refrigerators, air conditioners
Shin-Etsu Handotai	Selangor	1973	Japan	Unetched silicon wafers
SMK Electronics	Selangor	1989	Japan	Remote controls
TIM	Penang	1990	Japan	Fax machines
TM Air-Conditioning	Penang	1987	Japan	Industrial air conditioners
VDO Instrument	Penang	1984	Germany	Automotive instruments

Note: A/T = semiconductor assembly and test; D/A/T = semiconductor design, assembly, and test
Source: Dataquest (September 1995)

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Malaysia's Current and Future Semiconductor Manufacturing

Malaysia's only wafer fab is owned by Motorola, which has been in operation since 1988. This discrete manufacturing facility dedicated to internal consumption has qualified as a self-contained integrated wafer fab since early this year. Motorola's existing fab capacity in Malaysia is summarized as follows:

- City: Seremban
- Fab Name: Ismf
- Type: Foundry with assembly and test capabilities
- Year: 1988
- Maximum theoretical production capacity/month: 4,000
- Products: Power transistors, discretes
- Technology: Bipolar
- Linewidth: 3 microns
- Minimum cleanroom class: 100
- Maximum wafer size: 4 inches

Future Wafer Fab Directions

Malaysia's 20-year history of semiconductor back-end operation has induced the government to take the following measures to create a environment favoring development of wafer fabs:

- Research culture. Lack of R&D culture has compelled Malaysia to set up an autonomous body to promote high technology. The Malaysian Institute of Microelectronics (MIMOS) was set up in 1988 in a technology park in Bukit Jalil in the state of Selangor. MIMOS recently announced that it will purchase wafer fab equipment from Nikon, Applied Materials, and ASM Wafer Processing Equipment to establish the country's first wafer fab laboratory. The project, to "produce" 6,000 units of 6-inch ASIC wafers per month using 1-micron technology, calls for an investment of $40 million spread over three years.
- Manufacturing site. Malaysia has identified Kedah (near Penang) as the state that will house the country's first comprehensive industrial park, Kulim High Technology Industrial Park. The $500 million park will be ready to provide utility and waste disposal services by the end of this year. It will contain industrial/research centers, factories, a hospital, housing zones, and recreational facilities. Hualon recently signed a memorandum of understanding to construct an $800 million wafer fab through its subsidiary, Kedah Wafer Emas (KWE), an indication of the serious consideration it is giving to manufacturing semiconductors in Malaysia. Plans call for this new wafer fab to produce 24,000 wafers per month using 0.5-micron technology. KWE will begin operation next year.

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Dataquest Perspective

Malaysia has achieved its goal of complementing semiconductor back-end facilities with electronics equipment manufacturing, with much of the credit for this achievement going to foreign multinationals. The presence of foreign equipment multinationals has provided business opportunities for local contract manufacturing companies, and several of these indigenous companies have either grown to develop their own brands of products or are poised to achieve that objective. Foreign semiconductor companies, too, have spun off or attracted packaging subcontractors.

Malaysia is set to develop data processing manufacturing, having firmly established its semiconductor assembly/test and consumer equipment manufacturing facilities. Plans are under way for Malaysia to integrate its back-end semiconductor processes with front-end facilities.

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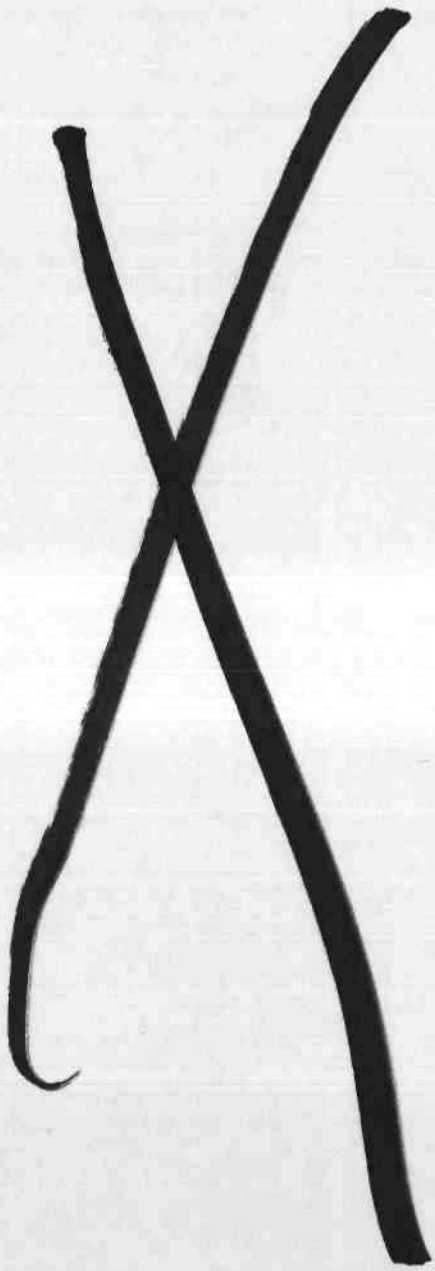
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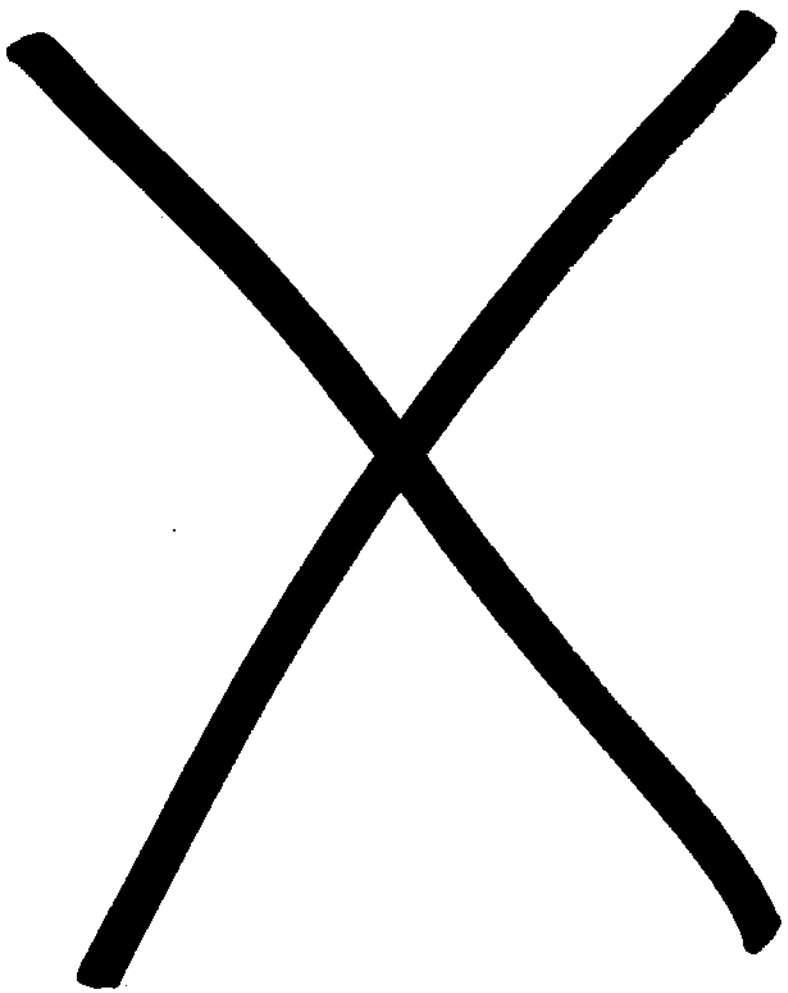
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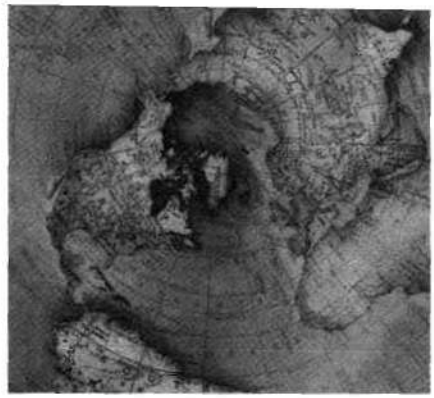
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Semiconductors in Rigid Disk Drives: A Focused Analysis



Focus Report

Program: Semiconductor Application Markets Worldwide
Product Code: SAMM-WW-FR-9503
Publication Date: October 23, 1995
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Semiconductors in Rigid Disk Drives: A Focused Analysis



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Chapter 1
Introduction

The rigid disk drive industry is driven by several factors, but technology holds the reins of magnetic storage. Semiconductor devices play a critical role in the rapid increases in capacity and performance. The current industry dynamics are described in four statements:

- Magnetic storage densities increase at 60 percent per year, bringing with them the associated increases in track and linear bit densities, as well as single-platter capacities.
- Semiconductor devices impact both the cost and performance of rigid disk drives.
- Disk drive product life cycles are nine months.
- Disk drive price erosion is 12 percent per quarter.

These factors combine to make the industry one that is exciting to participate in, but that has a high degree of risk associated with every move for OEMs as well as their suppliers.

Disk drives depend more heavily each year on semiconductors and microcode for improvements in recording densities as well as cost reductions. As recently as five years ago, the contribution of the electronics and printed circuit board (PCB) to the cost of a disk drive was only 25 percent. Now that function represents more than 50 percent of the burdened cost of a drive. The increase in percentage does not necessarily represent an increase in cost, but semiconductor prices have not eroded as fast as prices of heads and media.

The increased data-rate pressures on read channel performance, integration of device control and I/O control into single ASICs, and increased use of cache RAM and flash program memory all combine to increase the value of the semiconductors in a typical drive. More and more semiconductor vendors have developed parts and are offering them at competitive prices to an industry with a unit volume growth rate of 18 percent per year through 1999.

This report is intended to give the reader a background in the opportunity offered by serving the rigid disk drive industry and a review of the implementations currently being offered. It includes a perspective from both the disk drive and semiconductor applications views and presents relevant information gathered by a global group of Dataquest analysts. Dataquest's Computer Storage Worldwide group's focus is primarily on information relating to finished products (rigid disk drives), such as unit shipment forecasts and history, pricing, drive density trends, and technology trends. The Semiconductor Application Markets Worldwide group examines technology trends and issues in semiconductor components, with particular emphasis on identifying emerging applications and market trends.

Small form factor RDDs include the 3.5-inch, 2.5-inch, and 1.8-inch disk drives. This report focuses on these products and includes an overall snapshot of the state of the mass storage industry and the semiconductor components that are used in their design and manufacture.

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Chapter 2
Disk Drive Industry Review: 1994 and 1995

Summary

The rigid disk drive industry continues to be a nearly unique case study for the business world. No other manufacturing industry has been subjected to the stresses of high-technology hypergrowth and the resulting impact on its participants. The disk drive industry is made up of a sales revenue community with sales struggling to reach $20 billion, with its component suppliers estimated to be about $10 billion. With data recording densities growing at a 60 percent compounded annual rate, the products produced have the potential of outstripping the wildest dreams of the computer user. The combination of technological advances in recording heads, disk platters, and specialty semiconductors has positioned the entire industry on a growth path to the stars.

The disk drive market continues to thrive with good backlogs and limited supply because of component shortages. Virtually all of the currently shipping products were announced within the past nine months, and advanced areal densities have resulted in new requirements for head, media, and chip vendors, as well as tougher production ramps in the drive factories. Demand is strong at about 20 million drives per quarter, but a slow summer quarter in 1995 and product transitions will tend to keep the annual sales total close to Dataquest's forecast of 80.2 million units for the year.

The year 1995 has been, generally, a successful one for most vendors, with many sales and profit records set. Coming off of a banner growth year, most suppliers were jockeying for position with new products and placed component orders that portended another 35-percent unit volume growth year. Subsequent shortages at the head and media level of supply have combined with unusually difficult production ramp rates to keep the apparent growth rate at 17 percent, as Dataquest had predicted.

This year, there were indications that the summer slowdown began in June, restricting second-quarter sales to 20.9 million units, slightly up from the 20.6-million level of the previous quarter. The distribution channel was crammed with inventory. Continued corporate delays in buying decisions for networked PC upgrades will keep that segment quiet until 1996, so it appears that the year's big growth must come from home PC buyers in the December quarter. The much anticipated Windows 95 operating system from Microsoft will fuel immediate upgrades in memory and hard disks from the retail channel, but the massive replacement system upgrades will hold off until December 1995 and later. Doubtless, 1996 will be a banner year for Pentium computers and disk drives.

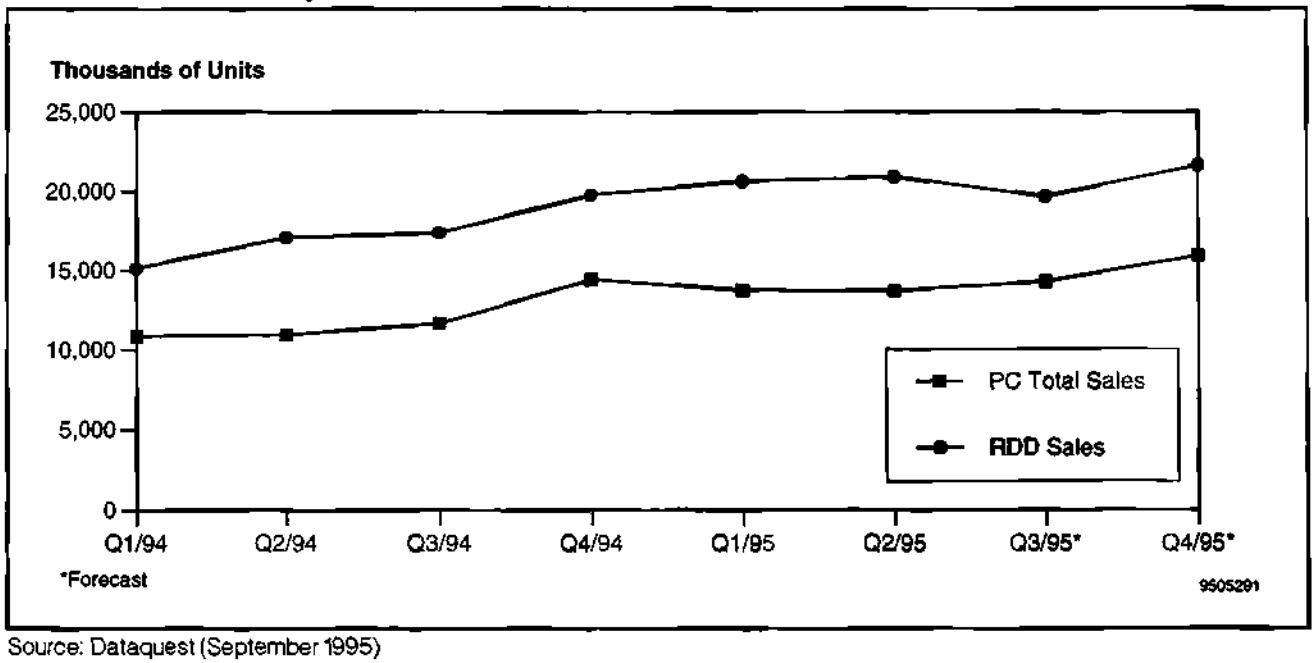
Inventories diminished in the first calendar quarter of 1995, but, contrary to "normal" behavior, the gross margins for the disk industry also fell. Usually, these two indicators are linked in the opposite direction. Things went exactly the other way in the June quarter, when gross profits recovered to 17.3 percent of sales and inventories rose from 31.6 percent to 33.5 percent of sales. No matter what the indicators show, the industry has experienced seven straight quarters of strong growth without a major recession, and all factors point to easy completion of a two-year stretch without a major problem.

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Fueled by strong orders from PC OEM buyers and a healthy distribution market, disk drive sales continued to grow in the first few weeks of 1995. The quarterly increase was only 4 percent; a far cry from the annualized 35-percent increase in 1994. Total drive sales were 20.6 million units in the first 90 days of 1995, compared with 15.1 million in the same period in 1994. Personal computer sales sagged somewhat with a 5 percent decrease from December's sales. Both PC and drive sales were constant in unit volumes between the first two quarters of 1995. Figure 2-1 shows quarterly sales of disk drives and PCs for 1994 and 1995.

Products sold in the first half of the year showed a fast increase in popular technology. Companies like Quantum that have large PC customers and that tend to offer lower-capacity, entry-level products found that their average capacity shipped in 1994 was under 300MB. In 1995, this entry-level range began over 400MB and will wrap up the year at about 850MB on the average. Table 2-1 shows the average capacities of all disk products shipped, reported by each of the suppliers to the entry level market.

Figure 2-1
Worldwide Quarterly PC and RDD Sales



Source: Dataquest (September 1995)

Table 2-1
Average Capacity Shipped per Quarter (Megabytes)

	First Quarter 1994	Second Quarter 1994	Third Quarter 1994	Fourth Quarter 1994	First Quarter 1995	Second Quarter 1995
Quantum	240	270	270	270	450	560
Maxtor	240	300	356	428	547	664
Conner	250	340	400	470	540	645
Western Digital	300	330	418	500	623	595

Source: Dataquest (September 1995)

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Performance by Company

Sales of disk drives by the top suppliers continued to grow and inventories were kept to a minimum, mostly as a result of component shortages. Dataquest tracks the key public companies (Conner, Maxtor, Micropolis, Quantum, Seagate, and Western Digital) and presents information quarterly on sales and production status. The production figure is simply the sales revenue adjusted by the quarterly change in inventory. Figure 2-2 presents these results for the total group.

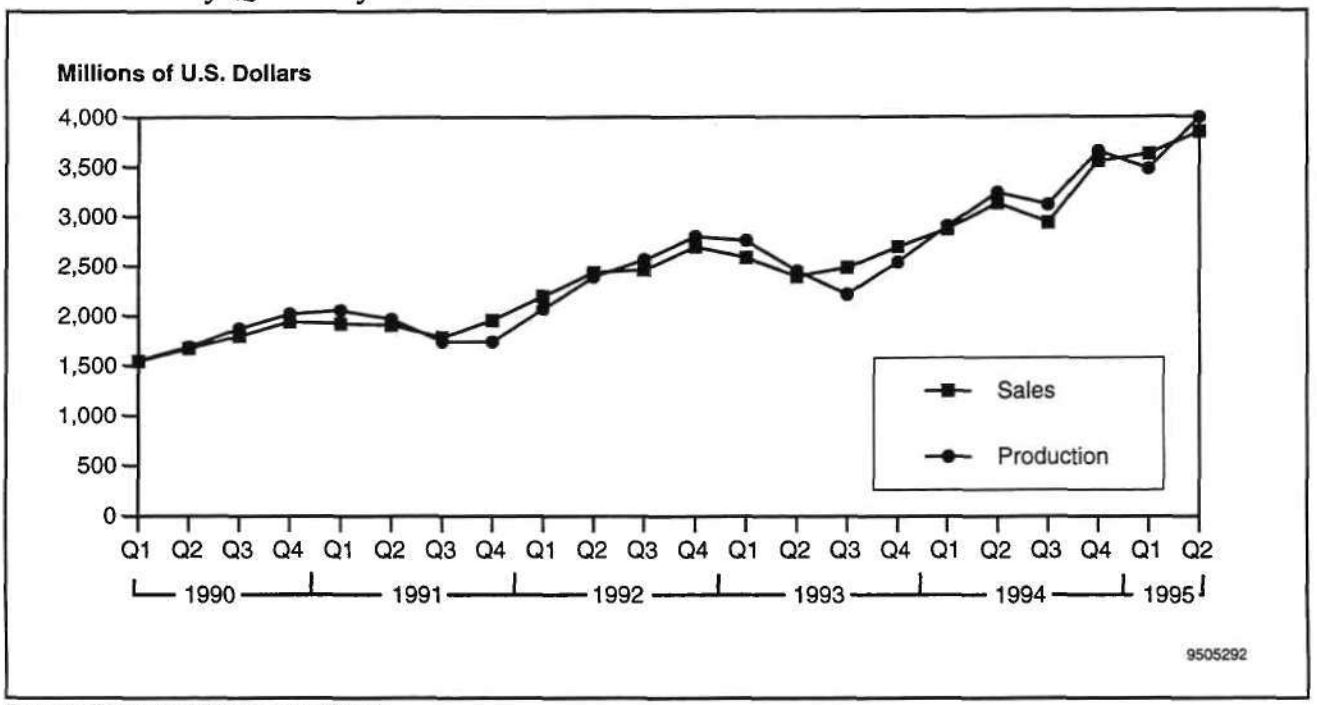
The figure shows good progress and exceptional control of inventory and production rates since the last major overproduction period in 1993. At the end of June 1995, the inventories climbed somewhat, and an industry tempering of production schedules is expected for the third quarter, ending in September. If production rates are driven hard during this period, there is likely to be the beginning of another glut.

There are strong indications, however, that disk drive producers are tempering their production plans, partly because of a more conservative approach to business, but mostly because of transitions from profitless 425MB and 540MB product lines to new product groups. A reluctance to build large quantities of two-platter 630MB and 850MB drives is developing, and these strategic moves may find the industry with a shortage of deliverable products just as the Christmas rush begins.

Profitability and Prices

The name of the game is profitability, and the disk drive industry is finding profits elusive. Figure 2-3 shows the effect of inventory levels in the industry and the gross profit resulting from doing business at these levels.

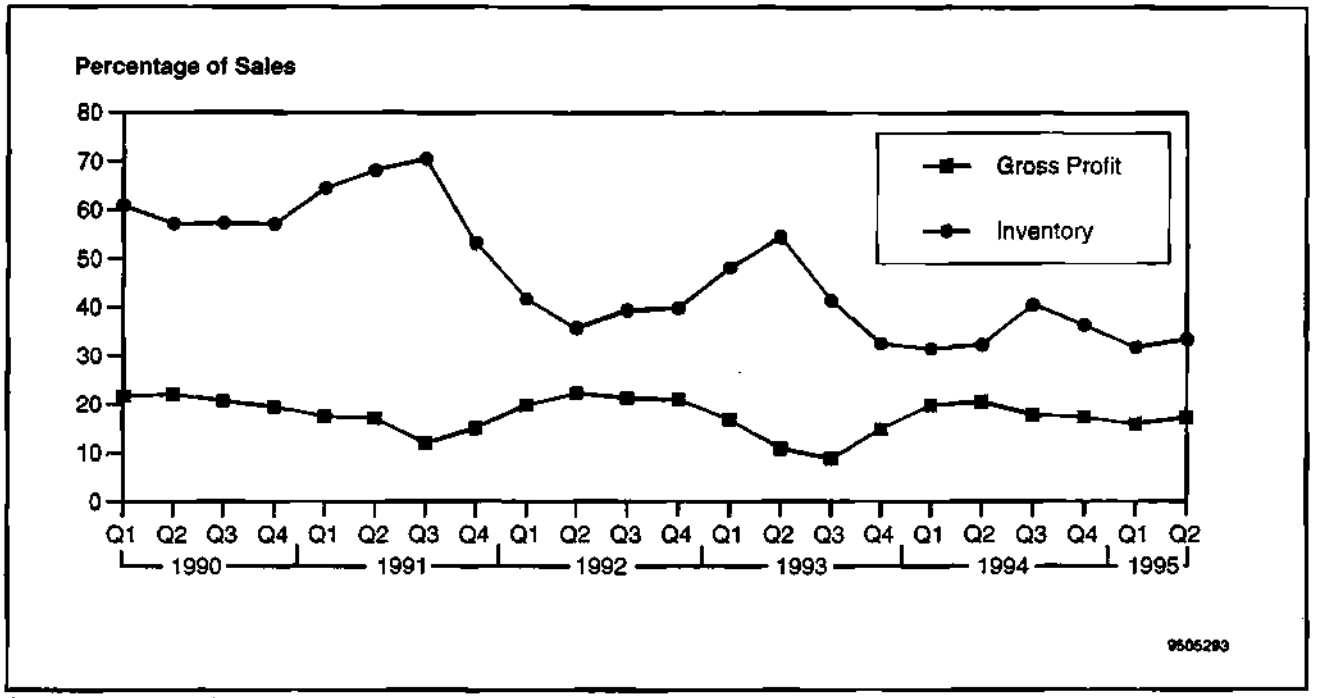
Figure 2-2
RDD Industry Quarterly Sales and Production



Source: Dataquest (September 1995)

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Figure 2-3
Rigid Disk Drive Industry Inventory and Gross Profit



Source: Dataquest (September 1995)

1994-1995 Financial Results

Total sales revenue from the six public, noncaptive drive makers totaled $2.9 billion in the quarter ending in September 1994, down somewhat from the $3.1 billion figure of June 1994. Sales in the industry's seasonal best quarter, the December period, increased handsomely to $3.6 billion.

September Quarter 1994 Results

Quantum Corporation reported record sales of $726 million for its second fiscal 1995 quarter, ended October 2, 1994. Sales were up 47 percent from the $494 million reported for the second quarter of fiscal 1994 and were flat with results from this year's June quarter. Net income for the quarter was $48.6 million, with gross profit at 18.4 percent of sales, down somewhat from the 21 percent profit of the June quarter. Quantum increased its share of publicly traded disk drive company revenue by 6.8 percent, reaching second place at 24.7 percent, behind Seagate's 31.8 percent. Seagate's position fell by almost 1 percent last quarter.

Quantum shipped nearly 4.1 million drives in what is generally a slow quarter, with its five largest OEM customers accounting for 50 percent of sales, up from 44 percent in the prior quarter. Two companies each represented more than 10 percent of Quantum's sales: Compaq was the largest customer at 21 percent of sales and Apple Computer represented 15 percent of revenue for the quarter. OEM sales were 79 percent of revenue, and Quantum's international business was down somewhat at 52 percent, compared with 58 percent in June. Quantum's inventory grew by 13.3 percent over the previous quarter for a total value of $200.9 million, where finished goods represented $152 million, raw materials $36 million, and work in process $13 million . The company reported pricing pressure of

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11 percent over the entire product line, with the already bargain-priced under-300MB drives falling less than that.

Maxtor Corporation was the hardest hit of the mainstream rigid disk drive makers in the summer quarter, with sales down 20 percent from the preceding period and gross margin falling to a negative $16.7 million. Unit volumes were flat from the previous quarter at 1 million units. The decrease in sales revenue and profit was the direct result of tumbling prices across Maxtor's product line.

Total write-offs amounted to $18 million for the quarter. The 1.8-inch market has not yet developed, and Maxtor was forced to write off $5 million in MobileMax drives and manufacturing equipment. A major customer returned a substantial number of excess drives and those were written off at $5 million. (While Maxtor will not comment on the customer, it is believed that these drives are the MXT-540 products returned from IBM.) The old MiniScribe factory in Singapore was retired and returned to its landlord, consolidating all manufacturing in Maxtor's own Singapore facility.

The inventory level at the end of September increased in value by 10.3 percent over the June quarter to a level of $107.5 million. Raw materials were reduced to $48.7 million, work in process increased slightly to $14.2 million, and finished goods jumped by $19.3 million to $44.5 million, the highest level since June 1993. Maxtor said that it had 300,000 disk drives in inventory, 200,000 of which were the 7345 models.

Maxtor reported that price competition in the September quarter caused a 20-percent erosion in distribution pricing and 15 percent in OEM. Distribution sales were 56 percent of the company's business. Sales geographically were split 54 percent, 22 percent, 20 percent, and 4 percent for U.S., Europe, Asia-Japan, and rest of world, respectively.

Conner Peripherals announced sales revenue totaling $559.5 million for the quarter ending September 30, 1995. Gross profits slipped to 18.1 percent from 21.9 percent in the previous quarter. This reduction was a direct effect of the weakening profitability of the older Bobcat line of 210MB and 420MB disk drives. Bottom line earnings amounted to $10.23 million or 1.8 percent of sales. The company reduced disk drive production rates from 3.0 million units to 2.7 million for the quarter. Total company inventory value increased by 19.7 million, up 7.1 percent over the June-ending quarter. Price erosion of 9.8 percent over the entire product mix is expected to continue or worsen as the year winds down. The most pricing pressure was on the 340MB products, experiencing a 14-percent price reduction.

International sales increased to 49 percent of revenue as Conner's strength in Europe continues to improve. OEM sales dipped slightly from 76 percent in June to 74 percent in September. This figure resulted from a weakening in top-tier PC shipments and a strengthening of the tape drive distribution sales. Compaq is still Conner's largest customer, at 14 percent of sales (down from 18 percent), with IPC, Packard Bell, Sun, and Acer as other major OEMs. When combined, these five companies represent 30 percent of sales.

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Seagate Technology had its growth spurt slowed somewhat in the third calendar quarter of 1994. Total sales revenue fell 6.8 percent from the all-time high of $1 billion in the June quarter. Sales were $933.1 million, and gross profit stayed at a high 21.1 percent. Net profit of only 2.4 percent of sales reflected a one-time charge of $43 million as a result of the acquisition of Palindrome. Seagate's disk drives sales totaled 2.8 million units for the quarter, a sharp reduction from the 3.3 million sold in the June quarter. The company was left with an estimated 800,000 units in finished goods inventory at the end of the period. The total inventory rose nearly $100 million over the June quarter and was at its highest level since the same point in 1991, when Seagate declared its last loss. For the most part, these products are the 210MB- and 260MB-class disk drives, and adequate reserves were established for reduced-price sales of these products before the end of 1994. Total inventory value was $440 million with $174 million in finished goods, $64 million in work in progress, and $202 million in purchased materials.

Regional sales for Seagate showed an increase in the United States portion to 65 percent. Europe was constant at 23 percent, and Far East sales fell to 12 percent from 15 percent in June. OEM sales were up slightly to 71 percent of the total. Headcount for the company grew to 53,993, up more than 1,300 from the previous quarter.

Western Digital Corporation reported increased sales revenue to a record $464.6 million for the September quarter, with a gross margin of 21 percent and a net of 7.5 percent. Feeling the industry price pressure, WD's disk drive gross margin fell somewhat from 21 percent in June to 19 percent this last quarter. Microcomputer Products returned 39 percent gross for the third quarter in a row. The company's inventory value rose 20 percent to $96 million. Disk drive sales were $414 million at 2.2 million units, up slightly from the 2.1 million in June. The company saw price erosion of 11 percent on OEM deals and 19 percent on distribution sales for the quarter. OEM sales were 72 percent of the business and North American sales rose to 59 percent, Europe remained at 24 percent, and Asia dropped 4 percent to 17 percent of the total.

WD's customer list includes Gateway 2000, Dell, AT&T, and IBM, with the top 10 list accounting for 48 percent of sales. Gateway's purchases were 12 percent of the total. IBM continues to increase its purchases from WD, with Apple Computer and Hewlett-Packard the only major PC vendors not yet taking volumes of the company's disk drives.

December Quarter 1994 Results

Gross margins for the year averaged 18.8 percent and net profit was 3.8 percent. These were substantial increases over the losing year of 1993, but hardly came near the 20 percent gross and 6 percent experiences of 1992.

Conner Peripherals saw sales revenue for the period of $591.6 million, coming from sales of 2.8 million disk drives, 360,000 tape drives, and other system and software storage solution products. Gross profit margin for the company was 16.5 percent, down from 18.1 percent in the September quarter. Net profit was bolstered by several unusual items, including a reduction in reserves related to restructuring, the proceeds of the sale of

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Sunward to Read-Rite, and a write-off of in-process R&D related to the acquisition of Quest Development. Sales came from OEMs (68 percent) and distributors (32 percent), with U.S. revenue (52 percent) leading European (35 percent). The drop in OEM sales to 68 percent from 74 percent of revenue is worsened by the fact that only 25 percent of sales comes from Conner's top five customers. Packard Bell is now responsible for 9 percent of sales, Compaq for 5 percent, Acer and IPC for 4 percent, and Tech Data for 3 percent. Conner showed a masterful reduction in inventory, in spite of the return of a substantial number of disk and tape drives by a major OEM customer. Conner was able to reduce its inventory value by 9.5 percent over the December quarter with 290,000 units remaining in finished goods, up from 249,000 in September. Of the $96 million in finished goods, $41 million worth of drives are new-design products, and this is a good sign.

Maxtor has set a record for disk drive industry public companies. It reported eight consecutive periods of losses. This dubious distinction places the company in the lead over the previous six or seven losing quarters by MiniScribe, Priam, and Micropolis. Maxtor's sales in the December 1994 quarter made a jump of 36.6 percent over the previous quarter to a level of $238.2 million, with a net loss of $16.4 million. The gross profit margin for the quarter rose to 9 percent of sales, a healthy increase from the negative 9.6 percent in the September period. While Maxtor admitted to selling one-third of its 1.3 million disk drive units at zero margin, the rest of the drives gave a 13 percent return on cost. Maxtor management admits to a 5 percent to 8 percent price erosion quarter-to-quarter, with the heaviest pressure on its 540MB 3.5-inch products. Maxtor's geographical split was about 49 percent to the United States, 27 percent to Europe, 19 percent to Asia, and 4 percent to ROW. European sales were increased from 22.5 percent in the September report (much the same story throughout the industry). OEM sales finally rose over 50 percent to 53 percent of revenue, with 47 percent to distribution, 7 percent of which were sold retail.

Quantum Corporation announced sales of $933 million for the December 1994 quarter. A one-time charge of $73 million for in-process R&D and other acquisition costs caused the company to report a loss of $48 million. Without the charges, Quantum showed a net income of $23 million.

The quarter's gross profit margin was 14.5 percent. This depressed figure was a result of higher manufacturing costs in the acquired Digital products as well as continued pricing pressure on all disk drive products. Quantum experienced an average price decline of 7 percent over the quarter, somewhat below the rest of the industry. Quantum reports that it backed away from the heavy price competition over the quarter and, as a result, found itself with a healthy increase in disk drive finished goods inventory with a total inventory value of $388 million, 41 percent of sales (up from 27.7 percent in the previous period). The Digital inventory acquired was $145 million, so the Quantum incremental change was rather small. Quantum's disk drive sales increased to 4.5 million units in the quarter with the high-end drives representing 23 percent of sales dollars indicating a healthy increase in shipments from Quantum's Milpitas, California, factory plus the acquired Digital products. The company's three top buyers were Compaq Computer (14 percent), Digital Equipment (14 percent), and Apple Computer (11 percent). OEM sales remained strong at 73 percent of revenue and international sales were 51 percent of the total.

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Hitting the billion-dollar mark for the second time, Seagate Technology reported shipments of 3.856 million disk drives in the quarter ending December 30, 1994. Sales totaled $1.13 billion and net income broke all Seagate records at $79.3 million. This report continued a string of 13 consecutive profitable quarters, the longest in the industry.

Gross profit trickled down to 20.1 percent of sales, the lowest in a year. Usually an indicator of price erosion, this was a slight decrease from the 21.2 percent posted 90 days earlier. Disclosing that the company's disk drive prices eroded 9.1 percent in the quarter, Seagate saw its Twin Cities Elite product prices decline by 7.2 percent, Oklahoma City high-performance drive prices down 10.4 percent, and the low-end desktop prices out of the Scotts Valley products down 9.5 percent. Seagate's sales included $62 million from nondisk products. The revenue produced by software subsidiaries Palindrome and Crystal was $6.5 million. The rest of the "other" category included $37.7 million for sale of recording heads in the merchant market. Seagate's split in the market was 71 percent OEM and 29 percent distribution, unchanged from the previous quarter. The regional markets shifted in favor of Europe, with North American sales at 60 percent of revenue, Europe at 28 percent, and the Far East at 12 percent.

Another interesting set of statistics is Seagate's split below and above the 1GB capacity point. The lower-capacity share was a commanding 82 percent of unit volumes but only 50 percent of total drive revenue. Seagate had an embarrassing 800,000 drives in finished goods inventory at the end of the September quarter, but was able to sell the excess quickly, early in the last period. The excess inventory was in drives with capacities under 300MB. The inventory picture at the end of December showed 835,000 drives in finished goods, representing a comfortable three weeks of sales. The value of the inventory was $399 million, with $154 million in finished goods, $59 million in work in process, and $186 million in purchased materials.

For the quarter ending in December 1994, Western Digital reported sales revenue of $552 million and disk drive shipments of 2.6 million units. The revenue attributable to disk drives was $500 million, with the rest coming from the microcomputer products division. The company's overall gross margin was 19.8 percent of sales (down from 21.0 percent in the prior period), and the disk drive margin was 17.4 percent (down from 19.0 percent). Bottom line profit was $42.5 million for the company, increasing its quarterly net to 7.7 percent of sales. WD's inventory rose slightly but remains well under control at 20.2 percent of sales. Inventory turns for disk drives rose to 20. Accounts receivable fell and the company's cash increased by 22.2 percent to $281 million. Headcount for the whole company increased by 400 to 7,100 employees worldwide. Strong OEM sales continued for WD, with 66 percent of sales to that channel, but the overall percentage of the company revenue from OEM customers fell from 72 percent in the previous quarter. The top 10 customers represented 44 percent of sales, down from 48 percent in September. Gateway 2000 continued to be the company's top customer at 12 percent of sales. North American sales were down slightly from 59 percent to 56 percent. Like Seagate, European sales were up from 24 to 29 percent. Price erosion of 9 percent was felt by the company, but was not as severe as that in the September quarter—11 percent OEM and 19 percent in distribution channels. WDC also produced 2 million disk platters in the quarter with a goal of making 50 percent of the company's needs.

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March Quarter 1995 Results

On sales of $610.4 million, Conner Peripherals showed a gross profit of $91.8 million or 15 percent of sales and a net profit of $4.6 million. Results were essentially break-even and included a gain on the repurchase of debt securities of $4.5 million, the sale of unused buildings, and other end-of-life charges of $5.5 million. Of the $610.4 million in total sales, disk revenue was $505 million, tape sales were $96 million, software $12 million and storage systems $2.3 million. For the first time, Conner sold disk media to outside customers, but the total was buried in the Disk Division number. Sales to OEMs across all product lines were 75 percent, up from 68 percent in the prior quarter and now the highest in the industry. For all products, Packard Bell was the company's largest customer, with 10 percent of sales. NEC was second at 5 percent, IPC and Sun Microsystems at 4 percent, and Compaq at 3 percent. Compaq was the No. 1 buyer of tape products at 10 percent of the total tape revenue, followed by Digital at 8 percent, Ingram Micro at 7 percent, IBM at 6 percent, and Sun Microsystems at 5 percent.

International sales accounted for 50 percent of the total revenue for all products. Conner shipped 2.78 million rigid disk drives in the quarter, slightly down from the 2.8 million of the December quarter. Conner's inventory for both tape and disk was reduced by 19.5 percent to $207 million. Disk products launched in the last six months accounted for 80 percent of first-quarter disk drive sales. The inventory was primarily raw materials ($83 million) with work in progress at $77 million and finished goods down to $47 million. Conner reported a 12.5-percent drop in average selling prices for disk drives over the quarter. Component shortages plagued the disk drive industry, and Conner experienced its share.

Maxtor Corporation has begun to show the effects of its turnaround efforts, and the first quarter of 1995 brought good results. On a 16 percent increase in sales to $275.9 million, the company showed a gross margin of 10 percent and net income of $1.1 million after a gain of $10 million on the sale of Maxoptix. Operating income showed a loss of $8.9 million. The IMS contract manufacturing operation contributed less than $10 million for the quarter. Maxtor increased its quarterly disk drive sales to 1.6 million units, an increase of 300,000 units over the previous period. The percentage of business attributable to OEM stayed at 53, the same as the December quarter. Maxtor experienced a price decline of 15 percent, quarter to quarter. Total inventories remained fairly constant, but finished goods rose by nearly $9 million. The company headcount rose by 800 employees to 7,000, worldwide, due mostly to increased manufacturing in Singapore. Maxtor's sales in the United States grew from 49 percent in December to 52 percent in March. Sales in Europe were 25 percent of total, leaving 17 percent for Asia/Pacific and 6 percent for rest of world.

Quantum had sales of $984 million for the quarter, and returned 15.2 percent gross profit and 2.3 percent net profit. The company shipped a record 4.8 million disk drives, solidifying its 24 percent unit market share. Below-the-line expenses were 11 percent of sales. Like many of its competitors, Quantum reduced its inventory considerably, dropping its finished goods from $236 million in December to $166 million in March. Quantum's distribution sales showed an increase from 27 percent of the business in December to 30 percent this last period. Its top OEM accounts remain

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Compaq Computer (14 percent), Digital Equipment Corporation (13 percent), and Apple Computer (10 percent), with the top five customers consuming 44 percent of sales. International sales continued strong at 52 percent of sales. Quantum's high-capacity products represented 21.5 percent of sales (down from 23 percent) and 2.5-inch drives accounted for less than 10 percent of sales once again.

Seagate Technology total sales for the period were about $1.19 billion, with drives accounting for $1.11 billion and outside sales of recording heads at $49 million. More than 4 million disk drives were sold in the quarter, up about 4 percent from the previous period.

Gross profit dropped somewhat as a result of steeper price erosion, falling from 21.3 percent in the December-ending quarter to 19.5 percent in March. Seagate's inventory position continued to improve, with finished goods inventory falling to $114 million from $154 million in December. The total inventory was $366 million or 10.4 turns. Price erosion was 11.7 percent for the quarter, generally across the entire product line, up sharply from the 9.1 percent level in December. Seagate saw the pressure intensify in the last 30 days of the quarter, but management believes that this level will not continue.

Sales to OEMs amounted to 72 percent of the total, holding that level over the past year. European sales continue to increase, hitting 30 percent, a seven-point increase over the past year. Sales to the Americas represented 58 percent of the total, and 12 percent of revenue came from the Far East. Sales revenue from drives with more than 1GB capacity rose to 58 percent of drive sales.

Western Digital disk drive sales volumes were flat, quarter to quarter, at 2.6 million drives, and price erosion for the quarter rose to 11 percent, compared with 9 percent in the December-ending period. Overall, the gross profit margin was 16.7 percent, down from 19 percent in the previous quarter, and net profit fell to 3.7 percent of sales from 7.7 percent in December. Total sales revenue for the company was $529 million, down 4.9 percent for the quarter, with disk sales at $481 million. Disk drive gross profit represented 14 percent of drive sales. Inventory fell 18.5 percent over the quarter to $94 million or 19 total turns. The disk drive inventory amounted to 22 turns, or one day's sales. Accounts receivable increased by 6.6 percent. WD's efforts to develop high-end SCSI disk drive products have pushed its R&D expenditure up to 6.3 percent of revenue, a 9.1 percent increase over the amount spent in the December quarter. WD added three new OEM customers this quarter, increasing its OEM sales percentage to 74 percent, the highest in the industry. The top 10 customers amounted to 52 percent of sales, up 7 percent from the previous period. Gateway 2000 is WD's largest OEM buyer, representing 12 percent of total revenue. Sales to North American customers remained at 56 percent of the total, with European sales falling 1 percent, quarter to quarter.

June Quarter 1995 Results

Conner Peripherals reported a quarterly increase in sales revenue of 5.2 percent to its historical second highest level of $642.3 million. Along with this improvement, gross profit jumped by 30.2 percent to 18.6 percent of sales, second only to Seagate for the quarter. Net profit for the period

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ending in June 1995 was $18.4 million, or 2.9 percent of sales, a sharp increase over the previous quarter. NEC became Conner's largest customer for the entire breadbasket of products, purchasing 7 percent of total sales. Sun Microsystems rose from 4 percent to 6 percent, and Packard Bell, Synnex, and Compaq were 4 percent each.

Total inventory rose by $27.2 million or 37 percent of sales, still a managed level for the current sales volume. There were 191,000 disk drives in finished goods at the end of the quarter.

Good sales of the entire Cabo line contributed to the company's sales of 2.8 million disk drives. Total revenue for the drive business was $531 million, up from $505 million in March. The total unit volume was slightly down from 2.9 million. The average unit selling price fell by 8.4 percent for the quarter, down substantially from the 12.5 percent per quarter erosion experienced by Conner in the first quarter. Gross margin on disk drives was 17 percent of sales. International sales amounted to 49 percent of the disk revenue and OEM accounts represented 76 percent of the total, up slightly from the March quarter. High-performance products doubled in revenue this past quarter, with particular success shown on sales of 150,000 units of the Antigua product. The 2GB and 4GB products sold somewhat less than 100,000 units.

Maxtor Corporation reported a 14.5 percent quarterly increase in sales revenue for the 14-week period ending July 1, 1995. Gross profit of $29.9 million was 9.5 percent of quarterly sales of $315.9 million. The company reported a net loss of $13.8 million. Of the total sales, Maxtor's subsidiary, IMS, had revenue of $6 million. In order to finance further expansion and operations, Hyundai Electronics Industries Co. (HEI) will provide a $100-million corporate guarantee for Maxtor to obtain new loan agreements. Maxtor's cash and short-term investments dropped by $26 million to $82.2 million, while inventories rose by $27.2 million to 37 percent of sales. Maxtor sold 1.9 million disk drives during the quarter, an increase of 300,000 from the previous period. OEM sales grew by two percentage points to 55 percent of the total by adding a second top-tier PC manufacturer to its customer list. Maxtor began shipments of its new Durango series of drives in June, shipping tens of thousands of the 1.6GB version. Price erosion on the 850MB and larger disk drives ranged between 12 and 15 percent this last quarter for Maxtor. Maxtor grew in Europe and Asia/Pacific, where other vendors did not. Sales to the United States were 46 percent, Europe 27 percent, Asia/Pacific 20 percent, and the remainder 7 percent.

Quantum Corporation sales revenue was down by 4.3 percent from the previous quarter to $941 million. Gross profit margin dropped from 15.2 percent to 13.2 percent of sales, and net proceeds were $12.9 million, or 1.4 percent of sales. The component supply problems that have plagued the industry for the first half of 1995 also came to roost at Quantum in the form of MIG head shortages, restricting sales of the hot Trailblazer product. Quantum also blamed slower than usual OEM qualification approval of the new Atlas 1GB, 2GB, and 4GB products. The OEM portion of Quantum's business increased to 72 percent of sales (after 70 percent in March and 73 percent in December 1994) with Digital Equipment emerging as its top customer, taking 13 percent of Quantum's business. Compaq and

Apple Computer each represented 12 percent of sales. The top five customers at Quantum made up 47 percent of the revenue, up from 44 percent last quarter. International sales slipped slightly from 52 percent to 50 percent of the total. Quantum sold 4.6 million disk drives in the June quarter, down from its high of 4.8 million in the March period. High-capacity products represented 21 percent of sales, and 2.5-inch drives were less than 10 percent of the total dollars.

Other items for the quarter include a 20.7 percent increase in value of the inventory to a total of $392 million. Finished goods amounted to $141 million of that total. Inventory was 41.6 percent of sales, the highest of the major drive makers and the most Quantum inventory since a similar period in 1993, just before the industry's disastrous September quarter.

Seagate Technology sales revenue of $1.292 billion was split $1.2 billion from disk drives and $91 million from other sources such as components, software, and repairs. Gross profit was $276.3 million, and bottom line net profit was $88 million. Seagate's disk drive sales were down slightly from the March-ending quarter at 3.908 million units. Once again the company's primary revenue sources were the high-capacity drives. Sales revenue from drives equal to and greater than 1GB in capacity represented 66 percent of the total (up from 58 percent in March and 50 percent in December). Drives with 2GB and above capacities comprised 50.8 percent of the total drive sales. The 2.5-inch business fell once again and resulted in $56 million in sales, while the growth came from 3.5-inch drives at $1.025 billion. The 5.25-inch Elite drives produced $120 million in revenue, up from $109 million in March. Component sales revenue was $70 million and the sales of software products from Seagate's acquired companies was $11 million.

Price erosion for the quarter eased somewhat for Seagate to an estimated 8 to 9 percent rate of decline. Seagate's inventory total increased by $30 million to $396 million, with $128 million of that amount in finished goods. Sales to the Americas increased from 58 percent to 61 percent, European sales dropped from 30 percent to 26 percent, and Far East sales continued to grow to 13 percent of the total. Total sales to Japan for the past 12 months were $96 million with $28 million in the last quarter alone.

Western Digital Corporation reported quarterly total revenue of $585 million, with disk drive sales amounting to $545 million or 93 percent of the total. WD's microcomputer product division produced the remaining $40 million in revenue. The disk drive business was run at a 15 percent gross margin while the computer component division return 44 percent gross. Net return for the quarter ending in June was $26.4 million. New company records set in this period included revenue, gross profit, earnings per share, operating income, net income, inventory turns, unit shipments, and total cash.

The company's two disk drive factories ground out 2.9 million units for sale during the quarter and began shipping the 1.6GB, three-platter Caviar drives. The highest volume products were the 540MB and 850MB capacity drives. Capital expansion in both Malaysia and Singapore has been completed, raising the company's disk drive production capacity to nearly

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4 million units per quarter. WD's employee count rose sharply from 6,985 in March 1995 to 7,653, with the bulk of the new hires in Asia.

The channel mix for WD soared to 78 percent OEM and a dwindling 22 percent to distribution. The top 10 customers represented 59 percent of the sales, up from 51 percent last quarter with the largest customer, Gateway, representing 12 percent of the business. WD's sales to the Americas grew to 58 percent, and Asian sales grew a bit to 17 percent. Europe fell off by three points to 25 percent. Inventories grew in line with the business, from $76 million to $83 million. Inventory turns for the company are still spectacular at 23.

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Chapter 3
Disk Drive Technology Review

Overview

Magnetic recording technology continues to be a major driving force in the rigid disk drive industry. With a goal of increasing areal density (amount of information per square inch of media) 60 percent per year, drive makers are pressed to the wall to purchase or develop components that will facilitate such an aggressive product schedule. This race, when coupled with what seem to be preordained price points for one- and two-platter disk drives, regardless of capacity, shrinks product life cycles to periods of nine months or less.

Dataquest believes that the requirement for increasingly higher recording densities could force companies into a position within the next two years where it will be impossible to produce high-yielding products to meet the growth curve, resulting in a lengthening of product cycles, a shortage of products, and a return to stability in pricing. This unusual situation would stem from the industry's inability to produce massive quantities of magnetoresistive (MR) heads or the disk drives that use them.

Generally, the 3.5-inch disk drive market is expanding at a record pace, segmenting into desktop PC products and high-performance server-class drives. It is likely that 1995 will be the last year when companies can make low-cost drives using metal-in-gap (MIG) ferrite inductive heads. The next salvation for these products is the thin-film inductive heads used in proximity recording, skimming to near-contact with the disk surface. MR heads are still pretty much IBM's domain, with Fujitsu and Hitachi also manufacturing production quantities of disk drives using this technology. Most vendors have announced or will announce MR-based products by the end of 1995, but there will be insufficient heads available from any source to allow mass production until 1997.

The 2.5-inch products now available are mostly based on glass substrate media, and IBM has successfully produced industry-leading quantities of drives using MR heads. These little drives are quickly moving into the gigabyte range, but pricing has squeezed most of the profit out of the industry. The price at which 1.8-inch drives can be manufactured is not low enough to convince mobile computer users to buy them, and the technology attributable to this market segment has been moving at a snail's pace.

What's Real?

Table 3-1 lists the areal densities and single-platter capacities that were actually shipping in high volumes at the time this document was prepared.

Figure 3-1 illustrates Dataquest's estimates of single-platter capacities that will ship in volume over time, by diameter.

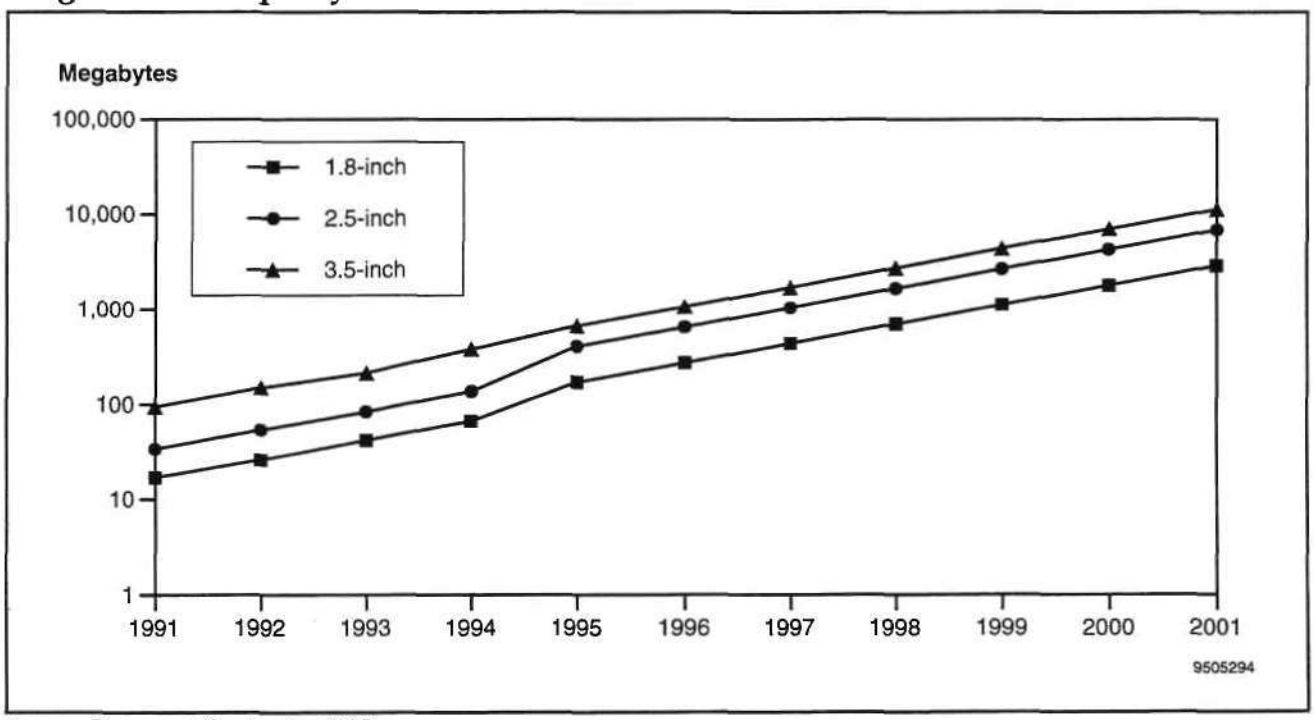
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Table 3-1
Current Technology Levels

	Platter Capacity (MB)	Maximum Drive Capacity (MB)	Areal Density (Mb/Sq. In.)	Technology Notes
1.8-Inch	170	341	630	Smooth metal media, PRML
2.5-Inch	405	1,215	700	MR heads, glass media
3.5-Inch	850	4,300	663	MR heads

Source: Dataquest (September 1995)

Figure 3-1
Single-Platter Capacity Forecast



Source: Dataquest (September 1995)

Current Products

For a list of all of the disk drives in production (or announced for production) in mid-1995, see Appendix A. The complete specifications for the drives are included and the list is sorted by company, drive diameter, and capacity. Since the product cycles are so short, it is difficult to predict how long this list will remain current, but it certainly is a snapshot in time of the drive industry.

1.8-Inch RDD

Once again, the 1.8-inch market failed to live up to market projections. For 1994 and 1995, the market remains at about 300,000 units, with little hope for an immediate boost. As the anticipated market dwindled, so did the number of producers and the new product announcements.

The current technology upon which leading products are based is either glass or smooth metal media with inductive thin-film heads. The highest areal density, 630Mb per square inch on the Integral Peripherals Viper 340

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drive, is a two-platter product. The track density is listed at 5,100 TPI and the linear bit density is 123,600 BPI. Flying height of the ramp-loaded heads is 1.8 microinches. Ramp loading prevents the heads from landing on the polished media. The read channel uses an advanced partial-response, maximum likelihood (PRML) chip to boost the bit density. These drives seek at 12ms on the average and have a rotational rate of 4,500 rpm. The highest internal data rate is 6 MB/sec and the best power rating is 2.1W maximum for read and write operations.

The single-platter capacity of this form factor sits at 170MB and has not risen to the anticipated 200MB level predicted for the Type II PCMCIA card drives. Maxtor announced a Type II drive series called the MobileMax Lite with 85MB per platter, but the products were shelved until some future date. Dataquest expects announcements of an increase in the single-platter drives to 200MB at COMDEX in November 1995. All products to be announced in 1995 and 1996 will be Type III drives.

Shock sensors are critical in these products and are found in all drives. Write gate is turned off and the heads are retracted upon shock, or upon increased g-forces. This action prevents off-track data "smear" and head slap on the media.

Dataquest believes that MR head technology will be introduced in this form factor in 1997. Proximity recording and PRML channels will provide continued density improvements. Most of the 1.8-inch products sold today use the PCMCIA interface, with only a few of the old IDE-interfaced products being made to finish up aging orders.

2.5-Inch RDD

The 2.5-inch market has finally moved into an area of interest for most of the industry, but lack of profitability still plagues most of the suppliers. IBM and Toshiba continue to be major market share holders, but others are gaining steam.

IBM is the technology leader with its Travelstar 1.2GB product, offering the highest areal density at 700Mb per square inch. The track density is 6,350 TPI and the linear bit density is 110,300 BPI through the use of MR heads. The single-platter capacity of these drives is 405MB, and the largest is a three-platter, 17mm-high product.

Maxtor announced a 1.34GB, four-platter drive in the 12.5mm format, using thin-film inductive heads and 1,900-oersted media to achieve an areal density of 468Mb per square inch. Maxtor's 2.5-inch offerings leverage heavily off of the MobileMax 1.8-inch technology and have only seven chips on a tiny, one-third-size board. The shock sensor protection is also carried over. Maxtor's peak-detect read channel keeps the maximum power usage down to 1.7W in the active mode.

Toshiba continues to use glass-based media to achieve its high densities. The largest Toshiba drive is a five-platter product with 1.35GB in a 19mm-high drive. Toshiba's areal density is not available.

The market for these drives is still demanding the highest capacity, the lowest form factor, and the most power-efficient operation. Often

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confusing these drives with the higher-volume 3.5-inch products, buyers have forced their prices down rapidly, compounding the profitability issues. This fact keeps most vendors away from the form factor. Dataquest's history and forecast of mobile computer shipments tracks the sales of 2.5-inch drives precisely, indicating that there is not much use for these drives outside of notebook and laptop PCs.

Dataquest continues to forecast that, as read channel rates soar toward 200 Mbps, the high-performance 3.5-inch drive designers will find it difficult to procure inexpensive integrated circuits that will operate in that range. Instead of yielding to the temptation to slow the drive spin rate to accommodate available parts, designers will move the performance drive platform to the smaller circumference of the 2.5-inch drives. Dataquest believes that 2.5-inch drive rotational rates of 12,000 to 14,000 rpm will arrive in 1997 and that these products will be welcomed into high I/O disk array configurations. At that time, single-platter capacities will be approaching 1GB.

The primary interface for 2.5-inch drives is the IDE connection, with SCSI-interface products diminishing in demand. As the performance products come on the market, it will be necessary to once again produce SCSI drives, but, in 1997, the parallel SCSI interface will have given way to one or more of the serial interface standards. The Serial Storage Architecture (SSA) and Fibre Channel-Arbitrated Loop (FC/AL) interfaces will be of particular use in the small dimensions of the 2.5-inch drives, since their connection takes substantially less real estate on the drive than parallel SCSI. These serial interfaces also offer much higher channel data rates.

There is a unique form factor that has cropped up in 1994 to 1995. Kalok has been re-formed under the corporate name JTS, and the clever designers have come up with a 3-inch-diameter disk drive that is targeted directly at the 2.5-inch notebook market. This somewhat larger diameter provides for more storage capacity per platter than the 2.5-inch but is configured as a two-platter, 10.5mm-high drive with nominal dimensions of 10 x 90 x 120mm. This product will be assembled at Xyratex in Havant, United Kingdom, using components manufactured by JTS in India. The capacity of the initial drives is believed to be 650MB, with a quick movement upward to 850MB. Offering a lower cost per megabyte, the JTS drives should give the 2.5-inch producers a run for their money. Production was planned to begin late in the third quarter of 1995.

3.5-Inch RDD

This form factor continues to set records for sales and growth, with no end in sight. 3.5-inch disk drives are now in use all over the world in applications that range from beginner's desktop systems to the largest of mainframes and supercomputers. The advent of disk array subsystems has caused this low-cost solution to be the product of choice by IBM in its RAMAC arrays and by all of the plug-compatible manufacturers (PCM) in their mainframe solutions.

The pain inherent in achieving an overall capacity growth rate of 60 percent per year in disk technology is felt deeply by the design engineers of 3.5-inch drives. IBM's record-setting areal densities are meeting these goals, and the rest of the industry continues to meet or exceed this growth rate by using smaller inductive heads that fly closer to higher coercivity media.

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The current champion in areal density is, naturally, IBM through the use of MR heads, PRML read channels, and headerless sector format. The highest density in a volume production product in August 1995 was the IBM DJAA 31210 and 31700 series of drives with 1.2GB and 1.7GB capacities. This family has an areal density of 663Mb per square inch and a single platter capacity of 850MB, with a rotational rate of 4,500 rpm. These particular drives use peak-detect read channels and MR heads and are aimed at the desktop market. IBM's DCMS-310800 and DCHS-38700 drives have been discussed in a technology announcement and are scheduled for delivery late in 1995. Their areal density is expected to be 793Mb per square inch with storage capacities of 10.8GB (5,400 rpm) and 8.7GB (7,200 rpm).

Hewlett-Packard, Quantum, Seagate, and Hitachi have all announced drives with areal densities over 420Mb per square inch that are scheduled for production later in 1995 or early in 1996. All of these products use MR heads and most products have experienced protracted delays in their schedules.

IBM's advanced drives have the highest per-platter capacity, with an expected record 1,080MB in 1995. The highest platter capacity shipping in August 1995 was the same drive with the highest areal density, the IBM DJAA series at 850MB. The highest non-MR product was Quantum's Fireball 1.09GB drive with 545MB per platter. Maxtor's 1.08GB and 1.6GB drives and Seagate's Medalist drives were next at 542MB per platter. Western Digital was the first to ship 540MB-per-platter drives, with early deliveries in April 1995. There is some question as to what the next platter capacity will be. Conner Peripherals is pointing toward the 635MB point by offering a two-platter, three-head drive at that capacity. Others have made 730MB a two-platter point, and still others believe that 850MB per platter will be the next big step in products.

The 1-inch-thick form factor has become a popular standard in the desktop and in some disk array subsystems. Seagate is the only 3.5-inch manufacturer to offer a smaller size, with the Decathlon 545MB, 850MB, and 1080MB drives sized at 0.75 inches thick. Seagate is the only supplier to have crammed six platters into a 1-inch-high drive on its Barracuda 2LP. Giving up a top platter head to accomplish this feat, the drive offers 2.147GB in this form factor. The highest capacity 1-inch drive shipping is the IBM DFMS-32600 with 2.66GB capacity, at 5,400 rpm. Dataquest expects to see limited volumes of 1-inch-high drives with 4GB capacities by the end of 1995.

The 3.5-inch industry has been segmented into desktop and performance products, with rotational rates the primary differentiator. Conner offers the highest capacity 3,600 rpm product at 1.6GB and the leader in the 4,500-rpm class is IBM with its DJAA series. The 5,400-rpm performance level is the beginning of the performance-class products, but Seagate and Western Digital are moving their low-end drives up to that low latency level for product differentiation. The lowest-capacity 5,400-rpm product is 540MB. The 7,200-rpm rate is the fastest now shipped, with Quantum's Atlas 1GB drive being the smallest capacity offered in this class.

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The highest-performance, high-capacity IDE drive is Seagate's 2.16GB Medalist at 5,400 rpm. There are few SCSI drives available with performance levels below 4,500 rpm, and most are in the 5,400 and 7,200 class. Most of the high-performance, high-capacity drives will be available with serial interfaces (SSA or FC/AL) in the near future.

5.25-Inch RDD

The high-end server and array market still loves the high capacity attainable from the 5.25-inch form factor. The Seagate Elite 9 and the Micropolis 1991 drives at 9.1GB are the highest-density products around. Shipment of 18GB to 20GB drives is expected in 1996.

Even while we have been believing that this form factor is dead, several companies have been developing low-cost, high-capacity 5.25-inch products for the consumer market. With its 675MB per platter capacities using low-cost (non-MR) technology, the dollar per megabyte prices can be very attractive. Dataquest believes that at least three vendors will announce low-cost 5.25-inch drives for desktop use before the end of 1995. The popularity of these drives will be short-lived as the prices of high-capacity 3.5-inch drives continue to plummet, but it is a clever idea to satisfy user needs.

SMART

Self-monitoring analysis and reporting technology (SMART) is a new feature making its way into rigid disk drives. SMART drives continually monitor various parameters within the drive to predict imminent failure. These drives communicate the likelihood of failure to the host computer. When drive failure becomes likely, the system administrator can back up the disk, replace it, and restore all of the information. This allows the drive to be replaced with minimal impact on the system and users. For drives in a RAID system, data can always be reconstructed, but that is more time-consuming than replacement before failure.

The greatest caveat with SMART for drive manufacturers is false reporting. For notification to be useful, hours of notice are preferable to minutes, but drive OEMs do not want to replace more drives than necessary. A scenario where drives report failure when failure is not imminent will merely result in more returned drives and higher warranty costs. From the user side, nobody wants to replace drives unnecessarily, but most would rather err on the side of more frequent replacements rather than face greater chances of data loss.

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Chapter 4
Opportunities in the Rigid Disk Drive Market

Rigid disk drives continue to be the focus of attention from all segments of the computer industry because of their growing importance in system configurations and application futures. The rapid, 60-percent-per-year technology growth appears to be continuing and is a driving force in shortening product life cycles and lowering cost per megabyte.

The products themselves are getting more difficult to design and build as the technology race heats up, and it is likely that technology itself may be the limiting factor in the rates of change. The inability of drive engineers and operations managers to put products into manufacturing on a nine-month cycle is becoming evident. The component suppliers are also hard-pressed to provide large enough quantities of heads, media, motors, and read channel components to meet the performance and delivery demands of the advanced drive designs. This chapter will outline the unit volumes and special configuration requirements that would be of special interest to semiconductor suppliers.

While it is easy to be optimistic about the growth in unit volumes going forward, caution must be exercised in becoming too bullish about the capabilities of the industry. On the plus side, a slowdown in product cycles may be sufficient to slow the price decay curve, and profits for the industry may regain a level of respectability. The unit volume forecast for all rigid disk drives is shown in Figure 4-1, broken down by capacity ranges. It is clear from this figure that the only capacity segments of disk drives that are projected for growth are those over 1GB.

1.8-Inch Drives

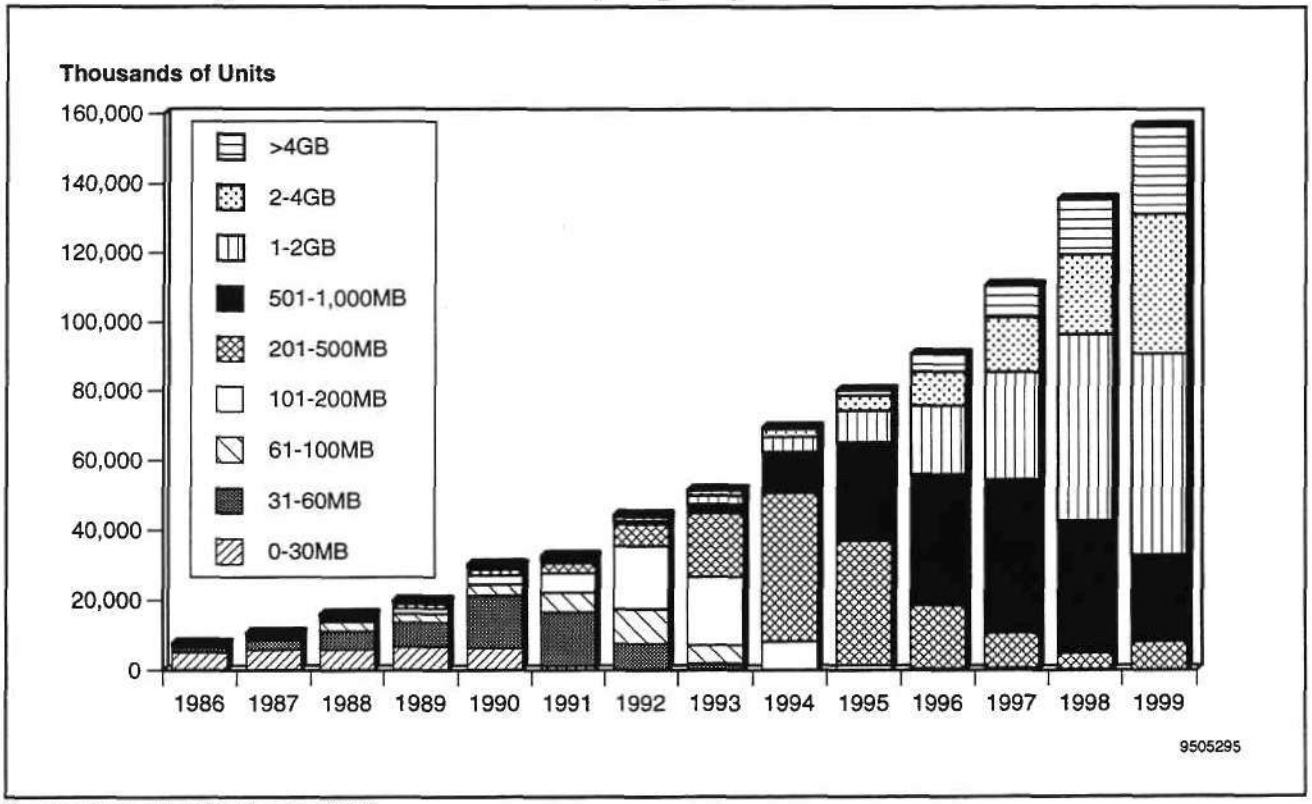
This form factor has been around since 1991, but system requirements are once again delayed and sales volumes of the 1.8-inch drives have been small. The product has been available in two configurations: AT/IDE interfaced and PCMCIA Type III interfaced. In 1994, 92.7 percent of these drives sold were PCMCIA and the rest had IDE or proprietary interfaces. In 1995, nearly 100 percent of all drives are PCMCIA. Capacities of recently announced products have ranged from 170MB to 341MB, with the largest number of shipments in the 170MB range.

The market for these little drives is still believed to be substantial, but the cost per megabyte of this form factor is four times greater than that of 3.5-inch products and buyers simply will not tolerate this expense. The 2.5-inch form factor has satisfied the needs of the mobile computer user, and removability is accomplished by some companies by simply encapsulating the entire 2.5-inch drive for easy replacement.

MiniStor was a 1994 casualty of the slowness of the market, filing for bankruptcy and eventually liquidating its assets. MiniStor was the first major client for the ZIA disk drive products. ZIA was the joint effort among Zilog, IMP, and Allegro to provide a complete electronics solution for use in small disk drives. Maxtor Corporation quietly stopped producing its MobileMax drives but continues to sell off its inventory.

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Figure 4-1
Worldwide Rigid Disk Drive Forecast by Capacity



Source: Dataquest (September 1995)

Integral Peripherals and Calluna are the only vendors still in production of 1.8-inch disk drives. Integral has found a market in supplying drives to Japanese PC makers that build pen-based computers for vertical markets. These systems are usually oriented to corporations or service companies needing manual inventory, patient record keeping, and delivery records, among others. Orders for this type of system come in spurts of tens of thousands of units, and suppliers of components for the little PCs are not given much lead time or visibility for future business.

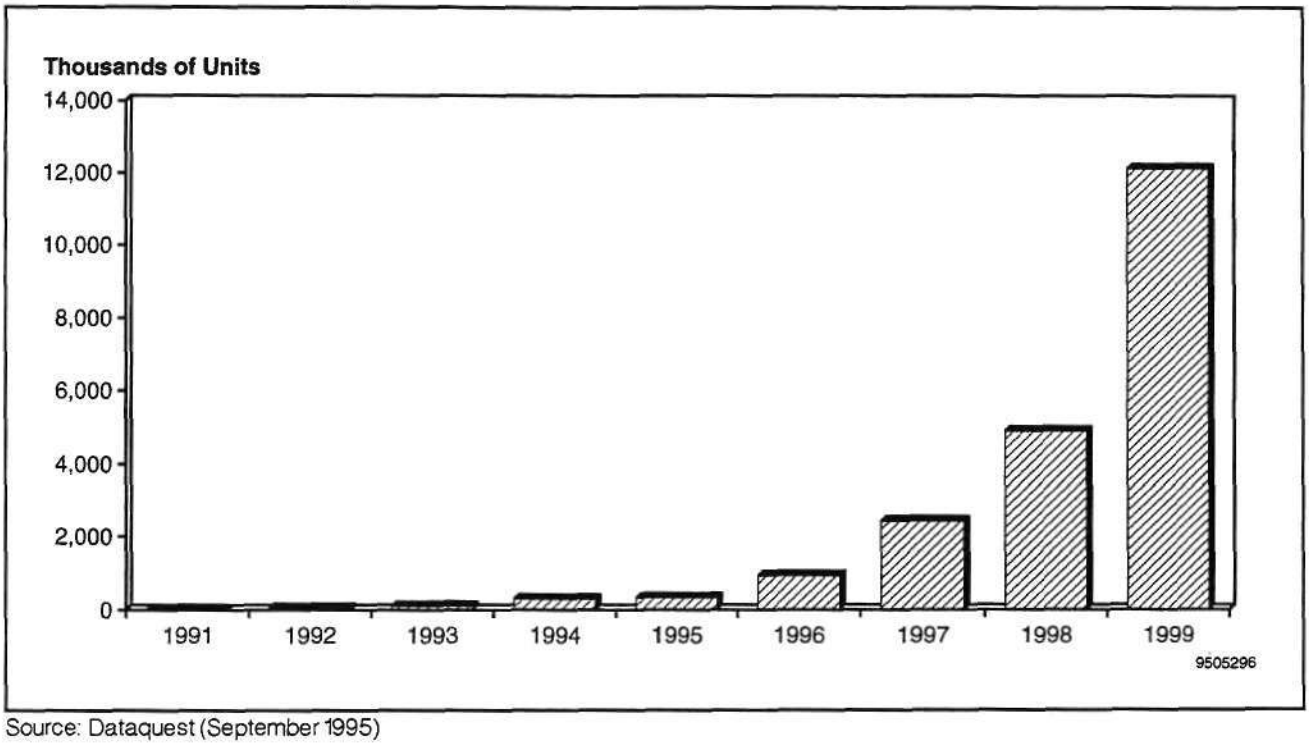
Integral Peripherals was the first of the drive makers to develop a multi-chip module that was to be used in its advanced 1.8-inch products. This approach, while attractive because of its low profile and small area requirements, was put on the shelf early in 1995 because of its high cost. Technological advances that increase the product cost of 1.8-inch disk drives cannot be tolerated during this phase in the life cycle of the form factor.

Forecast Discussion

Figure 4-2 shows Dataquest's 1.8-inch RDD forecast. This segment of the market is the most difficult to forecast because of the lack of a clear target market. It is likely that the 2.5-inch disk drives will someday take on greater use on the desktop and in server arrays. It is that migration path that will enable the market for smaller disk drives.

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Figure 4-2
Worldwide 1.8-Inch Rigid Disk Drive Forecast



Source: Dataquest (September 1995)

Dataquest has observed that users of removable cartridge disk drives normally purchase seven packs in the life of the drive. There is not likely to be such a correlation with PCMCIA products, but buyers will probably purchase more than one product. The sales of 1.8-inch drives in 1996 are expect to be just under a million units, worldwide, still not a very attractive market. The promise of use in digital cameras, mobile data collection, and font cartridges continues to be no more than a dream, since the price of the tiny drives still represents a very large percentage of the purchase price of the products they are intended to support.

The highest-volume capacity in 1995 will be the 170MB-class products, with the 260MB drives right on their heels. Some 340MB products will ship, and higher capacities will be announced. The single-platter capacity of the drives could be as high as 200MB in 1996 through the use of MR heads.

Since the form factor is reasonably new, prices will not fall as dramatically as those of the more mature drives, but the OEM price per megabyte on the average of all 1.8-inch products is anticipated to drop by 25 percent per year for the next five years, and the end-user price per megabyte will fall at 24 percent per year, compounded. Unit volumes could reach 12 million units by 1999.

Advances in multichip modules, further integration of functions, smaller motors, and lower-cost components all around will be required to make this forecast come true. Here is a real opportunity for a forward-thinking component supplier to forge a position in a coming market.

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2.5-Inch Drives

In 1995, this form factor will reach the magical 10 million unit sales mark, turning the 2.5-inch disk drive into an interesting high-volume product. IBM and Toshiba are pushing hard to lead the industry, while Seagate and Quantum appear to be discouraged about their portion of the market. Hitachi has entered the market after initial designs contracted through MiniStor and has developed a very respectable line of 2.5-inch drives on its own. Maxtor's recent entry into this segment brings the total number of producers to 10. This high number of competitors may be the reason for discouraging results from all but the top three producers.

IBM's leadership position was attained swiftly, with contracts in place from all of the major portable computer makers. The form factor seems well suited for IBM's product and process, with never a rumor of bad performance or quality. Toshiba's second-place position reflects considerable use in its captive market, but also good acceptance from competing notebook makers.

The most recent news is that JTS and Western Digital have entered a thin 3-inch drive into the portable market to compete directly against the 2.5-inch drives. With 50 percent more capacity on a single platter and a slim, 10.5mm thickness, the low-cost JTS drive has found considerable interest from Compaq and several other major portable suppliers as a 2.5-inch replacement. Lower cost per megabyte and higher ultimate capacity are the selling points. Production is just beginning at Xyratex in the United Kingdom, with components being assembled in India. Once the drive's durability is established, we can determine whether this product will further dilute the 2.5-inch market. The JTS drive uses the technology developed at Kalok for Point Five drives. All of the electronics are inside the head disk assembly (HDA) on a triangular board that fits in one corner of the enclosure. The high level of integration and simplicity of the system have allowed JTS to continue this process in order to provide a drive with such a thin profile. Other disk drive makers are candidates for such improvements, especially the 2.5-inch drives. A lower profile could be achieved on multiplatter drives, allowing a higher capacity for a given z-height.

Large volumes of 2.5-inch drives were built in 1991, slowing the requirement for new production in early 1992. The most important indicator of the instability of this market was the fact that Conner Peripherals sold fewer 2.5-inch drives in 1993 than in 1992 or 1991, when it led the market. Conner's share of this market fell from 55 percent in 1991 to 35 percent in 1992, 18.3 percent in 1993, and 4.4 percent in 1994. IBM surprised the industry by taking the top market share position in 1994 (26.2 percent), and it continues to expand its lead over Toshiba and Seagate.

Toshiba continues as a technology innovator in this segment, but has had difficulty making solid profit in the face of IBM's competition and the strong yen. Toshiba's share was 13.5 percent in 1992, 19.3 in 1993, and 23.6 in 1994.

Thin-film heads are required in 2.5-inch drives with capacities over 100MB. Since applications are primarily in mobile computing, drive size, weight, and power consumption specifications are critical. A 12.5mm

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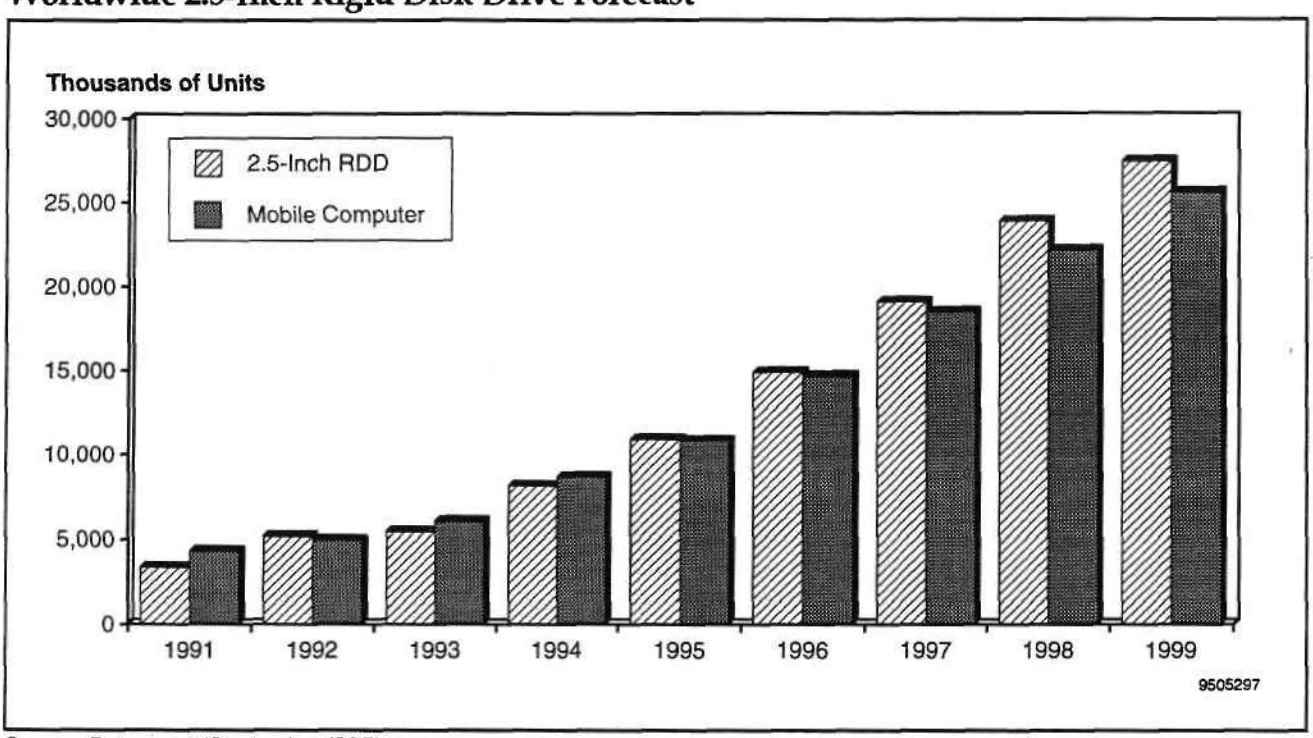
thickness is attainable on two-platter drives and seems to be popular with OEM buyers. Weights range between 4 ounces and 6 ounces for one- and two-platter drives. Power consumption depends on power management ICs and firmware designs, along with low-power-consuming motors. Spin-up times and power consumption curves vary by vendor.

Forecast Discussion

The 2.5-inch market is considered to be centered on the notebook and laptop mobile computer market. So far, there has been little or no interest in using 2.5-inch products on the desktop, but that may change in 1997 as 3.5-inch drives hit a performance limitation. Dataquest believes that the 2.5-inch disk drive will be the performance platform of the future, with models spinning as fast as 10,000 rpm to 14,000 rpm. The 3.5-inch disk drives will reach 200-Mbps read channel data rates at linear bit densities of 170 bits per inch (BPI) and 7,200 rpm rotational rates, and the smaller circumference of the 2.5-inch disk drive may be just the solution for low-cost CMOS read channel parts. If this is the case, 2.5-inch drives could well become the drive of preference in disk arrays for transaction-based based systems in 1997.

Figure 4-3 shows the Dataquest forecasts for 2.5-inch disk drives as well as their available market from the total of notebook and laptop computers. Historically, the 2.5-inch products have followed the mobile PC curve, and Dataquest's forecast for these drives through 1996 continues to follow the same curve.

Figure 4-3
Worldwide 2.5-Inch Rigid Disk Drive Forecast



Source: Dataquest (September 1995)

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The deviation from predicted mobile PC numbers that is seen in 1997 and 1998 is the result of speculation by many disk drive designers that the 3.5-inch areal densities will be excessive starting in 1997. At that time, it will be difficult to handle the internal data rates of 3.5-inch products, and 2.5-inch drives are thought to be the potential solution to the problem. The 2.5-inch products used in desktop or server applications will likely be SCSI-interfaced, with the SSA or FC/AL interfaces the likely best solution because of their small connector requirements.

Dataquest forecasts that the 810MB segment will dominate sales in 1996, with shipments of 7.5 million units. The 1998 popular point will be about 2GB, with 12.5 million units shipping in that capacity band. Prices are expected to fall by 36 percent per year for total OEM dollars per megabyte and by 38 percent to the end user.

3.5-Inch Drives

Still the most popular disk drive in the world, the 3.5-inch form factor grew by 34 percent in 1994 to a total of 59.5 million units and a factory revenue of $12.5 billion. In 1993, total unit sales were 44.4 million units, worth $11 billion to manufacturers. The CAGR from 1995 to 1999 is predicted to be 14.2 percent in unit volumes and 9.55 percent in factory revenue. The slower revenue growth is because of continued price declines and rapid increases in recording densities in single- and dual-platter configurations.

Positioned as the primary storage device of choice in desktop and midrange computers, the 3.5-inch drives are secure in their markets and have now become the drive of choice in large-scale DASD array applications. IBM's RAMAC disk array for mainframe computers uses 3.5-inch Allicat disk drives, and the RAMAC II is an array of StarFire drives. The 3.5-inch forecast is graphed in Figure 4-4. The bars in the graph are segmented by the application area of use for the drives, with personal computers in one segment; all servers in another; workstation, midrange, and mainframe use in another; and the upgrade market in the last.

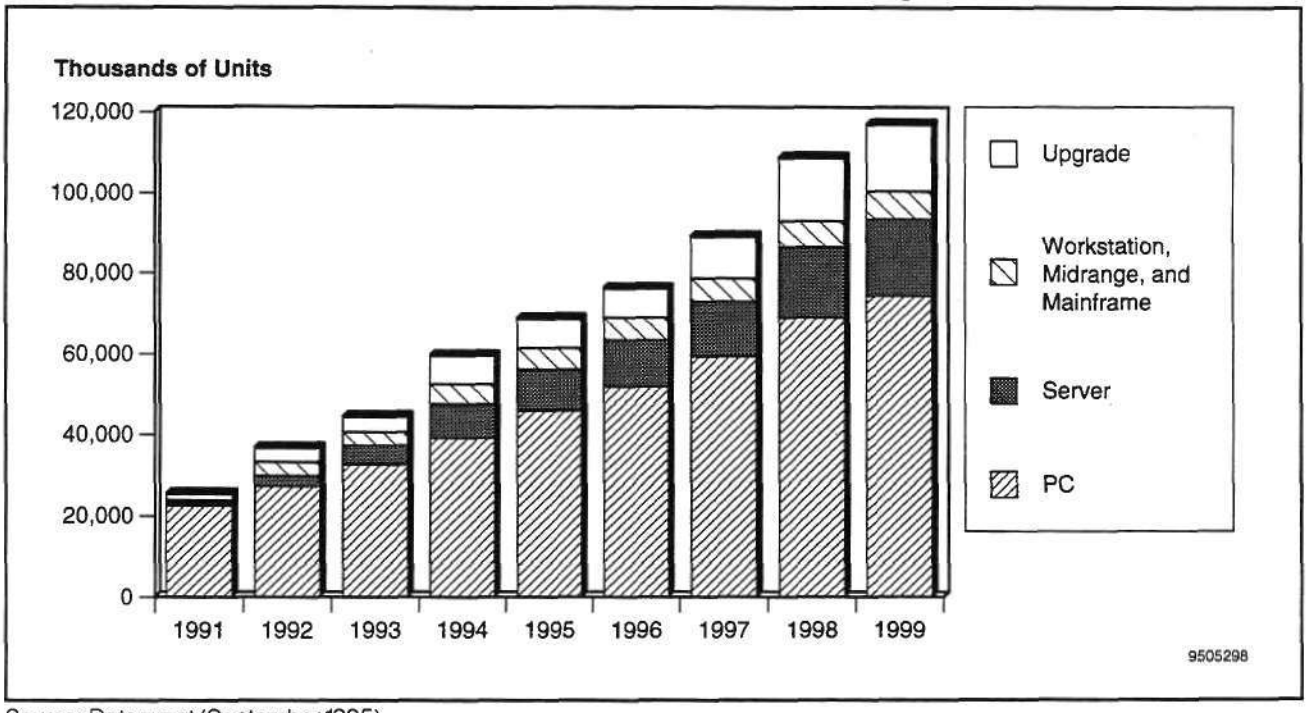
IBM is the technology leader in 3.5-inch products, offering a 5.25GB, eight-platter drive with 561 million bits per square inch areal density (compared with last year's 354 million bits per square inch). All of IBM's drives use advanced-generation MR heads and PRML channels to attain these densities.

The gigabyte market for 3.5-inch drives was dominated by industry captive producers in 1992, with IBM, Digital Equipment, and Hewlett-Packard winning most of the major OEM business. Dataquest believes that 438,300 of these drives were sold in 1992, 2.7 million drives with capacities over 1GB were sold in 1993, and 5.8 million were sold in 1994. The market shares of the producers in this segment have changed dramatically from 1992. Digital Equipment's drive unit was acquired by Quantum, but neither has kept up the torrid pace of Seagate and IBM, the leading producers of drives over 1GB. In 1994, Seagate and IBM shipped almost the same number of products in this segment, ending the year with just under 2 million units per company, tied at 33 percent share each.

By the middle of 1993, the most popular 3.5-inch drive was the 170MB product, and a year later in 1994 the 270MB, single-platter drives were

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Figure 4-4
Worldwide 3.5-Inch Rigid Disk Drive Forecast by Market Segment



Source: Dataquest (September 1995)

clear winners. In midyear 1995, the hottest product is 540MB, moving quickly to 625MB. By Christmas, the 850MB capacity will peak and we will enter the new year with 1GB drives as the entry-level capacity for personal computers.

The slim 1-inch-high drives are becoming the industry standard, with half-height 1.625-inch drives needed only for multigigabyte capacities. There is no doubt that the 1-inch format is the long-term standard for the 3.5-inch market.

Forecast Discussion

The 3.5-inch market is vigorous and still growing through the rest of the decade. The drive makers have increased capacity of all diameters to a total of more than 7.8 million drives a month, but caution is being exercised and the actual output in 1995 is about 6.9 million per month. Dataquest believes that about 70 million 3.5-inch drives will be sold in 1995.

With the dollar per megabyte prices for OEMs and end users falling at 32 percent per year for the next five years, Dataquest is forecasting that the average 3.5-inch drive will cost $0.05 per megabyte in 1999. The average capacity of these drives will reach 3.2GB in the same year.

The big trouble in 1995 is the product transition from 540MB per platter to 625MB or 850MB per platter as the areal density battles continue. The 425MB and 540MB drives have little or no profit left in them and will be brought to a swift end of life, even though there is still strong demand for 540MB in all channels. Premature price erosion will make this product transition more difficult than normal, since there will be few products to sell.

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5.25-Inch Drives

Sales of 5.25-inch RDD products in 1994 fell to only one-third of the 1993 level. There is little indication that the form factor will be triggered into new life even though Quantum and BMI will be introducing new, low-cost 5.25-inch desktop products at COMDEX 1995. This approach to competing with the 3.5-inch products at a cheaper dollar-per-megabyte level will not continue to be attractive when the 2GB and greater 3.5-inch drives become more available in 1996.

Only 484,000 units sold in 1994, and Dataquest expects that 250,000 will be the market size in 1995. Seagate continued to dominate this segment of the market, with HP and Micropolis holding shares over 10 percent. Seagate and Micropolis are the only companies in large-scale production of this form factor.

The bulk of the sales in 1994 were again over 1GB, and the current standard of popular drives has moved to 9GB. Dataquest expects shipment of 20GB, 5.25-inch drives by the middle of 1996. The SCSI interface is most popular in this form factor.

Disk arrays from EMC and Storage Tek with 5.25-inch drives have been shipping into the high-end DASD market. The switch to 3.5-inch drives in these systems has already begun.

The newfound market for 5.25-inch disk drives is the video-on-demand industry. Micropolis and Seagate have both found considerable success in their 9GB drives for use in storing motion pictures for simultaneous viewing in hotels. Micropolis has joined forces with EDS for production of systems for the Spectravision systems in 2,000 hotels. It is likely that this market will continue to favor 5.25-inch drives because of their high capacities and continuous data streams.

The 5.25-inch forecast is shown in Figure 4-5.

Forecast Discussion

This form factor, in its dying days, has become popular in the video market, and Dataquest's forecasts indicate stabilization of sales at about 1 million units in 1994 and 1995. Because of earlier price erosion and higher demand, the 5.25-inch drives will fall in price only about 14 percent per year over the next five years, so good profit can be made on their sales.

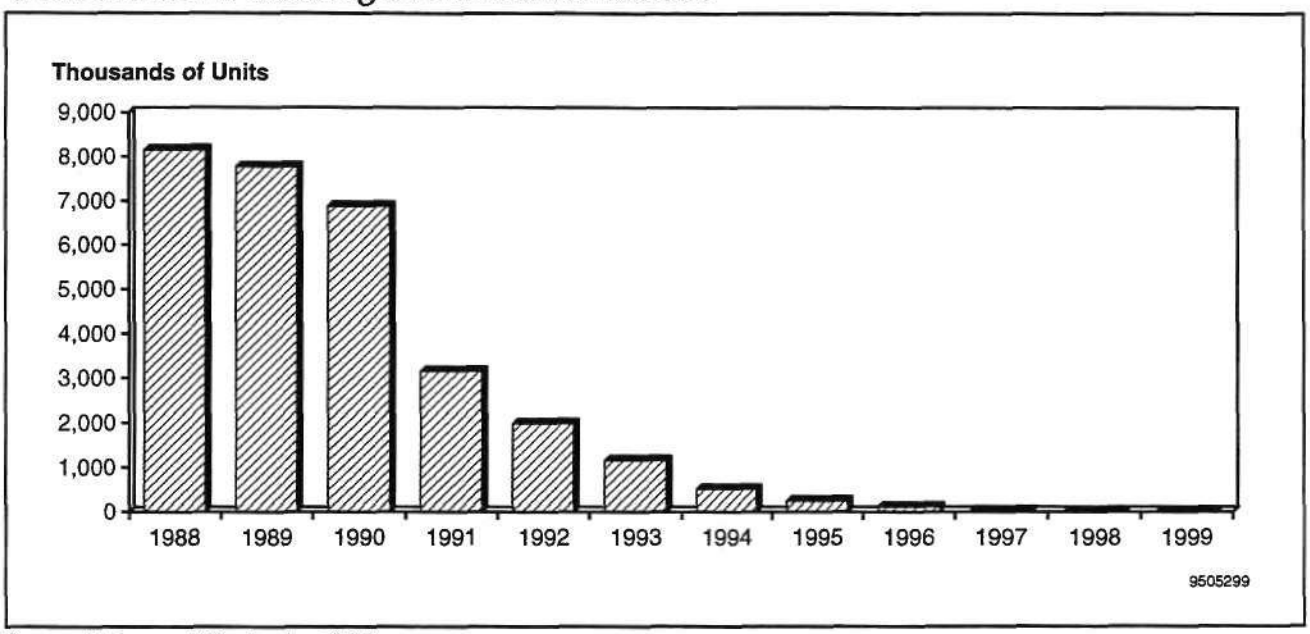
In 1995, the average capacity shipped will be in excess of 10GB per drive and, by the time the form factor fades away, the average capacity will be near 20GB. Since MR heads have not yet been used widely in these drives, considerably higher densities can be anticipated.

Regional Sales

Dataquest 1994 surveys of sales to the various regions of the world have produced unique results for each disk drive segment. Table 4-1 displays the unit market share for 1.8-inch, 2.5-inch, 3.5-inch, and 5.25-inch disk drive sales demand.

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Figure 4-5
Worldwide 5.25-Inch Rigid Disk Drive Forecast



Source: Dataquest (September 1995)

Table 4-1
Regional Market Splits, Percentage of Sales

	North America	Europe	Japan	Asia/Pacific
1.8-Inch	32.6	2.1	58.2	7.1
2.5-Inch	57.7	8.8	15.5	18.0
3.5-Inch	52.0	28.5	5.4	14.1
5.25-Inch	75.4	10.4	9.6	4.6

Source: Dataquest (September 1995)

Rigid Disk Drive Channel Trends

Rigid disk drive sales are made through three basic channels: captive, OEM, and distribution. While not all disk drive makers have a captive outlet for their products, certainly all of them have made concerted marketing efforts in OEM and distribution sales.

Captive Channel

Only the large companies like IBM, Hitachi, Fujitsu, Toshiba, and NEC have use for their own disk products in their computer systems. IBM holds a reasonable worldwide unit market share in 3.5-inch disk drives (9.6 percent) and is the market leader (26.2 percent) in 2.5-inch drives. Fujitsu, Hitachi, and NEC are not major players, but do manufacture large quantities of disk drives. Toshiba is the one exception, with its No. 2 status (23.6 percent) in the 2.5-inch market.

Table 4-2 shows the percentage of each company's unit volume sold captively to other divisions of the same company, indicating the trends over three years.

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Table 4-2
Percentage of Sales to Captive Channel

	1992	1993	1994
IBM 2.5-Inch	80	50	55
IBM 3.5-Inch	90	62	67
Fujitsu 2.5-Inch	NA	100	30
Fujitsu 3.5-Inch	18	90	37
Hitachi 2.5-Inch	NA	NA	26
Hitachi 3.5-Inch	0	0	20
NEC 3.5-Inch	83	53	67
Toshiba 2.5-Inch	60	29	25

NA = Not applicable; companies did not manufacture product during this period.
Source: Dataquest (September 1995)

The trend is clearly toward less captive use of products, since the vendors would much rather sell large volumes of products to the merchant market and reduce the cost of the disk drives used in their own systems. Also, the industry trend has been toward multisourcing of components such as drives, and these companies are purchasing increasing amounts of competitors' products.

OEM Channel

This is the largest channel for the sale of disk drives, directed at the manufacturers of computer products. As noted, these computer companies are now multisourcing products rather than developing sole-source dependencies. This protects them against shortages and assures them of competitive pricing. OEM prices are always the lowest and are discounted deeper for larger volumes.

Distribution Channel

This channel is one that allows for sale of products to industrial and commercial distributors for resale to VARs, system integrators, small OEMs, and retail outlets. Discounts to this channel result in prices about 10 percent above OEM prices. The gray market is a competitor to this channel, because large numbers of disk drives are resold by OEM companies to brokers in an effort either to relieve inventory or to increase their volume commitments. The gray market resells at nearly OEM prices and hurts distributors badly.

Industry Trends in Channels

Table 4-3 shows the average channel percentages for sales of 2.5-inch and 3.5-inch rigid disk drives. This is worldwide and an average of all vendors for three years.

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Table 4-3
Worldwide Channel Trends, by Percentage of Sales

	1992	1993	1994
2.5-Inch Captive	18.1	16.6	16.8
2.5-Inch OEM	74.9	80.0	72.2
2.5-Inch Distributor	6.9	3.5	11.1
3.5-Inch Captive	11.1	9.2	7.3
3.5-Inch OEM	54.1	61.2	61.5
3.5-Inch Distributor	35.8	29.6	31.3

Source: Dataquest (September 1995)

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Chapter 5
Interface Technologies

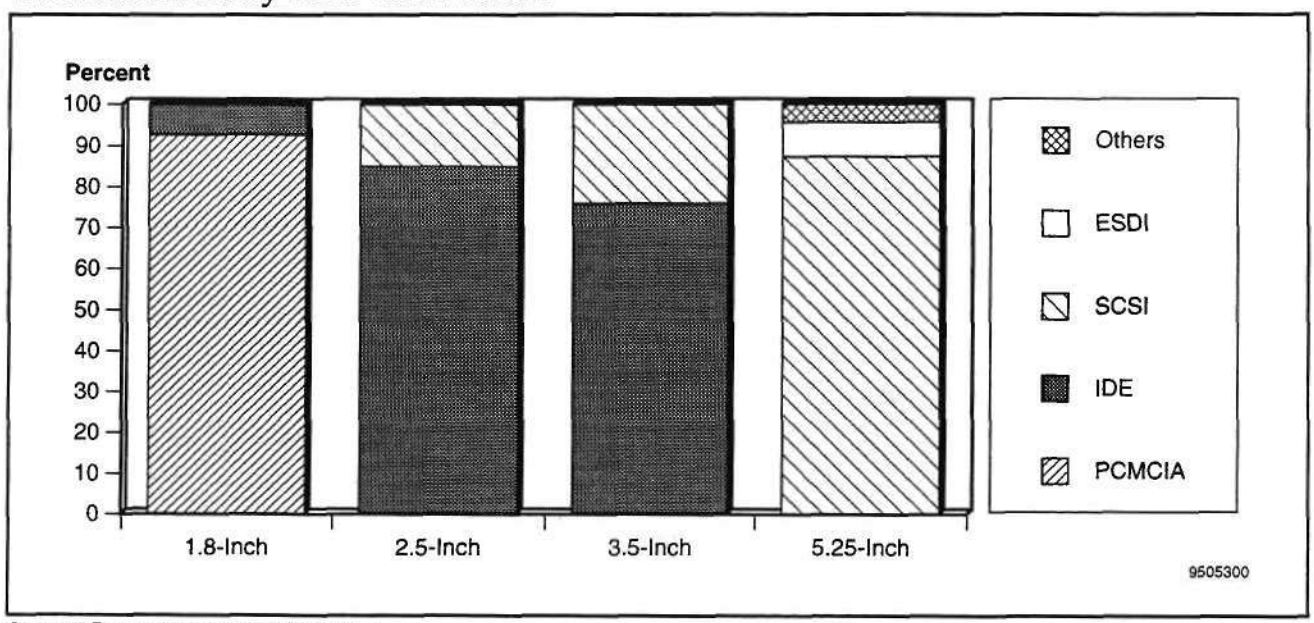
Overview

The popularity of the AT-attached disk drive with IDE or Enhanced IDE interfaces is being maintained as the desktop products move into the gigabyte-capacity range. SCSI continues to be the interface of choice for disk array subsystems and, generally, for products with high-performance characteristics. Figure 5-1 shows the split among interfaces on the various diameter disk products sold in 1994.

Figure 5-2 illustrates Dataquest's projected interface split between IDE and SCSI (parallel or serial) in the 3.5-inch form factor disk drives, and Figure 5-3 concentrates on 2.5-inch and 3.5-inch disk drives with capacities over 1GB and the segmentation of parallel and serial interfaces.

In the middle of 1995, SSA appears to have a definite lead on FC/AL for the device interface of choice. IBM is the inventor and key proponent of SSA, but also had considerable input into the Fibre Channel specifications. Hewlett-Packard, Quantum, and Seagate are the most vocal advocates of FC/AL, with apparently a large following of system makers that would love to have production quantities of disk drives for new, high-performance array products. Conner, IBM, and Micropolis are the drive makers that have announced SSA products, and IBM is, in fact, shipping production models. IBM is also designing SSA-interfaced disk drives into some of its midrange and high-end array products.

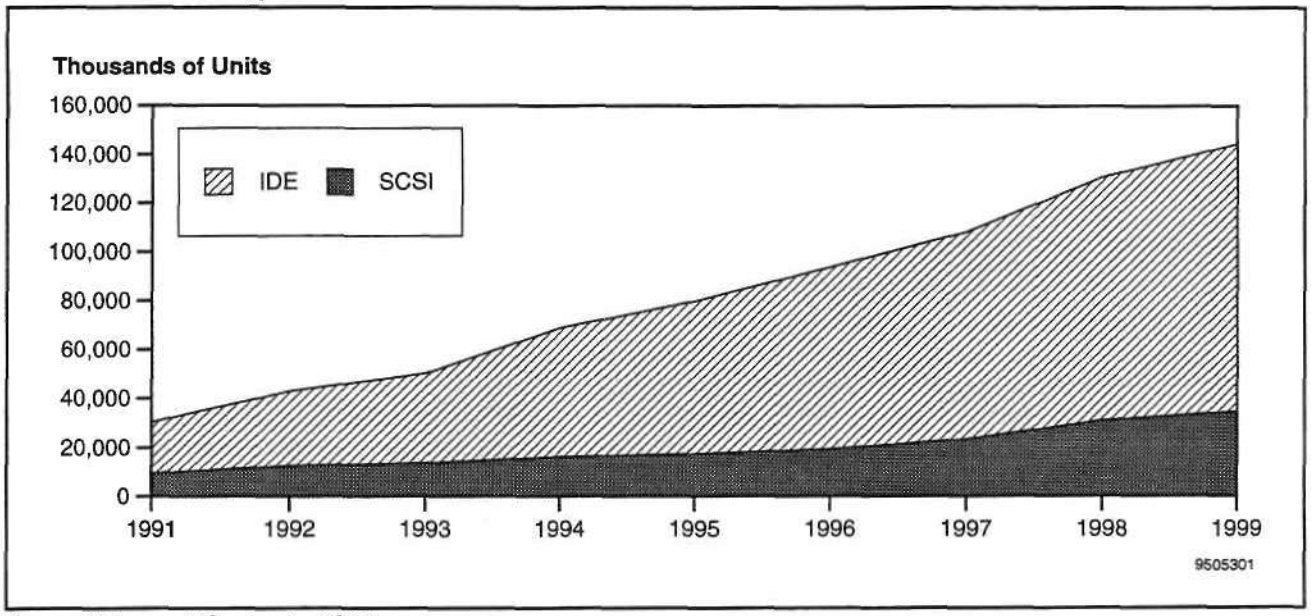
Figure 5-1
Interface Share by RDD Form Factor



Source: Dataquest (September 1995)

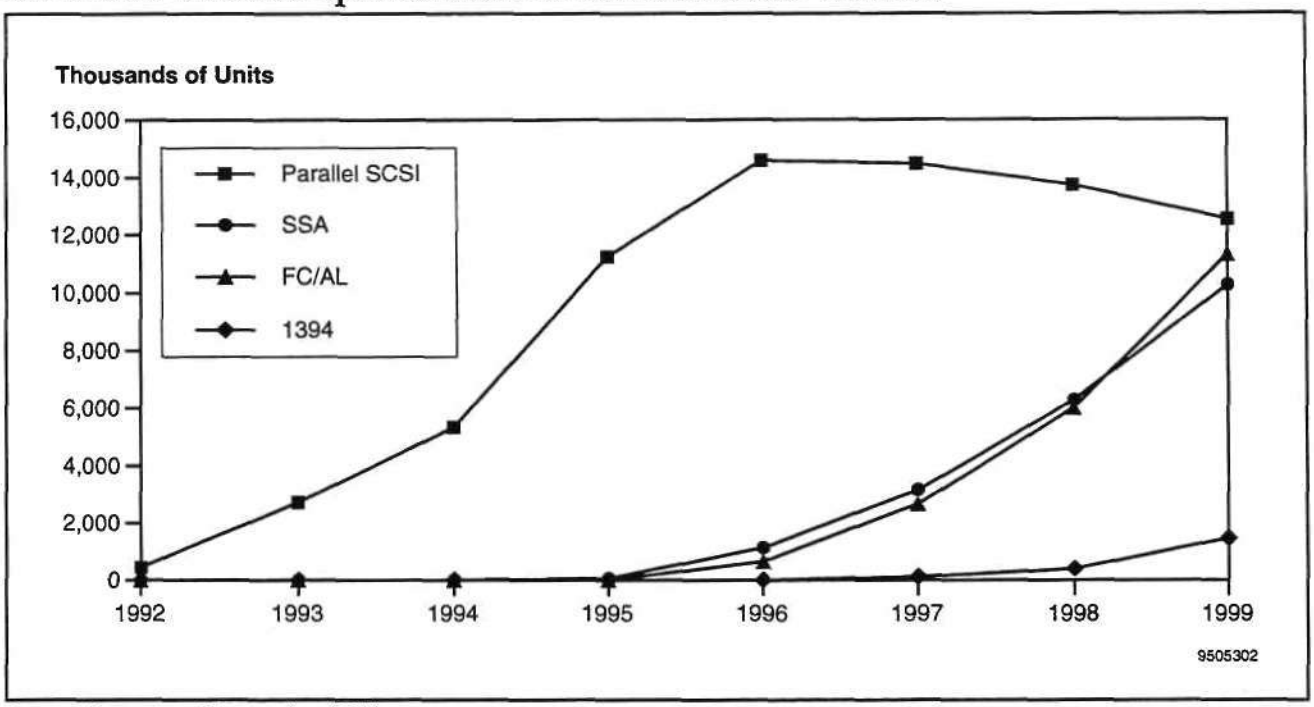
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Figure 5-2
RDD Interface Split Forecast for 3.5-Inch Drives



Source: Dataquest (September 1995)

Figure 5-3
RDD SCSI Interface Split between Parallel and Serial Versions



Source: Dataquest (September 1995)

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SSA is the lowest cost implementation of serial SCSI products, with interface parts available from IBM and VLSI. FC/AL interfaces are still expensive, but have been tuned downward in performance to make the interface chips easier to manufacture. Timing and cost are the decision criteria being used now to evaluate these competing interfaces. In 1997, there will be sufficient products available so that each can be judged on its own merit by performance and cost.

The Dataquest forecast for serial SCSI interfaced disk drives indicates SSA leadership, but FC/AL could take over in 1999. Actually, many changes could happen in that time, including a melding of the two interfaces into one powerful standard that all can use without arguing relative merits (much like the VHS and Beta wars of the last decade).

In summary, the serial interface battles are far from over, and it is difficult to project the long-term winners. The SSA interface continues to show that it will be more widely available at lower prices than the FC/AL interface disk drives. FC/AL, however, appears able to boast a larger following of system vendors that have selected it over SSA.

IDE/EIDE

The IDE interface was defined as part of the PC AT architecture in 1987. It is aptly named Integrated Device Electronics (IDE), but is also known as ATA or AT Attachment. The IDE interface replaced a de facto standard defined by rigid disk drive manufacturer Seagate known as ST-506. IDE provides a low-cost storage solution for PCs because it requires a controller only in the device rather than in both the device and the host PC. Only an IDE interface, rather than a full controller, is required on the host side, which keeps silicon costs at a minimum. The low cost for IDE has made it almost a universal feature for PCs, with over 80 percent penetration. Integration of the IDE interface into popular core logic chipsets will push the penetration rate for IDE/EIDE closer to 100 percent.

IDE controllers are best suited for single-user systems such as desktop or mobile PCs. The original IDE standard allows only two devices to be connected on a single IDE channel. Few desktop PCs require more than two rigid disk drives, but this is one limitation of the IDE specification. Other limitations have become more significant as disk sizes and file sizes have increased over the past decade. IDE drives have a maximum size of 528MB and file transfer rates were in the 2- to 3 MB/sec range. Another drawback of IDE is simply that only rigid disk drives could use the interface. Other interfaces such as SCSI allow a variety of devices to be attached, such as tape drives, scanners, and other peripherals.

These limitations have driven the industry to create a new standard that addresses these issues. Several versions of the new standard have emerged. Western Digital has named one specification Enhanced IDE, and this has widespread use in the PC world. Seagate has named a similar specification ATA-2. The principal difference between these two standards is peak transfer speed. Current EIDE controllers may not support transfer rates greater than 11.1 MB/sec. ATA-2 devices support two transfer modes (PIO mode 4 and DMA mode 2) that transfer data at a peak rate of 16.6 MB/sec. End users do not need to worry about their Enhanced IDE host interface recognizing their ATA-2 disk drive; it will, but the peak transfer rate will be 11.1 MB/sec. For this document, the term Enhanced IDE or EIDE will be used to describe EIDE and ATA-2 collectively.

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Enhanced IDE addresses many of the limitations of the original IDE specification. The EIDE specification recognizes disk drives as large as 8.3GB and provides two independent channels supporting two devices each, for a maximum of four devices. The speed issue has been addressed by new programmed input/output (PIO) modes as well as DMA modes. These new modes provide a maximum transfer rate of 11.1 MB/sec for PIO mode 3 and 16.6 MB/sec for PIO mode 4, but DMA modes will replace PIO modes for performance reasons. Dataquest does not expect any PIO modes to be developed beyond the 16.6 MB/sec mode 4. Instead, developers will focus on DMA modes. Two DMA modes have already been defined: Mode 1 multiword, which has a transfer rate of 13.3 MB/sec, and Mode 2 multiword, with a rate of 16.6 MB/sec.

Enhanced IDE has additional issues that are being addressed but are not yet finalized. At this time, two EIDE devices on a single channel must take turns. In fact, the issue is larger than just taking turns because when a request is submitted to one drive, that drive maintains control of the channel until it delivers the data. Access times for 3.5-inch rigid disk drives are typically 10ms to 15ms, so the channel is tied up unnecessarily for that time. Work is being done to define an overlapped I/O feature that will allow a second request to be made before the first request has received data. SCSI controllers already support this type of multitasking. For example, a request is made to drive No. 1 on channel No. 1 and while it is searching for the data (about 10ms to 15ms) a second request is made to drive No. 2 on the same channel. When the drives are ready to transfer the data, they will issue an interrupt, and whichever drive issues the interrupt request first will get to transfer its data first. This feature will increase the overall performance by making the channel available if it is not currently being used to carry instructions or data.

Another issue that will challenge EIDE in the near future is maximum transfer rate. Parallel SCSI has transfer rates of 20 MB/sec, with plans for 40 MB/sec. EIDE does not need to match those rates but does need to grow beyond the current 16.6 MB/sec maximum. Development work is being done on new DMA modes, with rates expected to be between 22- and 33-MB/sec.

One last issue that is not being addressed is cable length. EIDE cables have a maximum length of 18 inches and are designed to be an inside-the-box solution. Dataquest is not aware of any plans to expand the specification for longer cabling options to make external EIDE devices feasible.

SCSI

SCSI has long been the high-performance disk interface for desktop computers. The SCSI specification uses a parallel interface that is eight bits wide. Transfer rates started at 5 MB/sec, but new versions of parallel SCSI offer higher performance. SCSI controllers have been standard equipment in workstations and Apple Macintosh computers, but acceptance has been less widespread for x86-based PCs.

SCSI controllers have moderate acceptance for PCs because of the additional cost of implementing SCSI as compared to EIDE. SCSI requires a controller on the host PC side as well as in the SCSI peripheral. A SCSI controller card for a PC is several times the cost of an EIDE interface card because the additional controller chip is required. However, performance and expansion requirements have caused OEMs to add SCSI controller to many high-end desktop PCs as well as servers. Until the adoption of Enhanced IDE, SCSI controllers were the most convenient way to use

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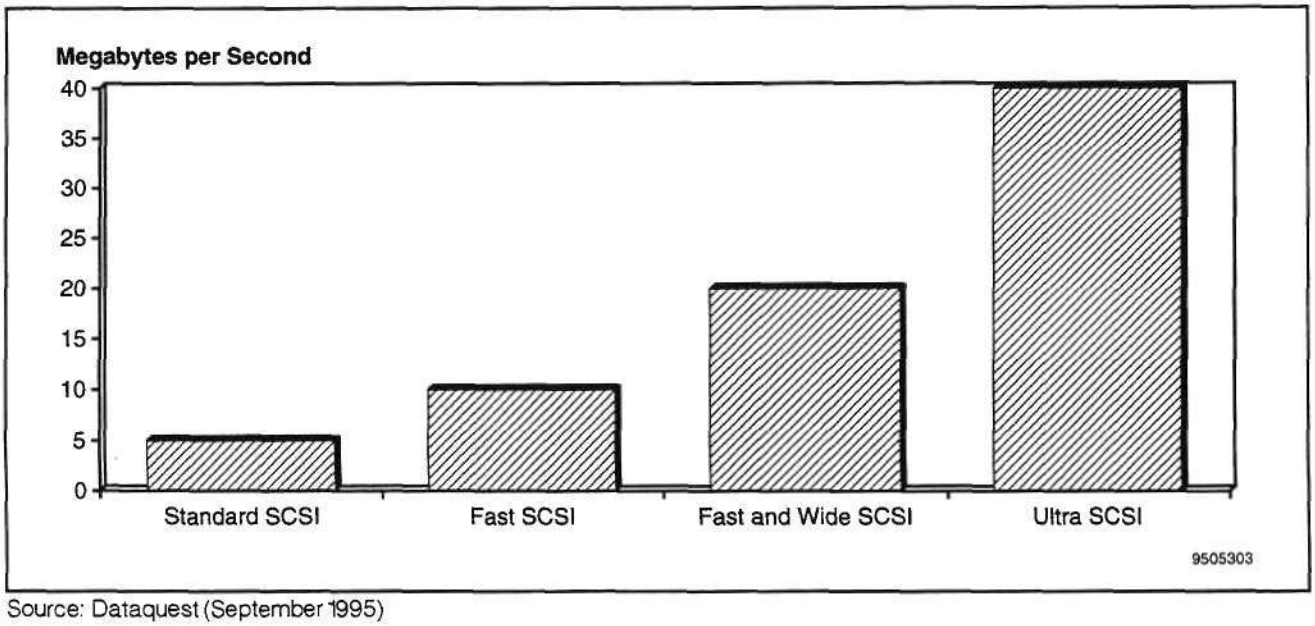
large disk drives (larger than 528MB) or add other devices such as optical drives (including CD-ROM drives) or tape backup units, as well as to provide a high-speed interface to external peripherals.

New SCSI protocol versions have been named numerically and with descriptive terms. SCSI-2 and SCSI-3 represent command set enhancements, while terms like "fast" and "wide" represent a doubling of the clock rate and a doubling of the interface width respectively. The original cable specification for SCSI uses a 50-conductor cable with an 8-bit parallel interface for data transfer. The "wide" versions of SCSI use either 68-conductor or 80-conductor cables and have a 16-bit interface for data transfer. The latest version is known as ultra-SCSI, which is the fastest version of SCSI to be finalized. An additional specification known as ultra-SCSI-2 is on the drawing board and could double the transfer rate of ultra-SCSI.

Versatility is one of the SCSI family's notable features. SCSI interfaces are found on a variety of peripherals such as disk drives, tape drives, and scanners because they provide a high-performance I/O standard for both internal and external peripherals. A standard SCSI chain can accept up to seven devices attached to a single host controller. This is one major advantage of SCSI over EIDE because EIDE is limited to four internal devices. The SCSI cabling specification allows cable lengths from 1.5m up to 6.0m, depending on transfer speed. There is an inverse relationship between maximum transfer rate and cable length, with the higher transfer rates requiring shorter cables. However, even the 1.5m cable length is over three times as long as the 18-inch limit for EIDE. Figure 5-4 shows parallel SCSI transfer rates.

The biggest hurdles for SCSI to overcome are the cost of implementation and the cabling complexity. EIDE is a lower-cost solution and meets the requirements of the typical desktop PC user. SCSI will retain some share of the market because of its ability to connect external peripherals and its current performance advantage, but it is unlikely to become a standard feature in a typical PC. Standard SCSI will lose market share to the serial SCSI architectures as the serial versions ramp through the rest of this decade.

Figure 5-4
Parallel SCSI Transfer Rates



Source: Dataquest (September 1995)

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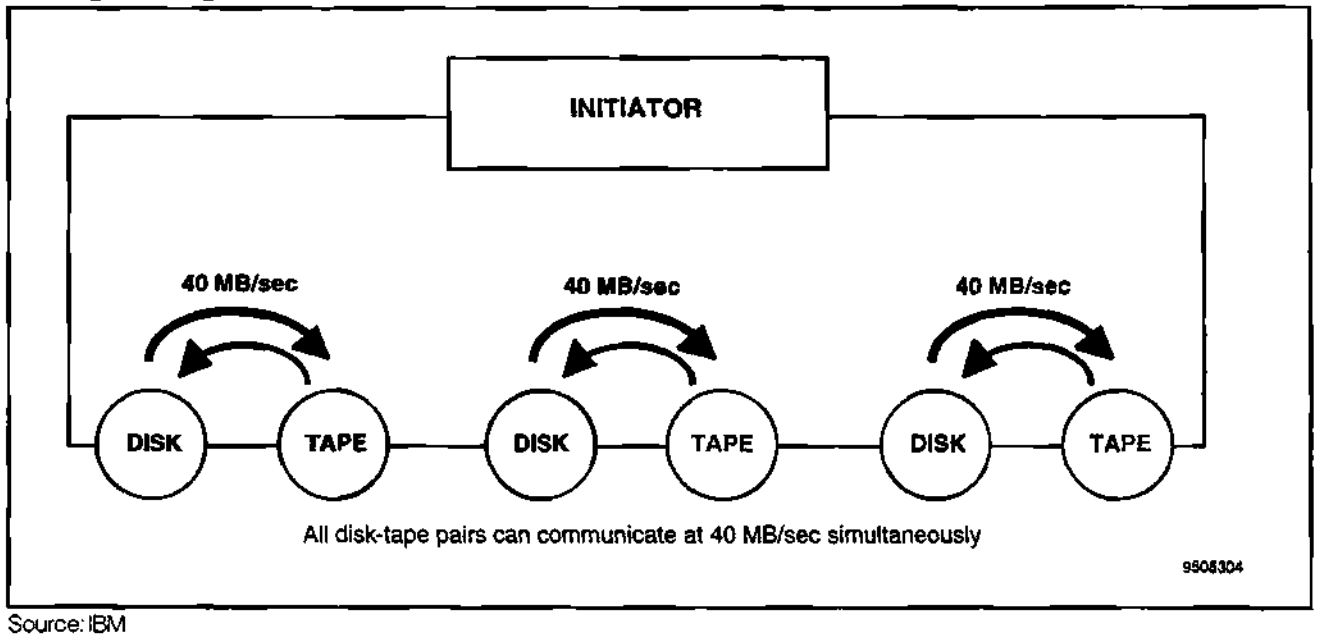
Serial Storage Architecture

SSA is a high-performance specification created and championed by IBM. SSA uses the SCSI-2 command set but provides higher performance and other benefits with a new cabling scheme. The cabling is actually four-wire cable, which provides four independent communications paths. Each path is capable of operating at 20 MB/sec bandwidth, so an SSA node has total bandwidth of 80 MB/sec.

SSA addresses many of the cabling problems associated with parallel SCSI. Parallel SCSI cables are wide (between 50 and 80 conductors) and not only can be difficult to route but may also block air flow in an enclosure. SSA cabling (four conductors) is much smaller and so does not have the same problems. Also, cabling for SSA is point-to-point and can configured in strings or loops. A loop configuration allows packets to be routed either way around the loop, so a single cable failure does not isolate any device on the loop. Faulty cables are easy to locate regardless of the configuration because a transmission error will identify specifically which section of cable (that is between which two nodes) caused the problem.

Spatial reuse is an additional feature of the point-to-point nature of SSA. Data packets travel from node to node rather than being broadcast to all of the peripherals simultaneously. This allows effective data rates much greater than 80 MB/sec. For example, imagine a configuration that features pairs of peripherals, with a tape drive and a rigid disk drive in each pair. If the cabling is routed as shown in Figure 5-5, then each of these pairs could transfer data at 40 MB/sec simultaneously. A configuration with three such pairs would actually be transferring 120 MB/sec (40 MB/sec times three pairs).

Figure 5-5
Example of Spatial Reuse with SSA Interfaces



Source: IBM

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1394 (Also Known as FireWire)

The IEEE 1394 specification is a high-speed serial bus that uses SCSI commands but defines a new cabling scheme. It was designed to be a universal I/O solution to connect a variety of devices with simple cabling and an overall low cost. The performance road map for 1394 places it firmly in the middle of its competitors. It is faster than parallel SCSI, but not as fast as the other serial SCSI specifications. 1394 will be adopted for applications where its mix of features make it attractive rather than competing on speed alone.

One feature distinguishing 1394 from the other serial SCSI standards is isochronous support, which allows guaranteed bandwidth. This feature makes 1394 well suited to applications that require real-time data, for example, playing motion video clips. Each frame of data must arrive at the frame buffer in time to be displayed. If some data is delayed, then the image quality of the displayed motion video clip will be compromised by incomplete or missing frames. Some applications particularly well suited for 1394 are consumer audiovisual equipment such as digital video cameras and videodisk players, as well as business applications such as multimedia authoring or video editing.

Several consumer electronics companies have endorsed 1394 as the preferred interface for many consumer devices, including digital VCRs, camcorders, and set-top boxes. Sony has already demonstrated products with the 1394 interface. Also, Apple computer has endorsed 1394 as an I/O standard for connecting a variety of peripherals to desktop computers.

Fibre Channel-Arbitrated Loop

Fibre Channel-Arbitrated Loop (FC/AL) is a serial peripheral interface standard. It is a subset of the Fibre Channel specification that defines an entire network architecture. The FC/AL subset was defined because full Fibre Channel compatibility is too expensive to implement in a peripheral device. FC/AL allows peripherals to use many of the features of Fibre Channel, particularly its high data rate, without adding unnecessary cost. FC/AL supports data rates up to 100 MB/sec and is the fastest standard interface available for rigid disk drives. Unfortunately, it is also the most expensive.

FC/AL is a serial SCSI interface, like its competitors SSA and 1394. The SCSI commands and protocols are used, but the cables and hardware are different. Up to 126 devices can be attached to a single FC/AL interface connection. Cabling can be configured as a single or a double loop. The advantage of the double loop is a doubling of bandwidth to 200 MB/sec and greater fault tolerance. FC/AL provides other advantages for disk arrays, including array-specific commands and XOR logic built into the disk drives. No special hardware is required on the host controller for RAID 5 because of those built-in features. This increases the array performance by reducing the workload of the host controller. FC/AL also lets the user define the ratio of data disks to parity disks in the array to balance cost of implementation versus speed of error recovery.

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FC/AL is the preferred interface for users who require maximum bandwidth and are willing to pay a higher price. FC/AL disk drives will be very popular with companies using Fibre Channel as their network protocol because the disk interface comes at no additional cost, but the mainstream market will find the cost of FC/AL drives to be high. FC/AL will continue to serve the high-end market, but is unlikely to gain significant market share in lower-performance markets through the remainder of the 90s. Table 5-1 compares RDD interface features.

Table 5-1
Comparison of Basic Features for RDD Interfaces

	EIDE	SCSI	Wide SCSI	SSA	1394	FC/AL
Relative Cost	Low	Medium	Medium	Medium	Medium	High
Transfer Rate (MB/Sec)	11.1	10.0	20.0	80.0	50.0	100.0
Approximate Silicon Cost– Host Side ($)	3-5	8-11	10-15	Over 20 today, 5-15 future	Over 25 today, 5-10 future	Over 80 today, less in future
Relative Cabling Cost	Low	High	High	Low	Low	Low
Maximum Cable Length (Copper)	18 in.	6m	6m	20m, device to device	10m	30m, device to device
Number of Conductors in Cable	40	50	68 or 80	4	6	Varies
Number of Devices per Interface	4	7	15	126	63	126
Hot Pluggable	No	Not standard	Not standard	Yes	Yes	Yes
Supports External Devices	No	Yes	Yes	Yes	Yes	Yes
Flexible Cable Configuration	No	No	No	Yes	Yes	Yes

Source: Dataquest (September 1995)

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Chapter 6
Semiconductors in Rigid Disk Drives

The major semiconductor devices in a rigid disk drive can be broken into the following categories: preamplifiers, read-channel ICs, motor controllers, servo controllers, peripherals controllers, and memory devices. The market for semiconductors in rigid disk drives is really a semicustom market. Semiconductor vendors develop core products as standard devices, but frequently end up creating a unique (although similar) part for each major customer. The design effort for the core product is leveraged for each customer, but production is customer-specific. A discussion of market trends and technologies follows for each of these categories. Figure 6-1 shows a simple block diagram for a rigid disk drive.

Preamplifiers

A preamplifier is necessary in a rigid disk drive because the electrical signal from the head is comparatively small. Such a small signal cannot reliably be carried outside of the disk enclosure because of electrical interference. The read signal is amplified by the preamp to minimize the effects of interference as the signal travels along a copper trace to the read-channel IC. Preamps are bipolar parts and are typically priced at $1.50. The merchant market for preamps is smaller in terms of units than that for the other semiconductor devices because many drive OEMs prefer captive solutions to merchant ones. These parts must be matched to the type of read/write head in the disk drive. A preamp for an MR head will not work with other types such as an inductive head.

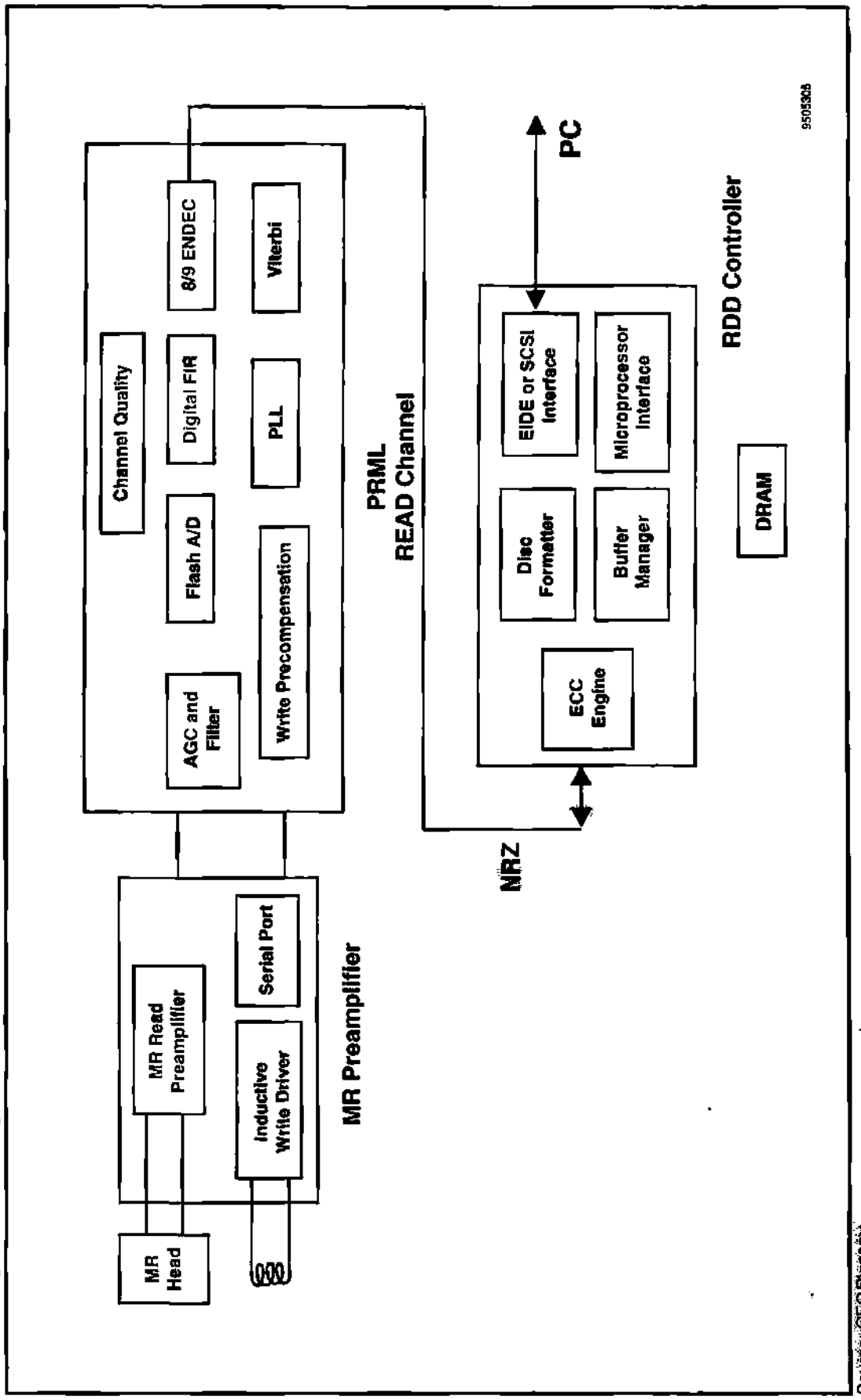
Read-Channel ICs

Once the signal from the disk drive head has been amplified, it requires additional processing before going to the disk controller. The first major step is identifying the peaks and valleys that represent encoded data. The goal is to reproduce the signal written to the disk. This conversion may be done using analog properties such as hysteresis, or the signal may be digitized before processing. The next step is to prepare the data stream for the disk controller. This process is called decoding and essentially separates the user data from the control and error correction data. The two data streams (user and error correction) are then passed to the disk controller.

Read-channel performance is a limiting factor in overall hard disk performance. The data rate for the read channel determines how quickly data can be read from the disk itself. Read-channel data rates for mainstream disk drives are 80 Mbps to 120 Mbps, with the high-end parts at 160 Mbps. These rates will rise to 200 Mbps in 1996 and are expected to reach 240 Mbps in 1997. These rates are specified in terms of user data rather than the data stream coming from the head. The data rate is a function of the maximum clock speed as well as the encoding scheme. Because the data stored on the disk is a combination of user data as well as error control data, the user data rate is always less than the data rate from the platter through the head assembly.

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Figure 6-1
Block Diagram for a Rigid Disk Drive



Source: GEC Plessey

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Common encoding schemes result in a 2/3 ratio of user data to written data, but new methods are producing an improved ratio of 8/9. In each case, the maximum clock speed multiplied by the ratio equals the user data rate. For example, a read channel operating at 180 MHz can handle user data rates of 120 Mbps with a 2/3 encoding scheme or 160 Mbps with an 8/9 encoding scheme. Obviously the 8/9 encoding scheme is a more efficient use of the channel because it carries more user data at the same clock speed. Faster read-channel ICs are needed to improve the performance of disk drives, but these devices are pushing process technology limits for speed and manufacturability. Single-chip peak-detect solutions are bipolar or BiCMOS parts. If the peak-detect functions are divided between two chips, then one is bipolar/BiCMOS and the other is CMOS. Most companies use BiCMOS processes for their PRML read-channel products, but others use CMOS or a mix of the two. Dataquest expects these products to be offered in both CMOS and BiCMOS through the end of this decade.

Two types of read-channel technology are predominant: peak detect and PRML. Peak detect read channels are commonly matched with thin-film heads and rely on analog peak detection to convert the signal from the preamp into the encoded data stream. PRML relies on digital signal-processing techniques rather than analog techniques. PRML read channels are commonly associated with MR heads but are used with thin-film heads also. PRML read channels are higher performance than peak detect but are also more expensive. As areal density continues to increase, along with motor speed and performance expectations for disk drives, PRML will become the dominant type of read channel. PRML is shipping in almost all disk drives from IBM as well as most drives from Quantum. Other manufacturers are still designing and manufacturing drives with peak detect for cost reasons as well as offering PRML-based drives.

Motor Controllers

Disk drives require motor controllers to drive the spindle motor for the rotating platters. These motor controllers have not changed radically since the early Winchester drives, even though the average rpm has increased significantly. This trend will change as speeds approach 10,000 rpm. High-end drives operate at 7,200 rpm and use ball bearings. However, demand for greater performance continues to push drive OEMs to design products with higher rpm. Dataquest expects drive OEMs to change their motor designs from ball bearings to fluid bearings to reach 10,000 rpm. This change will impact motor controller ICs because fluid bearings require nonlinear compensation. Another change that has affected the motor controller market for disk drives is a trend toward using digital signal processors (DSPs) in 1.8-inch drives instead of traditional disk controllers. For the smaller form factors, some OEMs are using a DSP for the overall disk controller as well as the motor and servo controllers. In these cases, the motor controller is replaced by a motor driver and the control functions are performed wholly by the DSP.

The rotational speed affects drive performance in two ways: raw data rate and seek time. The raw data rate is equal to the linear bit density multiplied by the linear speed of the platter under the head. This rate is limited by a number of factors, including the quality of the magnetic media, the rpm, and the read-channel speed. For this example, assume that the linear bit density is maximized, but the read channel is operating at 50 percent of

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capacity. If the rpm is doubled, then the raw data rate will be doubled without requiring higher-quality media.

Another way that rpm can affect drive performance is access time. Access time is the sum of seek time (the time it takes to position the head over the proper track) plus latency (the time it takes for the beginning of the proper sector to pass under the head). A typical latency is equal to the time for one-half rotation (just over 4ms for a 7,200-rpm drive), because the proper sector will never be more than a single rotation away once the proper track has been found.

Servo Controllers

Servo controllers are used to position the head assembly over the media in rigid disk drives. The speed of the servo controller impacts the seek time of the disk drive inversely: a higher-speed servo results in a lower seek time. As mentioned, access time is the sum of seek time plus latency. As track densities increase, more precision is required from the servo controller. Today, track densities are limited by the quality of the motor bearings as well as servo precision. The design shift toward fluid bearings as motor speeds increase may impact the servo controller market. Another trend that impacts this market is the shift toward DSP solutions for the smaller drives. Like motor controllers, servo controllers can be replaced by more simple servo drivers if a DSP is used for the disk controller.

Memory Devices

Memory devices are used in rigid disk drives for two functions: holding software and buffering data between the disk and the host interface. Software necessary for the disk drive to operate must be contained in the drive itself. OEMs have conventionally used EPROM to hold the drive software, but the trend is toward flash memory instead of EPROM. The disk drive PCB in Appendix B's Figure B-1 shows two 1Mb flash memories soldered to the card.

The amount of buffer memory installed in drives today varies widely from 32KB SRAM to a full MB of DRAM. A drive that has SRAM for the buffer will most likely have either 32 KB or 64 KB with a 25ns access time. Buffer sizes larger than 64 KB are almost certainly DRAM rather than SRAM. Typical DRAM buffers are either 128 KB or 256 KB with 70ns access times. As the PC market drives memory manufacturers to produce larger memory devices, some disk drive OEMs are concerned about availability of lower-density memory devices. A shortage of low-density memory devices could increase the average buffer size faster than consumers demand for performance reasons. Dataquest expects the total cost of the buffer memories to increase in disk drives as the average buffer size increases faster than memory prices decline.

Disk Drive Controllers

Disk drive controllers handle a variety of functions that have not been detailed. These functions are primarily communication with the host interface, data buffer control, serializing/deserializing data for the read channel, error correction, hardware defect management, translation of requests into commands for the various disk subsystems (motor, servo, and read-channel), and providing the interface to the subsystems. Actions such as formatting a disk and translating a logical block address into a physical block address are also handled by the disk drive controller.

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Several types of disk drive controller interfaces were described in detail in Chapter 5. These controllers are not cross-compatible, but, other than the interface to the host, they have a lot of functionality in common. The host interface logic can be considered a functional block within the controller. Many semiconductor vendors leverage their controller design efforts by producing controllers for more than one interface. This does not mean that a single device supports more than one interface. It simply means that two products that support different interfaces can be very similar except for the interface logic.

Some drive OEMs are using DSP solutions instead of standard controllers. This technique is more expensive than using standard controllers, but allows the motor and servo controllers to be replaced with driver ICs. It is most popular for the 1.8-inch drives because of space requirements. Dataquest expect DSP solutions will continue to be more popular for 1.8-inch drives than for larger form factors.

Table 6-1 shows a product matrix of several semiconductor vendors and the major devices they supply to the rigid disk drive industry.

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Table 6-1
Product Matrix for Semiconductors in RDDs

	Adaptec	Allegro	AMD	Analog Devices	AT&T Microelectronics	Cirrus Logic	GEC Plessey	Hitachi	IMP	Intel	Micro Linear	Motorola	National Semiconductor	Q Logic	SGS-Thomson	SSI	Symbios	Texas Instruments
Read Channel																		
Preamplifier							X	X	X		X		X	X		X		X
PD				X	X	X	X	X	X		X		X	X	X	X		X
PRML				X	X	X	X	X					X	X	X	X		X
Controller																		
IDE/EIDE	X					X								X	X	X	X	
Parallel SCSI	X					X								X	X	X	X	X
SSA																	X	
1394	X																X	X
Fibre Channel														X			X	
Microcontrollers/ASICs			X		X		X	X		X		X						X
Servo Control		X		X	X	X	X	X			X	X	X	X	X	X		X
Motor Control		X		X		X	X	X			X	X	X	X	X	X		X

Source: Dataquest (September 1995)

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Chapter 7
Semiconductor Market Forecast for Disk Drives

Table 7-1 shows unit shipment, average selling price (ASP), and revenue statistics and forecasts from 1990 to 1999 for disk drives with 2.5-inch and smaller form factors.

Table 7-2 provides unit shipments, ASP, and revenue statistics and forecasts from 1990 to 1999 for disk drives with 3.5-inch or larger form factors.

Table 7-3 provides statistics and forecasts for semiconductor revenue and content by size of disk drive and product category.

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Table 7-1
Worldwide 2.5-Inch and Smaller Rigid Disk Drive Market

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1990-1994	CAGR (%) 1995-1999
New Shipments (K)	813.60	3,382.20	5,223.50	5,557.70	8,437.40	11,235.00	15,803.00	21,496.00	28,760.00	39,540.00	79.5	37.0
ASP Factory ($K)	0.26	0.24	0.20	0.26	0.24	0.24	0.19	0.16	0.15	0.16	-2.1	-9.1
Revenue Factory ($M)	212.40	817.81	1,050.08	1,447.10	2,026.17	2,652.11	3,009.75	3,520.82	4,387.80	6,361.00	75.7	24.4
ASP End User ($K)	0.78	0.56	0.70	0.51	0.53	0.50	0.40	0.33	0.29	0.32	-9.3	-10.6
Revenue End User ($M)	635.20	1,877.32	3,678.33	2,842.57	4,449.73	5,593.98	6,284.05	7,182.58	8,469.00	12,579.20	62.7	22.5
Retirements (K)	0	0	25	814	2,590	1,260	1,485	4,222	6,627	10,982	NM	71.8
End Installed Base (K)	839	4,221	9,419	14,163	20,011	29,986	44,304	61,578	83,712	112,269	121.0	39.1
Average Megabytes per Drive	22.46	42.56	78.24	157.50	270.23	471.49	709.26	918.46	1,312.90	1,412.15	86.2	31.6

NM = Not meaningful
Source: Dataquest (September 1995)

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Table 7-2
Worldwide 3.5-Inch and Larger Rigid Disk Drive Market

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1990-1994	CAGR (%) 1995-1999
New Shipments (K)	29,233.38	29,122.68	39,019.26	45,952.10	60,892.20	68,948.40	74,951.20	89,042.00	106,709.20	116,904.00	20.1	14.1
ASP Factory ($K)	0.62	0.64	0.46	0.36	0.25	0.19	0.20	0.18	0.17	0.15	-20.4	-5.4
Revenue Factory ($M)	18,169.89	18,665.49	17,974.79	16,673.82	15,192.56	13,234.80	14,790.88	15,955.00	18,182.52	17,999.80	-4.4	8.0
ASP End User ($K)	1.34	1.52	0.80	0.56	0.33	0.28	0.27	0.26	0.23	0.20	-29.6	-8.2
Revenue End User ($M)	39,150.77	44,368.37	31,273.97	25,944.09	19,998.05	19,166.47	20,211.40	23,396.70	25,005.26	23,071.00	-15.5	4.7
Retirements (K)	2,321	6,327	9,076	14,264	21,399	30,646	33,562	40,833	46,469	60,099	74.3	18.3
End Installed Base (K)	89,091	111,888	141,832	173,520	213,013	248,980	291,259	339,468	399,708	456,343	24.3	16.4
Average Megabytes per Drive	114.59	161.38	200.70	335.51	518.64	803.11	1,339.71	1,736.76	2,270.84	3,161.74	45.9	40.9

Source: Dataquest (September 1995)

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Table 7-3
Worldwide Rigid Disk Drive Semiconductor Market (Millions of Dollars)

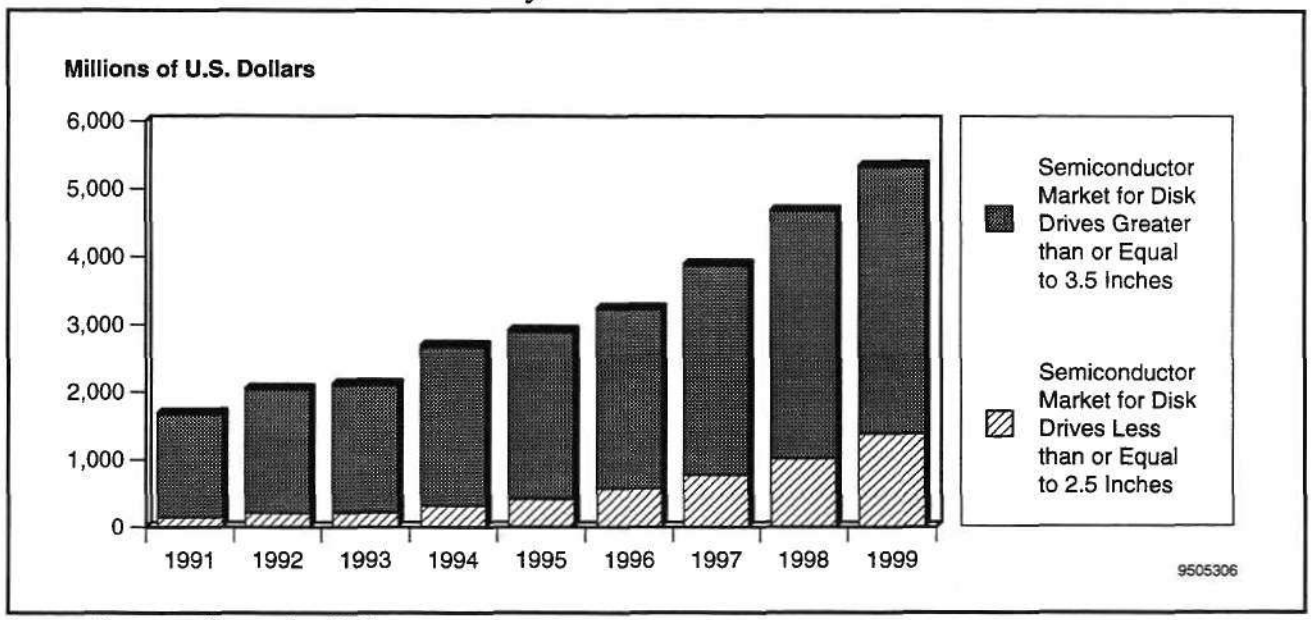
	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Content ≤2.5 Inches ($)	44.00	41.30	39.25	38.52	37.51	36.86	36.26	35.70	35.20	-1.8
Semiconductor Market ≤2.5 Inches ($M)	149	216	218	325	421	582	779	1,027	1,392	33.8
Semiconductor Content ≥3.5 Inches ($)	52.40	46.73	41.16	38.72	36.01	35.36	34.76	34.20	33.70	-2.7
Semiconductor Market ≥3.5 Inches ($M)	1,526	1,823	1,891	2,357	2,483	2,650	3,095	3,650	3,939	10.8
Semiconductor Content All RDD ($)	51.53	46.09	41.02	38.69	36.22	35.62	35.05	34.52	34.08	-2.5
Semiconductor Market All RDD ($M)	1,675	2,039	2,110	2,682	2,904	3,233	3,874	4,677	5,331	14.7
Memory ($M)	261	313	317	428	519	632	825	1,078	1,322	25.3
Analog ($M)	592	694	674	824	802	889	1,062	1,275	1,443	11.9
Microcontroller ($M)	223	279	301	395	435	471	547	640	708	12.4
ASIC/ ASSP ($M)	563	709	773	981	1,086	1,171	1,357	1,583	1,743	12.2
Standard Logic ($M)	24	29	29	32	36	41	49	59	68	16.1
Discrete ($M)	12	15	16	22	25	29	34	42	48	16.4

Source: Dataquest (September 1995)

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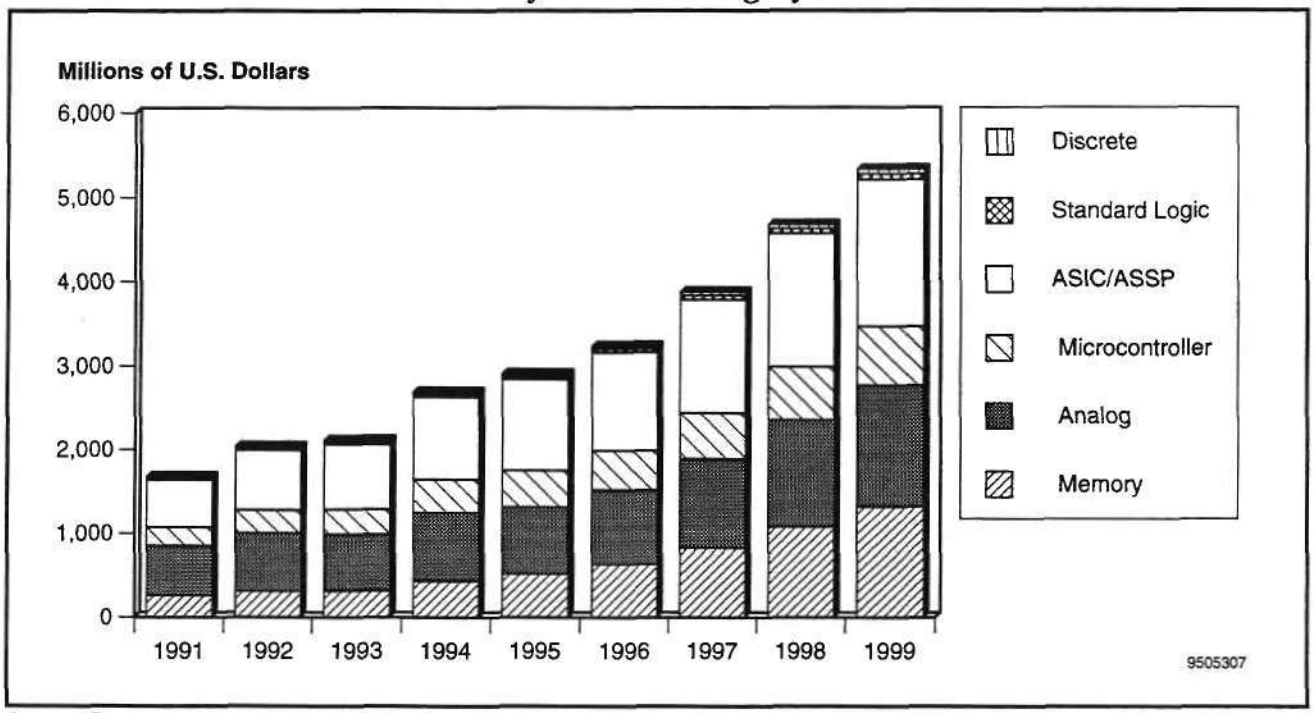
Figure 7-1 displays semiconductor market revenue for rigid disk drives by form factor. Figure 7-2 displays semiconductor market revenue for rigid disk drives by product category.

Figure 7-1
Semiconductor Market for RDDs by Size



Source: Dataquest (September 1995)

Figure 7-2
Semiconductor Market for RDDs by Product Category



Source: Dataquest (September 1995)

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Chapter 8
Dataquest Perspective

The market for semiconductors in rigid disk drives can be considered a pseudocustom market. Semiconductor devices for rigid disk drives are generally high-volume, customer-tailored designs. This does not mean that the entire industry is ASIC-driven because the level of customization for each account does not require an ASIC level of redesign and optimization. However, each design does generally require a new set of masks for production because customers demand varying amounts of memory as well as slight variations in other features. There are standard products available that are not customer-specific, but these are generally lower-performance and less expensive parts. Leading-edge products are designed in cooperation with the drive OEMs because no one wants to throw a party without guests (that is, customers). The relationships between the large OEMs and their suppliers appear to be "virtual" vertical integration with long-term cooperation.

Semiconductor vendors are advised to use the cooperative nature of these relationships. Semiconductor performance and costs are critical elements of disk drive performance and cost. Without continued development in semiconductors as well as heads and media, drive OEMs will not be able to sustain the 60 percent areal density growth rate the industry has exhibited over the past few years. Cooperation between semiconductor vendors and OEMs will result in better disk drives as the semiconductor vendors supply IC design expertise, process technology, and fab capacity and OEMs provide integration and assembly expertise.

Additionally, the drive OEM market is consolidating. Quantum purchased Digital Equipment Corporation's drive operations and Seagate has purchased Conner Peripherals. Fewer OEMs means fewer design-win opportunities for semiconductor vendors. Keeping a healthy relationship, fueled by continued process and device improvements, will be essential for semiconductor vendors to grow unit shipments and revenue. In other words, tend that garden and it will bear fruit.

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Appendix A
Current RDD Product Specifications

Table A-1 provides specifications for rigid disk drives 5.25 inches and smaller that are known to be shipping today.

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Table A-1
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Areal Technology	2.5-inch	A175	175	1	2	13	3,600	74,000	3,920	290	175	3.875	AT/IDE	0.49	2	150,000	Glass media
Areal Technology	2.5-inch	A270	270	1	2	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.5	1.9	250,000	Glass media
Areal Technology	2.5-inch	A340	340	3	6	13	3,600	76,000	2,800	213	113		AT/IDE	0.75	4	150,000	Glass media
Areal Technology	2.5-inch	A345	350	2	4	13	3,600	73,000	4,029	294	175	3.875	AT/IDE	0.5	2.15	150,000	Glass media
Areal Technology	2.5-inch	A525	525	4	8	13	3,600	76,000	2,800	213	131		AT/IDE	0.75	4	150,000	Glass media
Areal Technology	2.5-inch	A520	526	3	6	13	3,600	74,000	3,920	290	175	3.875	AT/IDE	0.75	2.375	150,000	Glass media
Areal Technology	2.5-inch	A540	540	2	4	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.5	1.9	250,000	Glass media
Areal Technology	2.5-inch	A700	702	4	8	13	3,600	74,000	3,920	290	176	3.875	AT/IDE	0.75	2.375	150,000	Glass media
Areal Technology	2.5-inch	A810	810	3	6	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.75	1.9	250,000	Glass media
Areal Technology	2.5-inch	A1080	1,080	4	8	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.75	1.9	250,000	Glass media
Calluna	1.8-inch	Callunacard 260	260	2	4	16	4,500				130	4.84	PCMCIA-III	0.41	2.2		
Conner	2.5-inch	CFN 170	170	2	4	12	4,500	58,230	2,611	152	85	3.5	IDE/SCSI2	0.77	1.4	150,000	
Conner	2.5-inch	CFN 250	250	3	6	12	4,500	58,230	2,611	152	83	3.5	IDE/SCSI2	0.77	1.4	150,000	
Conner	2.5-inch	CFN 340A	340	3	6	13	4,000	65,564	3,004	197	113	4	IDE	0.77	0.9	150,000	
Conner	2.5-inch	CFL 350A	350	2	4	12	3,750	70,600	4,110	290	175	4	IDE	0.50	0.75	300,000	Kiwi
Conner	2.5-inch	CFL 420A	422	2	4	12	3,600	80,000	4,200	336	211	4.125	IDE	0.50	1.3	300,000	Kiwi
Conner	3.5-inch	CFS 210A	213.4	1	2	14	3,600	58,566	2,774	162	213	4	IDE	1.00	5.7	250,000	
Conner	3.5-inch	CFS 270A	270	1	2	15	3,400	68,000	2,988	203	270	1.3	IDE	1.00	4.5	250,000	Cabo
Conner	3.5-inch	CFS 425A	425	1	2	15	3,600	75,000	3,840	288	425	1.3	IDE	1.00	5.7	250,000	Cabo
Conner	3.5-inch	CFA 425	426	1	2	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	
Conner	3.5-inch	CFS 420A	426.8	2	4	14	3,600	58,566	2,774	162	213	4	IDE	1.00	5.7	250,000	
Conner	3.5-inch	CFA 540	540	2	4	12	4,500	62,500	2,805	175	270	5.75	IDE/SCSI2	1.00	5	300,000	Steamboat
Conner	3.5-inch	CFS 540A	540	2	4	15	3,600	70,000	2,990	209	270	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFS 541A	540	1	2	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFS 635A	635	2	3	14	3,600	93,000	4,100	381	423	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFA 810	810	3	6	12	4,500	65,000	3,245	211	270	5.75	IDE/SCSI2	1.00	11.8	300,000	
Conner	3.5-inch	CFS 850A	850	2	4	15	3,600	75,000	3,833	287	425	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFA 850	852	2	4	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	Steamboat
Conner	3.5-inch	CFP 1060	1,060	4	8	9	5,400	65,131	3,147	205	265	6.875	SCSI2 F/W	1.00	14.3	500,000	

(Continued)

Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Conner	3.5-inch	CFP 1080	1,080	3	6	11	5,400	64,000	3,833	245	360	6.925	SCSI2 F/W	1.00	5.6	500,000	Antigua
Conner	3.5-inch	CFS 1081A	1,080	2	4	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFA 1080	1,080	4	8	10.5	4,500	65,000	3,245	211	270	5.75	IDE/SCSI2	1.00	12.8	300,000	Barbados
Conner	3.5-inch	CFS 1275A	1,278	3	6	15	3,600	75,000	3,833	287	426	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFA 1275	1,278	3	6	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	Steamboat
Conner	3.5-inch	CFS 1621A	1,620	3	6	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFP 2107	2,110	5	10	8.5	7,200	78,000	4,010	313	422	10.925	SCSI2 F/W	1.00	10	1,000,000	
Conner	3.5-inch	CFP 2120	2,120	8	16	9.5	5,400	64,980	3,147	204	265	6.875	SCSI2 F/W	1.63	17.1	500,000	
Conner	3.5-inch	CFP 2105	2,147	5	10	8.5	5,400	74,000	3,980	295	429	9.1375	SCSI2 F/W	1.00	7.6	1,000,000	
Conner	3.5-inch	CFP 4207	4,220	10	20	9	7,200	78,000	4,055	316	422	10.925	SCSI2 F/W	1.60	14.3	1,000,000	SSA available
Conner	3.5-inch	Aruba	4,320	4	8		7,200			810	1,080		SCSI2 F/W	1.00			MR heads, PRML
Conner	3.5-inch	Aruba	5,400	5	10		7,200			810	1,080		SCSI2 F/W	1.00			MR heads, PRML
Conner	3.5-inch	Aruba	8,640	8	16		7,200			810	1,080		SCSI2 F/W	1.60			MR heads, PRML
Conner	3.5-inch	Aruba	10,800	10	20		7,200			810	1,080		SCSI2 F/W	1.60			MR heads, PRML
Fujitsu	2.5-inch	M2704S	358	2	4	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	2.5-inch	M2705S	442	3	5	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	2.5-inch	M2706S, Hornet 5	532	3	6	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	3.5-inch	M2681SA	264	2	3	14	4,500				176	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2622T	326.7	4	7	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2682SA	353	2	4	14	4,500				177	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2623T	420.1	5	9	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2624T	513.5	6	11	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2684SA	532	3	6	14	4,500				177	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M160x	540	2	3	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M160x	720	2	4	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M160x	1,080	3	6	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M2927	1,130	4	7	9.6	5,400	75,535	3,353	268	323	6.8	SCSI2 F/W	1.00		500,000	MR heads, PRML channel

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Fujitsu	3.5-inch	M2903	2,110	7	13	9.6	5,400	75,535	3,553	268	325	6.8	SCSI2 F/W	1.63		500,000	MR heads, PR4Ml. channel
Fujitsu	3.5-inch	M2915	2,170	8	15	8.9	7,200	71,627	3,553	254	289	8	SCSI2 F/W	1.63		500,000	MR heads, PR4ML channel
Fujitsu	3.5-inch	M2909	3,100	10	19	9.6	5,400	75,500	3,550	268	326	6.8	SCSI2 F/W	1.63		500,000	MR heads, PR4Ml. channel
Fujitsu	3.5-inch	M160x	4,400	10	19	10	7,200	102,400	3,758	385	463	11.3	SCSI2 F/W	1.63		500,000	Allegro 2, MR heads, PR4ML
Fujitsu	5.25-in	M2654	2,055	12	21	11.5	5,400	50,200	1,840	92	196		SCSI2 F	3.25		500,000	2, 4, 8, or 16MB cache options
Hewlett-Packard	3.5-inch	C3323A	1,050	4	7	9.5	5,400	69,200	3,223	223	300	6	SCSI2 F/W	1.00	10	500,000	
Hewlett-Packard	3.5-inch	C2490A	2,100	10	18	8.9	6,400	58,500	2,840	166	233	6	SCSI2 F/W	1.63	15.8	500,000	
Hewlett-Packard	3.5-inch	C3325A	2,170	5	9	9.5	5,400	92,000	4,000	368	482	8	SCSI2 F/W	1.00	9.2	800,000	PRML channel
Hewlett-Packard	3.5-inch	C3330A	2,175	3	5	9.2	7,200	135,000	5,660	764	870	15	SCSI2 F/W	1.00	11.7	1,200,000	MR heads, PRML
Hewlett-Packard	3.5-inch	C3331A	4,350	5	10	9.2	7,200	135,000	5,660	764	870	15	SCSI2 F/W	1.00	11.7	1,200,000	MR heads, PRML
Hitachi	2.5-inch	DK222A-27	270	1	2	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.50	2	300,000	Glass media
Hitachi	2.5-inch	DK221A-34	340	2	4	12.6	4,464	83,000	3,500	291	170	5.9	ATA/IDE	0.50	2	300,000	
Hitachi	2.5-inch	DK221A-51	510	3	6	12.6	4,464	83,000	3,500	291	170	5.9	ATA/IDE	0.75	2	300,000	
Hitachi	2.5-inch	DK221C-51	510	3	6	12.6	4,464	83,000	3,500	291	170	5.9	SCSI2F	0.75	2	300,000	
Hitachi	2.5-inch	DK222A-54	540	2	4	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.50	2	300,000	Glass media
Hitachi	2.5-inch	Preview	720	2	4	12	4,464				360	6.1	EIDE	0.50	2	300,000	MR heads, PRML, glass
Hitachi	2.5-inch	DK212A-81	810	3	6	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.75	2	300,000	Glass media
Hitachi	2.5-inch	DK212A-10	1,080	4	8	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.75	2	300,000	Glass media
Hitachi	3.5-inch	DK326C-6	601	3	4	9.8	6,300	63,500	3,600	229	301	7	SCSI2 F	1.00		400,000	
Hitachi	3.5-inch	DK325C-6WD	601	3	4	9.8	6,300	63,500	3,600	229	301	7	SCSI2 W	1.00		400,000	
Hitachi	3.5-inch	DK326C-10WD	1,052	4	7	9.8	6,300	63,500	3,600	229	301	7	SCSI2 W	1.00		400,000	
Hitachi	3.5-inch	DK328C-10	1,052	2	3	9.8	5,800	120,000	5,400	648	701	11	SCSI2 F/W	1.00	2	800,000	MR heads, peak detect, embedded servo
Hitachi	3.5-inch	DK326C-10	1,052	4	7	9.8	6,300	63,500	3,600	229	301	7	SCSI2 F	1.00		400,000	
Hitachi	3.5-inch	Preview	2,100	3	5	9.8	7,200				840	11	SCSI2 F/W	1.00	2	800,000	MR heads, PRML, embedded servo

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Hitachi	3.5-inch	DK328C-21	2,100	3	5	9.8	5,800	120,000	5,400	648	840	11	SCSI2 F/W	1.00	2	800,000	MR heads, peak detect, embedded servo
Hitachi	3.5-inch	DK328C-43	4,300	5	10	9.8	5,800	120,000	5,400	648	860	11	SCSI2 F/W	1.00	4	800,000	MR heads, peak detect, embedded servo
Hitachi	3.5-inch	Preview	4,300	5	10	9.8	7,200				860	11	SCSI2 F/W	1.00	2	800,000	MR heads, PRML, embedded servo
IBM	2.5-inch	DHAA-2270	270	1	2	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAS-2270	270	1	2	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2360 Bolero	360	1	2	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DHAA-2405	405	2	3	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAS-2405	405	2	3	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2540 Bolero	540	2	3	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DHAS-2540	540	2	4	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAA-2540	540	2	4	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2720 Bolero	720	2	4	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DVAA-2810	810	3	6	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DPRA-20810 Presto	810	2	4	12	4,900	110,300	6,350	700	405	7.125	ATA-2 and SCSI2F	0.67	2.6	300,000	MR heads, Travelstar XP
IBM	2.5-inch	DPRA-21215 Presto	1,215	3	6	12	4,900	110,300	6,350	700	405	7.125	ATA-2 and SCSI2F	0.67	2.6	300,000	MR heads, Travelstar XP
IBM	3.5-inch	DSAS-3270	281	1	2	12	4,500	83,200	4,300	358	281	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3270	281	1	2	12	4,500	83,200	4,300	358	281	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAS-3360	365	1	2	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3360	365	1	2	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DPEA-30540 Pegasus	540	1	2	10.5	5,400	85,600	5,340	457	540	6.8875	ATA/SCSI2	1.00	6.3	500,000	MR heads, Deskstar XP

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
IBM	3.5-inch	DALA-3540 Aladdin	540	1	2	12	4,500	82,600	5,340	441	540	6.0875	ATA/SCSI2	1.00	5.2	350,000	MR heads, Deskstar
IBM	3.5-inch	DSAS-3540	548	2	3	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA3540	548	2	3	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAS-3720	730	2	4	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3720	730	2	4	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	0662A	1,052	3	6	8.5	5,400	78,200	4,077	319	351	6	ATA/IDE	1.00		500,000	MR heads, PRML channel
IBM	3.5-inch	0662	1,052	3	6	8.5	5,400	86,900	4,077	354	351	5	PIO, DMA	1.00		500,000	MR heads, PRML channel
IBM	3.5-inch	DFHS-31080	1,080	2	4	6.9	7,200	125,000	4,352	544	540	12.6	SCSI2, F/W	1.00	9.1	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-31080	1,080	2	4	8	5,400	128,900	4,351	561	540	12.2	SCSI2, F/W	1.00	9.4	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DPEA-31080 Pegasus	1,080	2	4	10.5	5,400	85,600	5,340	457	540	6.8875	ATA/SCSI2	1.00	6.7	500,000	MR heads
IBM	3.5-inch	DJAA-31210 Jaffar	1,210	2	3	12	4,500	99,000	6,700	663	807	7.7625	ATA/SCSI2	1.00	3.9	350,000	MR heads, Deskstar
IBM	3.5-inch	DJAA-31700 Jaffar	1,700	2	4	12	4,500	99,000	6,700	663	850	7.7625	ATA/SCSI2	1.00	3.9	350,000	MR heads, Deskstar
IBM	3.5-inch	0664 Allicat	2,014	8	16	9.2	5,400	81,913	3,168	260	252		SCSI2, F/W	1.60	12.7	750,000	MR heads, PRDF channel
IBM	3.5-inch	DFMS-32160	2,325	4	8	7.5	5,400	133,000	4,362	580	581	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFHS-32160	2,255	4	8	7.5	7,200	133,000	4,362	580	564	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFMS-32600	2,657	4	8	7.5	5,400	133,000	4,352	579	664	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFHS-34320	4,512	8	16	8	7,200	125,000	4,352	544	564	12.6	SCSI2, F/W	1.63	15.5	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-34320	4,320	7	13	8	5,400	133,000	4,352	579	665	12.6	SCSI2, F/W	1.63	11	1,000,000	MR heads, PRML channel
IBM	3.5-inch	Ultrastar AV	5,106	8	16	8	5,400	133,000	4,352	579	638	7.6	SCSI2, F/W	1.63	11.2	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-35250	5,318	8	16	8	5,400	133,000	4,352	579	665	12.6	SCSI2, F/W	1.63	11.2	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DCHS-38700 Scorpion HP	8,700	9	18	8.9	7,200	133,000	5,966	793	967	14.2	SCSI2, F/W	1.63	17.5	1,000,000	MR heads, PRML channel, SSA

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
IBM	3.5-inch	DCMS-310800 Scorpion HC	10,800	10	20	8.9	5,400	133,000	5,966	793	1,080	14.2	SCSI2, F/W	1.63	14	1,000,000	MR heads, PRML channel, SSA
Integral Peripherals	1.8-inch	Viper 105	105.4	2	4	15	4,500	70,000	2,840	199	53	3	PCMCIA-III	0.41	1.5	250,000	
Integral Peripherals	1.8-inch	Viper 170	170.8	2	4	12	4,500	84,000	3,800	319	85	3.5	PCMCIA-III	0.41	1.5	250,000	
Integral Peripherals	1.8-inch	Viper 260	260.7	2	4	12	4,500	112,350	4,300	483	130	6	PCMCIA-III	0.41	2.2	250,000	IBM media, PRML
Integral Peripherals	1.8-inch	Viper 340	340.6	2	4	12	4,500	123,600	5,100	630	170	6	PCMCIA-III	0.41	2.1	250,000	IBM media, PRML
Integral Peripherals	2.5-inch	Platinum 720	720	3	5	12	4,200	104,550	5,100	533	288	8	ATA-2	0.50	2	250,000	IBM media PRML
Integral Peripherals	2.5-inch	Platinum 1010	1,010	3	6	12	4,200	123,000	5,100	627	337	8	ATA-2	0.50	2	250,000	IBM media PRML
Maxtor	1.8-inch	MobileMax Lite 85	85	1	2	16	4,464	69,600	3,606	251	85	3.18	PCMCIA-II	0.20	1.65	300,000	Glass media, 3.3V, Type II
Maxtor	1.8-inch	MobileMax 105	105	2	4	19	4,464	58,000	2,727	158	53	2.425	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax Lite 121	121	1	2	16	4,464	86,500	4,110	356	121	3.18	PCMCIA-II	0.20	1.65	300,000	Glass media, 3.3V, Type II
Maxtor	1.8-inch	MobileMax 131	131	2	4	19	4,464	58,000	3,332	193	66	2.425	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax 171	171	2	4	16	4,464	67,500	3,555	240	86	3.1875	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax 262	262	2	4	16	4,464	67,500	3,555	240	131	4	PCMCIA-III	0.41	1.65	300,000	Glass media, proximity recording
Maxtor	2.5-inch	250837	837	3	5	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	2.5-inch	251005	1,005	3	6	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	2.5-inch	251340	1,340	4	8	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	3.5-inch	7135AV	135	1	1	14	3,551	64,100	3,100	199	270	4.75	IDE	1.00	4.07	300,000	
Maxtor	3.5-inch	7270AV	270	1	2	12	3,551	64,100	3,100	199	270	11.1	EIDE	1.00	3.9	300,000	
Maxtor	3.5-inch	7420AV	422	2	3	14	3,551	64,100	3,100	199	281	4.75	IDE	1.00	4.28	300,000	
Maxtor	3.5-inch	7425AV	426	1	2	12	3,551	73,870	3,900	288	426	5.36	EIDE	1.00	4.07	300,000	
Maxtor	3.5-inch	7540AV	540	2	4	14	3,551	64,100	3,100	199	270	4.75	IDE	1.00	4.28	300,000	
Maxtor	3.5-inch	7541A	541	1	2	12	4,480	92,130	4,232	390	541	8.1	EIDE	1.00	4.25	300,000	Proximity recording
Maxtor	3.5-inch	7546	546	2	4	12	4,500	68,500	3,050	209	273	5.6	IDE and SCSI2	1.00	3.7	300,000	
Maxtor	3.5-inch	7850AV	853	2	4	12	3,551	73,870	3,900	288	427	5.36	EIDE	1.00	4.07	300,000	
Maxtor	3.5-inch	71050A	1,050	3	5	12	4,500	78,400	4,030	316	420	6.19	IDE and SCSI2	1.00	5.6	300,000	
Maxtor	3.5-inch	71084AP	1,084	2	4	12	4,480	92,130	4,232	390	542	8.1	EIDE	1.00	4.25	300,000	Proximity recording

(Continued)

Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Maxtor	3.5-inch	71260A	1,260	3	6	12	4,500	78,400	4,030	316	420	6.19	IDE & SCSI2	1.00	5.6	300,000	
Maxtor	3.5-inch	71626AP	1,626	3	6	12	4,480	92,130	4,232	390	542	8.1	EIDE	1.00	4.25	300,000	Proximity recording
Micropolis	3.5-inch	4110	1,052	5	9	8.5	5,400				234	5.875	SCSI2 F	1.00	8.5	500,000	
Micropolis	3.5-inch	2210	1,056	5	9	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	2210AV	1,056	5	9	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	4110A	1,057	5	9	8.5	5,400				235	5.875	IDE	1.00	8.25	500,000	
Micropolis	3.5-inch	2217AV	1,765	8	15	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	2217	1,765	8	15	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	4221	2,140	5	9	8.9	7,200			320	476	10.125	SCSI2 F/W	1.00	10.25	1,000,000	Taurus
Micropolis	3.5-inch	3131	3,150	10	19	8	7,200				332	8.375	SCSI2 F/W	1.63	14	1,000,000	
Micropolis	3.5-inch	3243	4,290	10	19	8.9	7,200			320	452	10	SCSI2 F/W	1.63	14	1,000,000	Capricorn
Micropolis	5.25-inch	1991	9,100	14	27	12	5,400				674	9.625	SCSI2 F/W	3.25		1,000,000	
MiniStor Peripherals	1.8-inch	130A	130	2	4	15	4,464	76,500	3,200	245	65	3.225	PCMCIA-III	0.41	1.5	250,000	
MiniStor Peripherals	1.8-inch	260A	260	2	4	15	4,464	76,500	3,200	245	130	3.225	PCMCIA-III	0.41	1.5	250,000	Data compressed by Stac
MiniStor Peripherals	2.5-inch	M340	340	2	4	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.50	2	250,000	
MiniStor Peripherals	2.5-inch	M510	510	3	6	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.75	2	250,000	
MiniStor Peripherals	2.5-inch	M680	680	4	8	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.75	2	250,000	
NEC	2.5-inch	D2713	352	2	4	14.5	4,000	74,700	3,600	268.92	176	4.4	IDE	0.5		300,000	
NEC	3.5-inch	D3713	345	2	4	12	4,090	56,000	2,500	140	172.5	3	IDE/SCSI	1.00	4.8	250,000	
NEC	3.5-inch	D3723	365	1	2	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3823	365	1	2	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3724	426	1	2	14	4,090	85,500	3,800	325	426	7.2	ATA	1.00	4	300,000	PRML
NEC	3.5-inch	D3743	540	1	2	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3843	540	1	2	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3717	540	2	4	12	4,500	63,871	3,100	198	270	6	IDE/SCSI2	1.00	4.8	250,000	TF heads
NEC	3.5-inch	D3725	730	2	4	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	TF heads
NEC	3.5-inch	D3825	730	2	4	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3726	853	2	4	14	4,090	85,500	3,800	325	426	7.2	ATA	1.00	4	300,000	TF heads, PRML
NEC	3.5-inch	D3845	1,080	2	4	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3745	1,080	2	4	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3727	1,083	3	6	11	4,090	71,000	3,800	269.8	361	6	IDE	1.00		300,000	TF heads

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
NEC	3.5-inch	D3827	1,083	3	6	11	4,090	71,000	3,800	269.8	361	6	IDE	1.00		300,000	TF heads
NEC	3.5-inch	D3847	1,620	3	6	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3747	1,620	3	6	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3896	2,160	5	9	9	7,200	78,000	4,070	317.46	480		SCSI2	1.00		800,000	TF heads
Quantum	2.5-inch	GLS 85	85	1	2	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.49	2	350,000	
Quantum	2.5-inch	Daytona 127	127	1	2	17	4,500	71,600	3,100	222	127	4	IDE OR SCSI2	0.50	2.2	350,000	
Quantum	2.5-inch	GLS 127	127	2	3	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.67	2	350,000	
Quantum	2.5-inch	GLS 170	170	2	4	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.67	2	350,000	
Quantum	2.5-inch	Daytona 256	256	2	4	17	4,500	71,600	3,100	222	128	4	IDE OR SCSI2	0.50	2.2	350,000	
Quantum	2.5-inch	GLS 256	256	3	6	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.75	2	350,000	
Quantum	2.5-inch	Daytona 341	341	3	6	17	4,500	71,600	3,100	222	114	4	IDE OR SCSI2	0.75	2.3	350,000	
Quantum	2.5-inch	Daytona 514	514	4	8	17	4,500	71,600	3,100	222	129	4	IDE OR SCSI2	0.75	2.3	350,000	
Quantum	2.5-inch	Europa 540	540	2	4	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.49	2.5	350,000	MR heads, PRML
Quantum	2.5-inch	Europa 810	810	3	6	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.74	2.5	350,000	MR heads, PRML
Quantum	2.5-inch	Europa 1080	1,080	4	8	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.74	2.5	350,000	MR heads, PRML
Quantum	3.5-inch	LPS 127	127	1	2	14	3,600	48,865	2,670	130	127	3.5	IDE OR SCSI2	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 170	170	1	2	14	3,600	48,865	2,670	130	170	3.5	IDE OR SCSI2	1.00	4.6	300,000	
Quantum	3.5-inch	Maverick 270S	270	1	2	14	3,600	60,204	2,950	178	270	4.51	SCSI	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 270	270	1	2	12	4,500	62,600	2,875	180	270	5.75	IDE OR SCSI2	1.00	5.2	300,000	
Quantum	3.5-inch	Maverick 270AT	270	1	2	14	3,600	60,204	2,950	178	270	4.51	IDE	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 340	340	2	4	12	3,600	49,273	2,670	132	170	3.5	IDE OR SCSI2	1.00	4.3	300,000	
Quantum	3.5-inch	Lightning 365S	365	1	2	11	4,500	63,515	3,794	241	365	5.9	SCSI	1.00	5.7	300,000	
Quantum	3.5-inch	Lightning 365A	365	1	2	11	4,500	63,515	3,794	241	365	5.9	IDE	1.00	5.7	300,000	
Quantum	3.5-inch	Trailblazer	425	1	2	14	4,500	74,258	3,794	282	425	6.7125	Fast ATA, SCSI2	1.00	4.5	300,000	MIG heads
Quantum	3.5-inch	Lightning 540A	540	2	3	11	4,500	63,515	3,794	241	360	5.9	IDE	1.00	6.3	300,000	
Quantum	3.5-inch	Lightning 540S	540	2	3	11	4,500	63,515	3,794	241	360	5.9	SCSI	1.00	6.3	300,000	
Quantum	3.5-inch	Maverick 540AT	540	2	4	14	3,600	60,204	2,950	178	270	4.51	IDE	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 540	540	2	4	12	4,500	62,600	2,875	180	270	5.75	IDE OR SCSI2	1.00	5.9	300,000	
Quantum	3.5-inch	Maverick 540S	540	2	4	14	3,600	60,204	2,950	178	270	4.51	SCSI	1.00	4.6	300,000	
Quantum	3.5-inch	Fireball	545	1	2	12	5,400	92,982	4,200	391	545	10.5	Fast ATA, SCSI3	1.00	5	500,000	
Quantum	3.5-inch	Capella 3055	551	2	4	8.5	5,400	57,996	3,256	189	276	6.5	SCSI2 F/W	1.00	6	700,000	

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Quantum	3.5-inch	Lightning 730A	730	2	4	11	4,500	63,515	3,794	241	365	5.9	IDE	1.00	6.3	300,000	
Quantum	3.5-inch	Lightning 730S	730	2	4	11	4,500	63,515	3,794	241	365	5.9	SCSI	1.00	6.3	300,000	
Quantum	3.5-inch	Trailblazer	850	2	4	14	4,500	74,258	3,794	282	425	6.7125	Fast ATA, SCSI2	1.00	4.5	300,000	MIG heads
Quantum	3.5-inch	Atlas XP31070	1,075	3	5	8	7,200	72,490	3,858	280	430	8.5	SCSI2 F/W	1.00	11	800,000	
Quantum	3.5-inch	Empire 1080	1,080	4	8	9.5	5,400	61,300	3,014	185	270	6	SCSI3 F/W	1.00	7.5	500,000	
Quantum	3.5-inch	Fireball	1,090	2	4	12	5,400	92,982	4,200	391	545	10.5	Fast ATA, SCSI3	1.00	5.5	500,000	
Quantum	3.5-inch	Capella 31110	1,108	2	4	8.5	5,400	92,000	4,350	400	554	6.9	SCSI2 F/W	1.00	7	800,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire 1400	1,400	4	8	9.5	5,400	80,000	3,150	252	350	8	SCSI3 F/W	1.00	10.5	500,000	PRML channel
Quantum	3.5-inch	Empire 2100	2,100	6	12	9.5	5,400	80,000	3,150	252	350	8	SCSI3 F/W	1.63	12.5	500,000	PRML channel
Quantum	3.5-inch	Grand Prix XP32140	2,140	5	10	8.6	7,200	79,600	4,000	318	428	9.7	SCSI3 F/W	1.63	10	800,000	PRML channel
Quantum	3.5-inch	Atlas XP32150	2,150	5	10	8	7,200	72,490	3,858	280	430	8.5	SCSI2 F/W	1.00	10	800,000	
Quantum	3.5-inch	Atlas II XP32181	2,180	3	5	7.8	7,200	106,000	6,000	636	872	13.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire II VP32181	2,180	3	5	8.9	5,400	98,000	5,701	559	872	11.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, PRML channel
Quantum	3.5-inch	Capella 32210	2,216	4	8	8.5	5,400	92,000	4,350	400	554	6.9	SCSI2 F/W	1.00	7	800,000	MR heads, ASABET chipset
Quantum	3.5-inch	Grand Prix XP34280	4,280	10	20	8.6	7,200	79,600	4,000	318	428	9.7	SCSI3 F/W	1.63	14	800,000	PRML channel
Quantum	3.5-inch	Atlas XP34300	4,300	10	20	8	7,200	72,284	3,858	279	430	8.5	SCSI2 F/W	1.63	14	800,000	
Quantum	3.5-inch	Atlas II XP34361	4,360	5	10	7.8	7,200	106,000	6,000	636	872	13.25	ULTRASCSI3 F/W	1.00	10.7	1,000,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire II VP34360	4,360	5	10	8.9	5,400	98,000	5,701	559	872	11.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, PRML channel
Quantum	3.5-inch	Empire II VP39100	9,100	10	20	8.9	5,400	98,000	6,200	608	910	11.25	ULTRASCSI3 F/W	1.63	14	1,000,000	MR heads, PRML channel
Quantum	3.5-inch	Atlas II XP39100	9,100	10	20	7.8	7,200	111,000	6,000	666	910	13.875	ULTRASCSI3 F/W	1.63	14.6	1,000,000	MR heads, ASABET chipset
Samsung	3.5-inch	SHD-30280A	280.5	1	2	12	3,600	69,132	3,125	216	281	4.7625	AT/IDE	1.00	4.2	250,000	
Samsung	3.5-inch	SHD-30420A	420	2	3	12	3,600	69,132	3,125	216	280	4.7625	AT/IDE	1.00	4.2	250,000	
Samsung	3.5-inch	PLS-30540A	547	2	3	11	4,500	70,000	4,100	287	365	4.7625	AT/IDE	1.00	4.2	300,000	
Samsung	3.5-inch	SHD-30560A	561	2	4	12	3,600	69,132	3,125	216	281	4.7625	AT/IDE	1.00	4.2	250,000	

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Samsung	3.5-inch	PLS-30850A/S	850	2	4	11	4,500	70,000	4,300	301	425	4.7625	AT/SCSI	1.00	4.2	300,000	
Samsung	3.5-inch	TBR-31080A	1,080	2	4	9	5,400	85,380	4,504	385	540		EIDE	1.00	10.7	500,000	
Samsung	3.5-inch	PLS-31100A/S	1,270	3	6	11	4,500	70,000	4,100	287	423	4.7625	AT/SCSI	1.00	4.2	300,000	
Seagate	2.5-inch	ST9150AG Marathon	131.2	1	2	16	3,980	59,124	2,760	163	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9240AG Marathon	210.4	2	3	16	3,980	59,124	3,282	194	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9300AG Marathon	262.1	2	4	16	3,980	59,124	3,282	194	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9385AG	340	3	6	16	3,980	60,000	3,300	198	113	3.4625	AT/IDE	0.75	1.9	300,000	
Seagate	2.5-inch	ST9420AG Marathon	420.8	2	4	16	4,500	90,000	3,807	343	210	5.5	ATA-2	0.50	1.9	300,000	Glass media and PRML
Seagate	2.5-inch	ST9550AG	455	4	8	16	3,980	53,000	2,400	127	114	3.4625	AT/IDE	0.75	1.9	300,000	
Seagate	2.5-inch	ST9655AG	524	4	8	16	3,980	72,100	3,227	233	131	3.525	AT/IDE	0.75	1.9	300,000	
Seagate	2.5-inch	ST9816AC Marathon	810.7	4	8	16	4,500	90,000	3,807	343	203	5.5	ATA-2	0.75	2.1	300,000	Glass media and PRML
Seagate	3.5-inch	ST3250A Medalist XE	214	1	2	14	3,811	53,000	2,400	127	214	4	AT/IDE	1.00	3.4	300,000	Fast ATA
Seagate	3.5-inch	ST3295A Medalist XE	272	1	2	14	3,811	53,000	3,100	164	272	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST3391A Medalist XE	341	2	4	13	3,811	53,000	3,100	164	171	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST3491A Medalist XE	428	2	4	14	3,811	53,000	3,100	164	214	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST5660N Decathlon 545	545	2	4	12	4,500	68,000	3,309	225	273	5.25	SCSI2 F	0.75	5.5	300,000	
Seagate	3.5-inch	ST5540A Decathlon 545	545	1	2	11	5,400	73,344	4,923	361	545	8	ATA-2	0.75	5	300,000	Fast ATA-2
Seagate	3.5-inch	ST3660A Medalist XE	545	2	4	14	3,811	53,000	3,100	164	273	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST5660A Decathlon 545	545	2	4	12	4,500	68,000	3,309	225	273	5.25	ATA-2	0.75	5.5	300,000	Fast ATA
Seagate	3.5-inch	ST3780A	722	2	4	12	4,500	70,101	4,250	298	361	5.875	AT/IDE	1.00	6	300,000	Fast ATA
Seagate	3.5-inch	ST5850N Decathlon 850	854.7	2	4	11	5,400	68,000	3,309	225	427	7.70625	ATA-2	0.75	5.5	300,000	Fast ATA-2
Seagate	3.5-inch	ST31051 Hawk 2XL	1,050	2	4	9	5,411	87,000	4,800	418	525	8.75	SCSI2 F/W	1.00	6.5	500,000	PRML, ASAII
Seagate	3.5-inch	ST31230N Hawk 2LP	1,050	3	5	9	5,400	78,000	4,200	328	420	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST51080A Decathlon 1080	1,080	2	4	11	5,400	73,344	4,923	361	540	8	ATA-2	0.75	5	300,000	Fast ATA-2

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Seagate	3.5-inch	ST51080N Decathlon 1080	1,080	2	4	11	5,400	73,344	4,923	361	540	8	SCSI2	0.75	5	300,000	
Seagate	3.5-inch	ST31220A Medalist	1,083	3	6	12	4,500	70,101	4,250	298	361	5.875	AT/IDE	1.00	6	300,000	Fast ATA
Seagate	3.5-inch	ST31640A Medalist	1,625	3	6	10	5,400	80,000	4,500	360	542	8.375	AT/IDE	1.00	7.7	300,000	Fast ATA
Seagate	3.5-inch	ST31930N	1,700	4	7	9	5,400	78,000	4,200	328	486	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST12450W	1,780	10	19	8	7,200	53,000	3,100	164	187	14.125	SCSI2 F/W	1.63	24	500,000	2-head parallel 20MB/sec
Seagate	3.5-inch	ST32430N Hawk 2LP	2,140	5	9	9	5,400	78,000	4,200	328	476	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST32151 Hawk 2XL	2,147	4	8	9	5,411	87,000	4,800	418	537	8.75	SCSI2 F/W	1.00	6.5	500,000	PRML, ASAII
Seagate	3.5-inch	ST32550N 'Cuda 2LP	2,147	6	11	8	7,200	72,680	4,048	294	390	8.775	SCSI2 F/W	1.00	20.4	800,000	
Seagate	3.5-inch	Barracuda 4LP	2,150	3	6	8	7,200	120,000	5,500	660	717	15	ULTRASCSI3 F/W	1.00	11	1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	3.5-inch	ST32140A Medalist	2,167	4	8	10	5,400	80,000	4,500	360	542	8.375	AT/IDE	1.00	7.7	300,000	Fast ATA
Seagate	3.5-inch	ST15150N 'Cuda	4,100	11	21	8	7,200	52,000	4,000	208	390	8.9375	SCSI2 F	1.63	24	500,000	
Seagate	3.5-inch	ST15230N Hawk	4,294	10	19	9	5,400	52,000	4,000	208	452	8	SCSI2 F/W	1.63	24	800,000	
Seagate	3.5-inch	ST15150FC 'Cuda	4,294	11	21	8	7,200	52,000	4,000	208	409	9	FC-AL	1.63	24	800,000	FC/AL available
Seagate	3.5-inch	Barracuda 4LP	4,350	5	10	8	7,200	120,000	5,500	660	870	15	ULTRASCSI3 F/W	1.00	11	1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	3.5-inch	Barracuda 8	8,700	10	20	8	7,200	120,000	5,500	660	870	15	ULTRASCSI3 F/W	1.63		1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	5.25-inch	ST410800N Elite 9	9,080	14	27	11	5,400	71,000	4,000	284	673	8.125	SCSI2 F	3.25	30	500,000	
Toshiba	2.5-inch	MK-1422FCV	86	1	2	15	3,600				86	2.2	AT/IDE	0.50	1.8	150,000	Glass media
Toshiba	2.5-inch	MK-1522FCV	126	1	2	15	3,600				126	3.6125	AT/IDE	0.50	3	150,000	Glass media
Toshiba	2.5-inch	MK-1624FCV	213	2	4	13	4,000				107	3.9	AT/IDE	0.50	2.7	150,000	Glass media
Toshiba	2.5-inch	MK-1724FCV	262	2	4	13	4,000			0	131	3.875	AT/IDE	0.50	2.7	150,000	Glass media
Toshiba	2.5-inch	MK-2124FC	130	2	4	17	3,200			0	65	2.0375	AT/IDE	0.50	1.8	150,000	Glass media
Toshiba	2.5-inch	MK-2224FC	213	2	4	12	4,000			0	107	3.95	AT/IDE	0.75	3.3	150,000	Glass media
Toshiba	2.5-inch	MK-2224FB	213	2	4	12	4,000			0	107	3.95	SCSI2 F	0.75	3.6	150,000	Glass media
Toshiba	2.5-inch	MK-2326FC	340	3	6	12	4,200			0	113	3.7	AT/IDE	0.75	2.9	150,000	Glass media
Toshiba	2.5-inch	MK-2326FB	340	3	6	12	4,200			0	113	3.7	SCSI2 F	0.75	3	150,000	Glass media
Toshiba	2.5-inch	MK-1824FCV	352	2	4	13	4,200			0	176	5.46875	ATA-2	0.50	2.5	300,000	Glass media
Toshiba	2.5-inch	MK-2428FC	524	4	8	12	4,000			245	131	3.95	AT/IDE	0.75	3.6	150,000	Glass media

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-Inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MB/sec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Toshiba	2.5-inch	MK-2428FB	524	4	8	12	4,000			245	131	3.95	SCSI2 F	0.75	3	150,000	Glass media
Toshiba	2.5-inch	MK-2526FB	528	4	6	13	4,200			0	176	3.95	SCSI2 F	0.75	3.6	300,000	Glass media, ATA/ IDE also available
Toshiba	2.5-inch	MK-1924FCV	540	2	4	13	4,200			0	270		Fast ATA-2	0.50	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2528FB	704	4	8	13	4,200			0	176	3.95	SCSI2 F	0.75	3.8	300,000	Glass media, ATA/ IDE also available
Toshiba	2.5-inch	MK-2628FCV	810	4	8	13	4,200			0	203	5.375	Fast ATA-2	0.75	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-1926F	815	3	6	13	4,200			0	272	5.6125	Fast ATA-2/ SCSI2	0.50	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2728FC	1,080	4	8	13	4,200			0	270	5.375	Fast ATA-2	0.75	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2720FC	1,350	5	10	13	4,200			0	270	5.6125	Fast ATA-2/ SCSI2	0.75	1.4	300,000	Glass media, SCSI available
Western Digital	3.5-inch	WDAC1270	270.4	1	2	11	4,500	61,000	3,300	201	270		AT/IDE	1.00	3.6	250,000	Enhanced IDE, MIG heads
Western Digital	3.5-inch	WDAC1365	365.4	1	2	10	4,500				365	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC1425	426.8	1	2	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC2540	540.8	2	4	11	4,500	61,000	3,300	201	270		AT/IDE	1.00	3.6	250,000	Enhanced IDE, MIG heads
Western Digital	3.5-inch	WDAC2700	730.7	2	4	12	4,495	68,100	4,000	272	365		AT/IDE	1.00	3.25	250,000	Enhanced IDE
Western Digital	3.5-inch	WDAC2700	730.9	2	4	10	4,500				365	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE, Sturgeon
Western Digital	3.5-inch	WDAC2850	853.6	2	4	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31000	1,096	3	6	12	4,495	68,100	4,000	272	365		AT/IDE	1.00	3.25	250,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31200	1,280	3	6	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31600	1,625	3	6	9	5,200				542	9.625	EIDE	1.00	4.3	300,000	Enhanced IDE, Tri-Pad head+U28a, PRML

Source: Dataquest (September 1995)

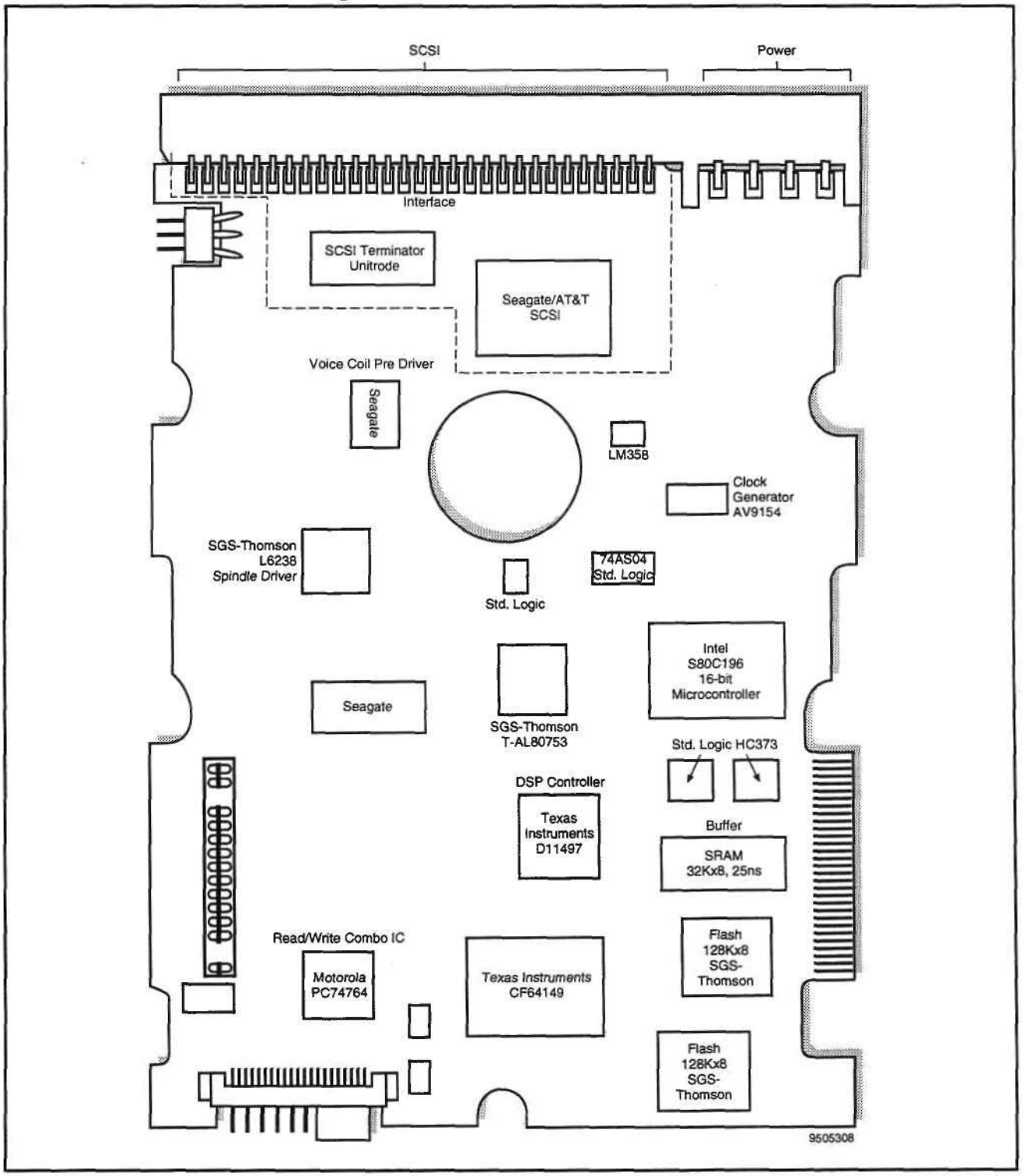
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Appendix B
RDD Board Graphic

Figure B-1 shows a printed circuit board from a Seagate rigid disk drive.

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Figure B-1
PCB for a 540MB, 3.5-Inch Rigid Disk Drive



Source: Dataquest (September 1995)

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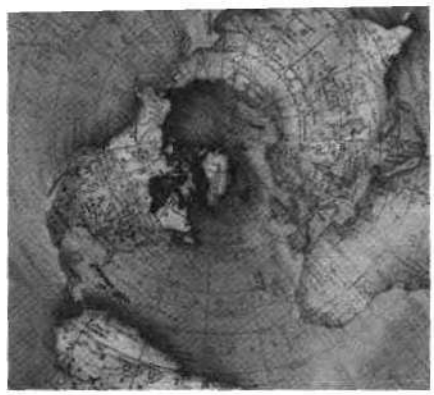
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Emerging Automotive Electronics Applications



Focus Report

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Chapter 1
Executive Summary and Introduction

Executive Summary

The market for automotive electronics is now set for further growth as global issues begin to place even more emphasis on strict exhaust emission regulations for both petrol and diesel engines becoming enforceable over the next few years. Developments of advanced driver information and traffic control systems will keep this strong momentum into the new millennium.

Historically, powertrain electronics and safety electronics have been the growth drivers in this market segment. Dataquest estimates that growth in automotive electronics is reaching maturity for powertrain electronics, which now accounts for nearly 50 percent of the worldwide automotive electronics market. Safety applications such as antilock braking systems (ABS) and airbags have also emerged and will continue to grow into the next decade as factory installations and aftermarket opportunities increase.

Fresh new impetus for further growth is anticipated to come from newly emerging communications applications for road transport/traffic and vehicle systems. The European Union (EU) and the European automobile manufacturers have committed more than $1 billion in the PROMETHEUS research program, which aims to halve the EU's 50,000 road deaths a year by the year 2010 through greater use of in-car electronic information systems and other technological developments.

The new "smart" cars for the next decade will be intelligent cars that can:

- Illuminate long distances in the dark with infrared and ultraviolet headlights
- Cruise intelligently by automatically keeping pace with the vehicle in front
- Know exactly where they are, using satellite navigation
- Summon emergency services to the exact location of a breakdown or accident with or without any driver action

This report explores the implications of this future strategy for cars of the future—so-called "smart cars"—for the electronic components industry and provides an insight to developments in this area. The report identifies 25 newly emerging electronic applications for the intelligent cars of the future and identifies the opportunities for future electronics growth in this fast-growing market segment.

Introduction

Automotive electronics is a rather fragmented semiconductor application market, but all the automotive electronics systems will eventually become integrated. This integration will occur as multiplexing technology advances to allow each of the subsystems to be interconnected. Thus, it is conceivable that automobile electronics will become one of the top five

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global electronics markets for semiconductor and passive electronic components. As a single system application, the personal computer aside, automotive electronics is forecast to be one of the single most important "engines" for semiconductor components in the next century. Worldwide, the average semiconductor content of a vehicle is now estimated to be in excess of $100.

By the year 2000 average semiconductor content per vehicle will be nearly $200. Worldwide automotive semiconductor consumption in 1994 amounted to $5 billion. By 2000, the demand for semiconductors by cars and commercial vehicles is expected to at least double, exceeding nearly $10 billion.

Electronic applications in the car (specifically integrated circuits) first appeared in commercial volumes during the 1960s as voltage regulators for alternators and also ignition control. During the 1970s the world fuel crisis led to the introduction of electronic control for fuel injection and carburetor engines. The 1980s brought legislation in the United States for electronic engine control systems to curb engine exhaust pollution. By the 1990s electronics in the car was widespread in various automotive applications from engine management, air conditioning, dashboard, security systems, vehicle tracking devices, and safety applications such as airbags and ABS, and driver navigation systems for route planning and traffic information.

In the 1980s and 1990s, environmental factors were driving electronic penetration in cars. Recently (the late 1980s and early 1990s), electronics was used as a product differentiator among car manufacturers, and the use of electronics has now advanced past that stage, ushering in a new era where vehicle emission legislation and safety regulations account for growth. Nowadays, these metrics are taken for granted, and electronics is being used to improve vehicle safety and optimize vehicle functionality.

Current research indicates that electronics and vehicle electrics account for nearly 12 percent of the total cost of a midrange car; by 2005 this cost is forecast to exceed 25 percent of the cost of a new car. New factors are beginning to drive the use of electronics in cars. Virtual market forces (aside from legislation and regulation) are now emerging as, for example, insurance companies begin to mandate the use of electronics to enhance car security.

By the end of the decade social, political, and economic factors enforced by governments, and the entire fleet transportation industry, will begin to drive the use of electronics in cars. The millions of dollars spent on research and development for the transportation industry will also be expected to yield dividends for the commercial sector. At the end of 1994, the European Commission was publicly censured by automotive manufacturers for failing to honor its financial and strategic planning obligations under the joint industry and EU precompetitive research program.

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We have partitioned each emerging technology development in the report into three main sections:

- **Advanced driver information and communication systems (Chapter 6):** This looks at all the areas of development that contribute to increased driver awareness for road safety and road conditions.
- **Powertrain electronics (Chapter 7):** Covers all aspects in motor vehicles that affect the physical design of powertrain or motion aspects of the vehicle and include engine management, suspension control, and vehicle handling.
- **Body control electronics (Chapter 8):** Deals with the entire electronics infrastructure from door body control, windows, central locking, lights, wipers, and security systems.

Please note that in the tables showing worldwide penetration of electronic systems, penetration rates are shown as a proportion of annual car production volumes in each world region.

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Chapter 2
Factors Driving Demand for Emerging Automotive Electronics Applications

Because the automotive industry is a global industry, certain regional factors have a very strong impact on the global markets. Legislation, safety, security, and environmental issues have recently impacted automotive electronics applications in cars. Europe, the United States, and Japan are the three major car producing regions worldwide. Any future changes affecting this industry are mostly influenced by the issues and decisions of these major regions.

Emerging electronic automotive applications will be influenced by a combination of factors as car manufacturers, governments, and communities actively respond to curbing the rate of vehicle traffic congestion and the effect of global air pollution in major world cities. Figure 2-1 summarizes new areas for development toward the year 2000 and beyond. These plans are expected to result in increases in demand for electronics in automobiles.

In a regionally structured initiative, the major automotive markets worldwide—namely the United States, Europe, and Japan—have each formed research coordinating organizations aimed at achieving the above objectives. In the United States, the entire concept is referred to as IVHS (Intelligent Vehicle Highway Systems), and in Japan it is known as ARTS (Advanced Road Transport Telematics), while in Europe it is commonly referred to as RTI (Road Transport Informatics).

IVHS America is a coordinating organization set up by the federal government to pursue and advance the development of research programs, pilot trials, and precompetitive cooperative product development of infrastructure systems for road transport telematics. Participants of IVHS America are government agencies, companies allied to the automotive industry, and the information technology industries in the United States.

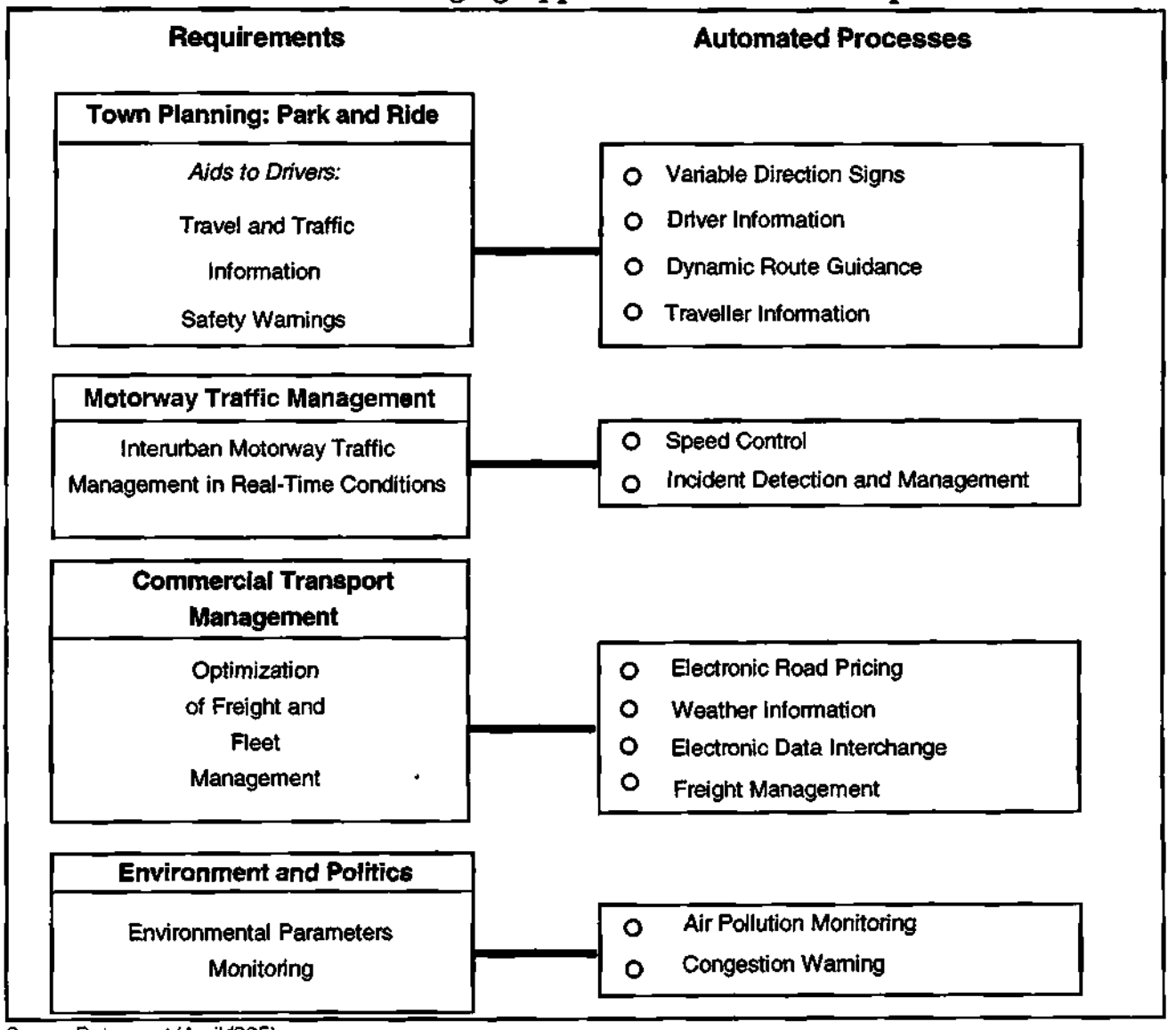
ARTS is the Japanese initiative which aims to coordinate a number of national and governmental research projects involving companies in the automotive industry (both manufacturers and suppliers) to achieve goals similar to the IVHS America initiative.

RTI is the active program in Europe to realize advanced road traffic systems under way across Europe. It coordinates, through a number of European Commission research projects, precompetitive cooperative research among competitor companies, car manufacturers, and government agencies.

Telematics refers to the merging of communications and computing technology making it possible for traffic information to become more widely accessible by motorists. Telematics is a central infrastructural requirement of the global IVHS efforts and will itself require yet more investment in certain infrastructure areas before implementation. Worldwide, the target date of 2010 set by IVHS America and Europe's PROMETHEUS program is steering the industry toward achieving these goals.

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Figure 2-1
Advanced Road Telematics: Emerging Applications from New Perspectives



Source: Dataquest (April 1995)

This report identifies future opportunities for automotive electronic penetration in vehicles that will make the European initiative achieve the 2010 objective. It also identifies the potential new semiconductor markets that will be generated as a result of this objective for the global automotive market.

Most microelectronics applications in cars improve the control or efficiency of existing mechanical systems. Consequently, the use of electronics is often perceived as additional cost. Nowadays, electronics addresses more than control and efficiency. It provides more accurate monitoring of the various parts of a car. From ignition, engine, transmission, through to braking control—start to stop—electronics are used to maintain optimal performance. Microcontrollers (MCUs) are used to control, monitor, and process analog signals from the mechanical operations of the car. Thus, most automotive systems have a microcontroller, voltage regulator, analog interface, and an I/O driver interface.

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Chapter 3
What Future for Microelectronics in the Car?

Future car microelectronics will be toward replacing some mechanical systems and permitting further integration of electronics and mechanics. Independent surveys of the automotive industry show that nearly 90 percent of all electrical faults that occur in vehicles are because of the connector. Therefore, in at least 90 percent of all electronic fault cases, the system itself is not responsible for failure.

Several companies have advanced research in system connectors. Specifically in Europe, BMW is among those that have advanced car electronic connector technology, and its patents are now being licensed to several German and European car manufacturers. But there is still more development ahead for integrated systems such as mechatronics.

A second area of equal importance and market potential for development is the use of silicon sensors. The automotive industry is now approaching certain requirements that can no longer rely on existing technology. Where existing technologies can meet these requirements, they are often too costly to implement and design-in.

Specifically for airbag applications, micromachined accelerometer sensors are required to further reduce the risk of false airbag trigger. In meeting the U.S. legislation for side impact protection, most manufacturers are seeking newer but lower-cost silicon sensors that predict crash impact. A combination of radar and optical sensors could be used for side impact detection but the limitations here are false airbag triggering, as some vehicle collision is avoided even after getting as close as two millimeters.

Mechatronics is the concept of integrating electronics and mechanical parts to form a completely integrated system. Antilock braking systems are a prime example of mechatronics, where brake plungers and electronic sensors are designed into mechanical components for controlling vehicle braking.

Many areas still remain to be resolved as car electronics (and car electrics to a lesser extent) is a relatively young technology in search of many solutions from the semiconductor industry. Furthermore, some of the technologies required for automotive application are not readily available as costs are still too high for automotive engineers to design-in such components. In the sensors area, for example, suppliers of military electronic systems that found their markets extinguished at the end of the cold war have attempted to diverge into the automotive segment. Here, new processes and technology are required to meet the automotive needs. The volume application potential for silicon sensors for automotive applications is very substantial.

Much still needs to be resolved as car electronics is a relatively new technology in search of many solutions from the semiconductor industry. New developments in the semiconductor industry itself present many automotive opportunities, and examples include integrated IC connectors, electronic packaging, wiring, multiplexing, and semiconductor technology for

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applications such as smart power, radiofrequency (RF), millimeter-wave sensors, piezo-electric sensors, and newer but cheaper accelerometer sensors.

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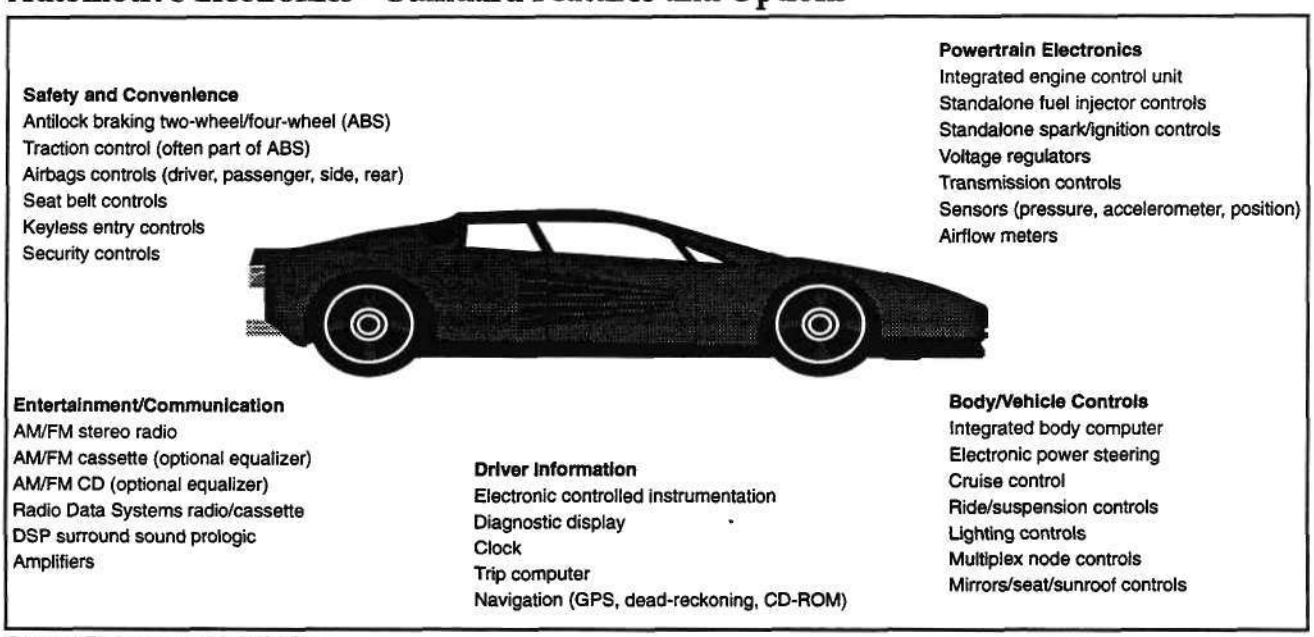
Chapter 4
Worldwide Automotive Electronic Markets

Figure 4-1 shows the current electronic systems that are available for automotive applications. Many of these systems are available as aftermarket systems that are not installed at the factory by the vehicle manufacturer. This report focuses on the new emerging applications (see Figure 5-2 in the next chapter). To bring the volume applications of these systems into perspective, Table 4-1 gives our current forecast for worldwide car production.

Europe is the leading manufacturer of cars worldwide, accounting for almost 35 percent of global car production. This pattern will likely change as the big emerging markets (BEMs) of Asia, central and eastern Europe, and Latin America begin to take shape. The final formation of car production demographics beyond the year 2000 is still quite uncertain as car ownership has a very strong correlation with economic gross domestic product (GDP). However, China represents the single car market with the largest potential and is likely to become an important producing country beyond 2000. Other important BEMs include eastern Europe and Latin America, although it is widely acknowledged that eastern Europe holds more prospects than the Latin American markets.

Dataquest believes that the major car manufacturers will continue to control car production globally and will retain the relationships of established suppliers rather than extending their supplier relationships with more suppliers. Already, automotive component procurement is being actively trimmed by most manufacturers in a drive to further cut manufacturing costs. Some car manufacturers are forming joint procurement groups to procure components with their competitors to drive down system costs.

Figure 4-1
Automotive Electronics—Standard Features and Options



Source: Dataquest (April 1995)

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Table 4-1
Worldwide Car Production Forecast
(Millions of Units)

Region	1993	1998	2000
North America	7.34	8.33	8.65
Light Trucks	5.83	7.47	7.80
Europe	11.33	11.84	13.53
Japan	8.50	9.29	10.29
Light Trucks	0.96	1.20	1.35
Asia/Pacific-ROW	3.97	5.15	7.24
Total Cars	31.14	34.61	39.71
Total*	37.93	43.28	48.86

*Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

Japanese car production is forecast to slow toward the year 2000 and will probably decline as production shifts away from Japan to Europe begin to gain momentum toward the end of the decade. U.S. car production will continue a healthy growth as favorable currency exchange rates continue to make U.S. cars competitive in the global markets. European car production will soar toward the year 2000 as eastern European manufacturing begins to ramp up and Japanese transplant manufacturing activities enter their final phase of production volume expansion.

Manufacturers from the Asia/Pacific region are expanding capacity and beginning to establish manufacturing sites outside their region. The region is dominated by the Korean vehicle manufacturers but there is also a sprinkling of minor car manufacturers serving countries in this region. The newest car manufacturing company is electronics conglomerate Samsung of Korea, which is working with Nissan Motors of Japan to start manufacturing cars.

Penetration of car electronics across all regions is forecast to grow rapidly toward the year 2000. The automotive industry in the 1990s is achieving goals of reducing car development cycles from five years to three years on average, and this is now rapidly approaching two years. Moreover, the automotive industry is experiencing some very radical market trends that will stimulate increased electronics penetration.

The latest trend shows that traditional market demographics of small, medium-size, and large car markets are moving to include more exotic vehicles. The new demography includes performance sport cars (ranging from high-performance roadsters to hatchback convertibles), four-wheel drive (4WD) vehicles (high-end, midrange, and low-end versions), and multipurpose vehicles (MPVs). Nowadays, the new vehicles are all fitted with standard electronic systems such as ABS, airbags, engine management controls, power windows/sunroof/roof (convertibles), central door locking, alarm systems and immobilizers, and RDS (Radio Data Systems) stereo radiocassette systems. On a worldwide basis about 100 new car models are introduced on the market each year. Each new car model

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announced ultimately increases the numbers of controllers, sensors, electric motors, actuators and general electronics in cars.

Automotive Electronics Systems Market Trends

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming 6 modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the powertrain area. A trend toward 32-bit microcontroller-based integrated modules is being stimulated by efficiencies needed for even stricter and tighter emission controls and fuel consumption requirements.
- Electronic-intensive antilock brakes and airbag controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (legislation in Europe) to be used in high-end and midrange cars.
- Driver-side airbags are becoming standard equipment on almost every vehicle. Passenger-side airbag versions have now entered the market, and rear passenger airbags (rear-seat and door/side impact) are emerging as an option. Strictly speaking, side-impact is being driven by legislation in the United States for side impact protection by 1998. Three versions are emerging: those installed in the door, seat, and car frame pillars.
- Europe is leading the world in the development of side-impact airbags. Volvo was first to come to market with side impact, quickly followed by Saab and BMW. Porsche, Mercedes, and Jaguar are planning introduction later this year for 1996 models. The European standard for side impact airbags is more rigorous than the U.S. standard: the European standard is based on deflection and force, while the U.S. standard is based on acceleration.
- Electronic suspension and steering are now beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information, and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry and light timers are proving popular options in an ever security-conscious world.
- Personalization features such as memory seats, memory mirror, and radio settings are now popular on high-end models, with future models extending personalized settings to include engine management, glove compartment locks, and fuel usage depending on driver code.
- Entertainment systems continue to be cassette-based today, with CD-based systems emerging at a modest rate. New digital compact cassette (DCC) and Mini-Disc (MD) systems have begun to find their way into 1994/1995 vehicles. Intelligent/distributed speaker systems (surround sound) are becoming more common.

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- Digital audio systems and technology for car radio is still developing rapidly with RDS now being introduced in the United States, and Japan likely to follow. RDS alerts the driver to traffic reports and will display radio station format and call letters. Digital audio broadcasting (DAB) for car radios is also set to emerge by the end of the century.
- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 multiplexing protocol has been adopted in the United States. This interface is heading toward serving the communication link between modules. Europe is settling on a standard called ISO 9141 and other proprietary standards like Intel's and Bosch's CAN, and the French VAN standard.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement for a 2 percent requirement on all vehicles sold in that state by 1998 (10 percent by 2003). Several manufacturers have chosen a minivan test platform. The most critical challenges are creating cost-effective battery technology and fast-charge batteries. Nickel metal hydride seems to be the leader at the moment. Electric vehicles currently cost about 50 percent more than the petrol versions. Battery life averages about three years; it costs the consumer $3,000 to replace them. Hybrid approaches are being considered including advanced flywheel technology.
- Navigation systems based on dead-reckoning technology and the Global Positioning by Satellite System (GPS) are becoming very popular in Japan and are now emerging as standard options in the United States and Europe. General Motors has introduced a $2,000 system that uses a PCMCIA format card for the map database and a Motorola-based 68EC020 processor for GPS and dead-reckoning processing (made by Zexel and Rockwell). BMW has chosen the Philips CARIN navigation system with dead-reckoning, GPS, and audio annunciation—it also doubles as an in-car television set.
- With the pressure on environmental cleanliness and fuel efficiency, diesel car sales are now on a rapid and steady growth curve. New diesel engine technology is allowing electronic diesel engine management systems to proliferate, achieving performances matching petrol cars and increasing fuel efficiency of traditional diesel engines. Diesel engines are also benefiting from the use of electronic engine control systems that help reduce the emission of harmful exhaust particulates.

World Automotive Electronics Production

Worldwide factory revenue of automotive electronic equipment production reached nearly $36 billion during 1994 (Table 4-2). The fastest-growing regions continued to be North America and Europe, with some growth also measured in the Asia/Pacific region specifically in Singapore and Korea.

During 1994, key market growth indicators from a global perspective include:

- **Powertrain electronics**: Engine management systems and diesel engine management systems
- **Safety and convenience electronics**: Airbags and ABS

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- **Body control**: Multiplex door wiring and car security systems
- **Security systems**: Immobilizers and car alarms
- **In-car entertainment**: CD players and navigation systems

Dataquest forecasts that first-generation systems for driver information systems such as integrated car navigation and traffic information systems will begin to appear on the market from 1988 onward. The market for these systems are forecast to begin to take off when infrastructure systems become available. Table 4-3 shows our worldwide forecast for automotive electronic production by end-application segment.

Table 4-2
Worldwide Automotive Electronics Production by Region, Factory Revenue (Millions of Dollars)

Region	1993	1994	1998	2000
North America*	9,458	11,311	15,022	16,824
Europe	8,558	9,953	15,763	17,313
Japan*	11,519	11,843	14,099	15,981
Asia/Pacific-ROW	2,676	2,922	4,596	6,994
Total*	32,211	36,029	47,480	57,112

*Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

Table 4-3
Worldwide Automotive Electronic Production by End-Application Segment, Factory Revenue (Millions of Dollars)

Segment	1993	1994	1998	2000
Entertainment	5,871	6,191	8,452	9,652
Body Control	3,077	3,495	5,532	6,594
Driver Information	5,464	5,893	7,584	9,068
Powertrain	10,607	11,929	16,425	18,541
Safety and Convenience	7,193	8,521	11,486	13,257
Total	32,211	36,029	49,480	57,112

Source: Dataquest (April 1995 Estimates)

We have projected a conservative forecast for the overall automotive electronics market to reach more than $57 billion by the year 2000. Powertrain electronics and safety and convenience electronics are forecast to dominate as requirements for increased security functions and tighter regulations governing emissions take off. A number of factors such as legislation, pressure from insurance companies and, ultimately, demand for further electronics could push up the demand for automotive electronics even more.

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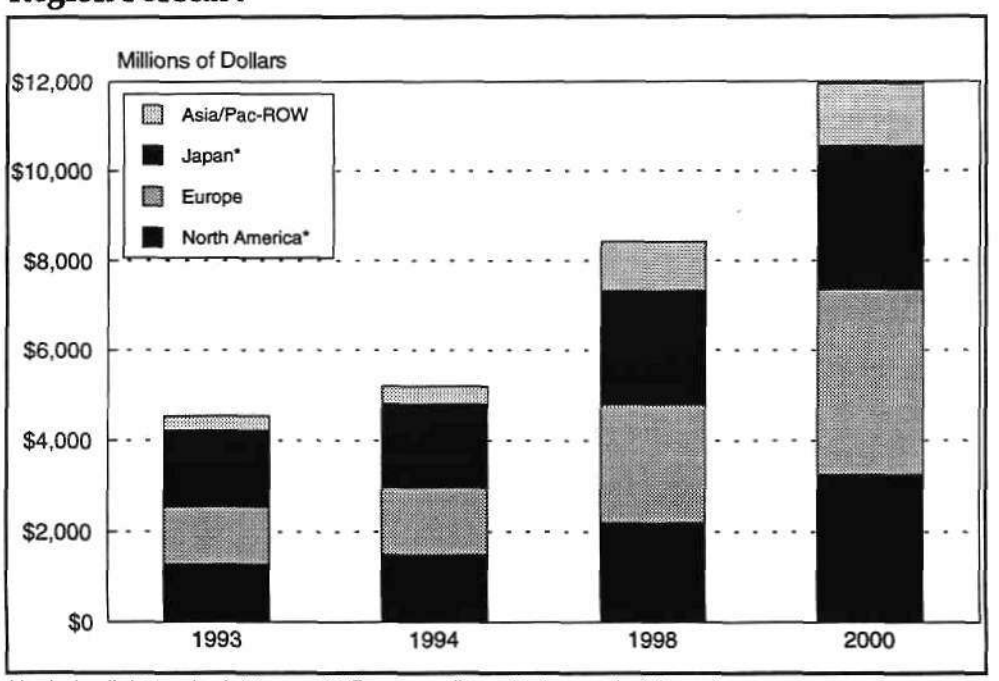
Chapter 5
Worldwide Automotive Semiconductor Markets

Dataquest estimates that the worldwide semiconductor market for automotive applications reached $5.2 billion in 1994. By the year 2000, worldwide semiconductor demand for automotive applications is forecast to reach nearly $10.2 billion (Figure 5-1). By that time, the fastest-growing regional market for automotive semiconductor components will be the Asia/Pacific region. However, as a result of global component procurement, just-in-time deliveries, and flexible but shorter cyclical R&D requirements for local automotive production, Dataquest forecasts that by 2000, Europe will account for 40 percent of the worldwide semiconductor consumption, and Japan and the United States will account for 24 percent and 32 percent, respectively.

In North America the factors driving growth are tighter emission controls with more sophisticated engine control units being developed as well as safety applications like airbags to meet side-impact protection legislation in the United States from 1997.

European automotive semiconductor growth has been spurred by growth in electronic engine immobilizer systems and car security systems, in addition to airbags, ABS and engine control units. Diesel engine management systems are also taking off in Europe—already nearly 25 percent of cars sold in Europe are diesel engine cars. Toward the year 2000, we anticipate that digital audio broadcast receivers will begin to appear in car radios and driving stability guidance systems (an extension of ABS and traction control).

Figure 5-1
Preliminary Worldwide Automotive Semiconductor Markets by Region Forecast



* Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

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The Japanese automotive segment is driven by the entertainment and driver information systems markets. Car navigation systems are proving very popular in Japan and are forecast to maintain this growth momentum toward 2000, by which time many Japanese car manufacturers will be fitting these systems into cars at the factory.

Growth in the Asia/Pacific region is coming from demand by Korean car manufacturers such as Hyundai, Kia, and Daewoo, and Malaysian car manufacturer Proton, which are ramping up manufacturing capacity to match demand coming from both western and eastern European countries. This means that they now have to meet the emission control legislation in these markets and therefore fit more engine management systems and catalytic converters to their cars.

Overall, by end-application market segment (see Table 5-1), powertrain electronics represents nearly 50 percent of the automotive semiconductor total available market (TAM). Safety and convenience applications now account for nearly 25 percent of the automotive semiconductor market. The remainder of the market is mostly in-car entertainment electronics.

Table 5-1
Preliminary Worldwide Automotive Semiconductor Markets by End-Application Segment (Millions of U.S. Dollars)

Segment	1993	1994	1998	2000
Entertainment	681	727	1,262	1,793
Body Control	545	519	842	1,195
Driver Information	363	416	505	956
Powertrain	2,044	2,389	3,871	5,258
Safety and Convenience	909	1,143	1,936	2,749
Total	4,543	5,194	8,416	11,950

Source: Dataquest (April 1995 Estimates)

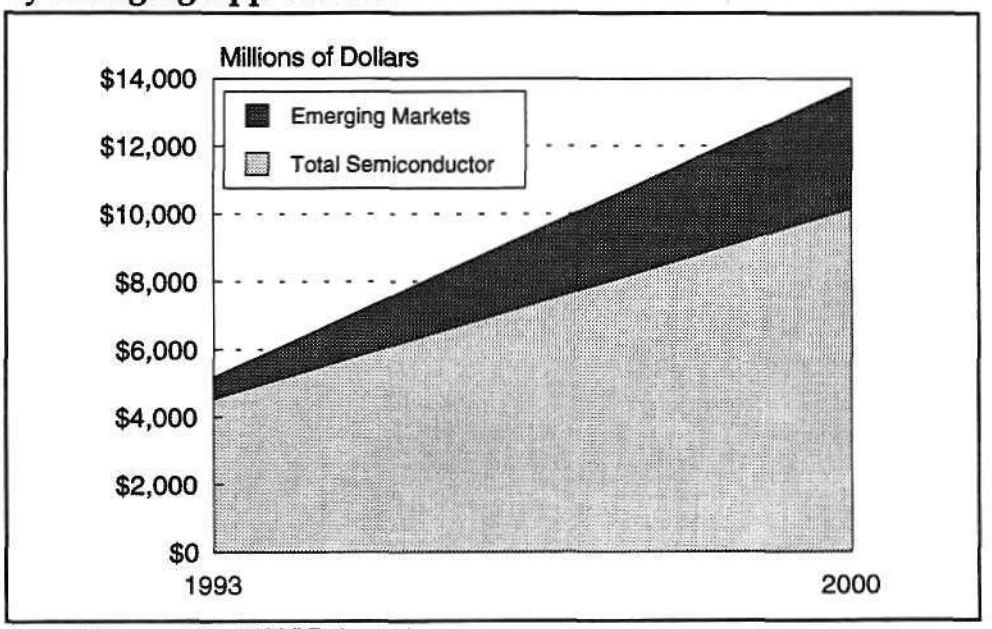
Emerging applications highlighted in this report are mostly driver entertainment, powertrain, and body control electronics. This could add an additional 10 to 50 percent of semiconductor business to the worldwide automotive segment alone. This report identifies the additional electronics business potential for emerging automotive applications shown in the top layer of Dataquest's forecast for worldwide automotive semiconductor markets in Figure 5-2.

Product Trends of Existing Automotive Electronic Systems in the Car

Cost sensitivity in automotive electronics affects product trends of existing systems. Car electronic systems are continually being upgraded, improved, and refined. In many nonsafety or nonlegislated application areas, the automotive industry itself cannot justify development costs. Often, economies of scale in other related electronics markets, such as communications and consumer electronics, drive down technology costs before they appear in the car. Figure 5-3 illustrates the systems included in the so-called "smart car" of the future.

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Figure 5-2
Contribution to Worldwide Automotive Semiconductor Growth by Emerging Applications



Source: Dataquest (April 1995 Estimates)

In the driver entertainment area, new technologies have enhanced car stereo systems as developments in audio technology have migrated from the home into cars. Examples are compact disc players, digital audio tapes (DAT)—albeit not very successful to date—digital compact cassettes, Mini-Discs, and in the near future, digital audio broadcasting. The evolution of in-car entertainment continues with the pace of development in consumer entertainment markets.

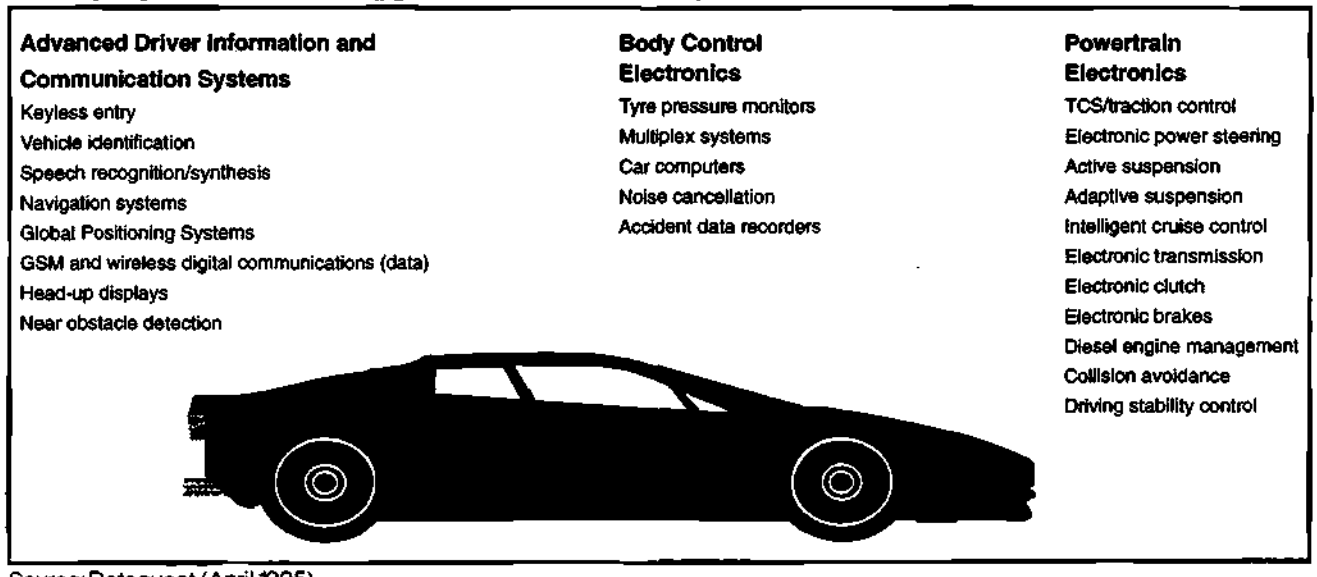
Other factors such as environmental pressures continue to affect development in areas such as ignition and engine control systems: fuel shortages of the 1970s led to the introduction of fuel injection engines and electronic injection control systems. Environmental pressure has resulted in the growth in the sales of diesel cars, and now more electronic development is being applied to meet new tighter emission control regulations aimed at reducing dirty and harmful particulates from diesel exhaust emission.

Additionally, heightened driver awareness has stimulated demand and growth in automotive safety applications such as antilock braking systems, antiskid, traction control, and airbags. Each new era in the car electronics evolution is creating further demand for electronics, and in some cases newer electronic systems and technology are being sought.

As an example, in the current airbag phase, where legislation for side-impact protection and full frontal protection is required in the United States from 1998, car manufacturers are seeking newer collision detector sensors at low cost to sense side-impact collision. Electronic solutions for the automotive business seem to be endless, restrained only by costs.

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Figure 5-3
Emerging Automotive Applications—Future Systems



Source: Dataquest (April 1995)

However, the automotive industry has one major constraint, and that is the customers. It is often customer needs that dictate the level of electronic sophistication the cars have—in the end the customer has to pay for all the car electronics.

The Automotive Environment

The automotive environment is often described as very harsh with most electronics expected to reach the level of military specifications for semiconductor device qualification. Compared with other electronic devices, this is a valid perception. The following are some of the factors that have to be tolerated when designing-in semiconductor devices for automotive applications:

- Dust-proof
- Electromagnetic compatibility (EMC)
- Humidity (including sudden changes in humidity from air conditioners)
- Oil and fuel resistant
- Shock and vibration resistant
- Short-circuit-proof
- Surge voltage resistant
- Temperature resistant (possible low temperatures of -50°C.)
- Voltage changes
- Waterproof
- Proof against polarity reversal

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As a guide, Table 5-2 provides some basic conditions that are currently applicable as conditions for electronic components in automotive applications.

Minimum operating temperatures for most of these systems are set by regional automotive electronics bodies like the Society of Automotive Engineers (SAE) in the United States, JASO in Japan, and in Europe by the various national governments' transport department. But most car manufacturers generally tend to apply the extreme limits of specification for electronic systems in order to qualify for exports to all countries.

Table 5-2
Semiconductor Device Temperature Thresholds for Automotive Applications

Location		Maximum Temperature (°C)
Chassis	Overall vehicle chassis	85
	Near heat sources	121
	Oil chassis	175
Body	Outside	121
Engine Compartment	Engine walls	140
	Engine surfaces	150
	Choke surface	205
	Starter cable (near exhaust pipes)	205
	Exhaust manifold	650
Passenger Compartment	Floor surface	85
	Real parcel shelf	107
	Instrument panel (surface)	113
	Instrument Panel (general)	85
Boot/Trunk		85

Source: Dataquest (April 1995)

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Chapter 6
Advanced Driver Information and Communication Systems

Driver Information in the Technology Evolution Process

For many years driver information systems have graduated from crude generations of roadside signs through to advanced, electronically controlled active matrix roadside information boards. Roadside information networks have advanced to a stage where most developed countries now have a computerized information control room that displays relevant traffic information on specific road routes. This infrastructure development has occurred mostly over the last decade.

Along with roadside information boards are car radios, which have also undergone quite substantial advances in technology. Microelectronics has developed the car radio to provide more information than what is audible. Text-based information is also transmitted to modern car radios using the RDS channel on FM analog radios.

Communication systems in the car have also advanced with the introduction of cellular telephony, which is now making a further advancement from analog cellular communication systems to digital cellular communications. These developments have occurred largely as a result of a market need for mobile communication systems. The introduction of digital telephony offers a new dimension to road users as it is now possible to transmit data (in addition to voice) over the digital networks by using a relatively simple data interface.

Global Positioning by Satellite Systems have also emerged as a viable technology for automotive applications. The applications for GPS in the automotive segment range from car navigation, security (vehicle movement tracking), through to very accurate clock-timing precision.

Dataquest predicts that car radios will become the hub for future driver information systems that will incorporate digital cellular communications, navigation and route guidance systems, and digital audio broadcast. The car radio is currently going through a technology evolution that will change the way these systems are used in the future, and this chapter looks at parallel developments in driver information systems that will shape future in-car driver information systems.

This chapter covers the following emerging technology areas that will have roles to play in future driver information systems:

- Keyless entry
- Vehicle identification
- Speech recognition – audio, entry, carphones, navigation
- Global Positioning Systems – alternative identification/location
- Navigation systems

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- GSM/wireless communications
- Digital audio broadcast: car radio/cassettes (versus RDS/TMC/EON)
- Head-up displays
- Near-obstacle detection (NODs)/blind-spot camera/mirrors

Keyless Entry

What Is Keyless Entry?

Keyless entry at its lowest specification allows door locks to be locked or unlocked without using the traditional car key. The most common implementation uses a remote control key-fob or "plip." More sophisticated models will have intelligent functions that may automatically lock doors once the engine is started (for security or safety purposes).

Current applications use infrared remote controls with trends toward integrating technology. The RF technology holds a unique code, which is transmitted to a receiver that controls the engine management system (EMS). The codes activate either the fuel pump relays, or the EMS itself.

Keyless Entry Features

Keyless entry improves existing car security and safety as it is also possible to configure the system to switch on or off inside/courtesy lights, alarms, and immobilizers, and quickens entry into the car by the driver (especially in dark places). RF adds additional security to EMS. The level of security required to combat vandals, joy riders, car theft, and higher insurance premiums are currently best addressed using electronics. Future keyless entry systems will use more sophisticated software to increase electronic security. Further integration of the modulator/demodulator unit into the engine management system, for example, will expand the application possibilities of keyless entry.

Table 6-1 shows the anticipated level of demand in each major world region. Although Europe is the largest car-producing region, keyless entry systems have been slower to reach the market compared with the North American region. Japan has the second-highest penetration rates for keyless entry systems because of the volume of exports to other world regions where these systems are sold or installed by respective regional car dealers through aftermarket channels.

Table 6-1
Worldwide Automotive Market Penetration of Keyless Entry Systems (Percent)

Region	1993	1998	2000
Europe	10	65	80
Japan	15	75	97
North America	15	30	40
Asia/Pacific-ROW	5	15	30
Total	12	50	64

Source: Dataquest (April 1995 Estimates)

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Future Keyless Entry Applications

Wireless communication itself as an enabling technology will in future allow linkage of engine management, transmission, and braking system for immobilization. Future RF keys could offer more processing power on-chip to increase the security level by implementing rolling codes or ciphering on-chip, thus permitting new application capabilities for keyless entry (wireless) offering customized keys for each family member that will, for example, automatically reset:

- Driver seat/mirror to memory position
- Restrict driver speed (depending on preset key priorities)
- Restrict the distance travelled (mileage), or fuel usage (for garage mechanics)
- Restrict access to boot or glove compartment
- Reset driver preferences for preset-radio, CD, and so on

Current EU vehicle type approval is for door lock, antitheft steering column lock, and transmission. Although there is no regulation in place for keyless entry, it will become mandated for EU vehicle type approval when it becomes fully implemented as a high-security door lock.

The major supplier companies of ignition keys, car alarms, engine management, and engine immobilizers will continue to work toward the development of keyless entry systems. Major original equipment manufacturers (OEMs) active in this area are shown in Table 6-2.

Table 6-2
Major OEMs of Keyless Entry Systems

Company	Country
AB Electronics	United Kingdom
Ford Electronics	United Kingdom
GM-Delco	Kokomo, Indiana, U.S.A.
Kiekert	Germany
Kokusan	Japan
Lucas	United Kingdom
Magneti-Marelli	Italy
Nippondenso	Japan
Omron	Japan
Valeo	France

Source: Dataquest (April 1995)

Because these systems are addressing the mass production car markets, all the major volume car manufacturers are evaluating keys that enhance vehicle security. A further addition to keyless entry is RF transponder keys. Ford of Europe pioneered this application in Europe by introducing Texas Instruments' TIRIS RF key across the entire entry-level car range,

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resulting in new insurance ratings for the Fiesta and Escort models. Other major end-user market customers include the following:

- BMW
- Chrysler
- Delco Electronics
- Ford
- GM (Adam Opel/Vauxhall)
- Honda
- Jaguar
- Mercedes-Benz
- Mitsubishi
- Nissan
- Porsche
- PSA Group (Peugeot/Citroën)
- Renault
- Subaru
- Toyota

Vehicle Identification

What Is Vehicle Identification?

Current EU vehicle type approval regulations for vehicle identification specify serial Vehicle Identification Numbers (VIN) to be etched into a vehicle identification plate that is affixed onto the car body and the car engine.

Global efforts to develop world standards for smart cars and highways using computers, wireless communications, and electronic traffic control systems have resulted in a need for electronic vehicle identification. Research and development are being coordinated in the United States through the IVHS program, in Europe through the EU's PROMETHEUS program, and in Japan through the government's Info-Mobility projects.

Although there may be no world standards for vehicle identification, the various research efforts being undertaken will develop common standards to address the main aspects of electronic vehicle identification. The generic feature for all these systems requires wireless vehicle identification systems that may be designed around radiofrequency identification (RF/ID): radar, infrared, or digital cellular communication technologies.

RF/ID is a method of electronically tracking items using embedded tags or transponders, stationary or mobile readers, data input devices, and system software. In low-frequency passive systems, usually 30 kHz to 500 kHz, a reader transmits a signal to an embedded or attached tag, charging the transponder and sending back a signal identifying the tagged item's unique code.

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Low-frequency devices work best at a range of a few feet or less and transmit at 20 miles per hour. High-frequency systems, in the 900-MHz to 2.5-GHz range, are capable of transmitting a greater amount of information over a wider geographic area. High-frequency devices can be used at distances of 250 feet and at speeds of more than 150 miles per hour. In Europe some systems have been developed to operate within the 5.8-GHz range specifically for road-tolling applications.

Vehicle Identification Features

Electronic vehicle identification improves existing vehicle security and traffic/vehicle monitoring/control. It offers the capability of transmitting vehicle identification for specific applications such as prepaid road-tolling systems.

Current proposals for prepaid road-tolling systems are mostly smart card-based so that older cars can benefit. However, future systems may use an integrated car identification system that will hold the car owner's details. This could offer some added benefits for car security when the "intelligent highway" concept becomes a reality. For example, access to future transaction services (such as booking car parking spaces) may be accessed more easily electronically as VIN effectively provides a user address.

Other features driving future growth for vehicle identification include:

- Road tolling (debiting/crediting transactions)
- Ability to restrict access of certain vehicle categories to road lanes
- Control and monitor road access
- Prebooking parking space at destination
- Fleet transport movement control and antitheft applications

Future Car Identification Applications

With an electronic vehicle identification system linked to cruise control and collision avoidance systems, it is possible that cars traveling to the same destination could be chained together in a train. Such a combination is believed to control traffic speed and ease traffic flow, potentially making road traffic conditions safer. This concept is known as cooperative driving in the EU PROMETHEUS program. Future development starts in 1995 for what is known as medium-range preinformation systems that will involve cooperative driving, autonomous intelligent cruise control, and automatic emergency calling. Table 6-3 gives Dataquest's forecast for these systems.

Table 6-3
Worldwide Automotive Market Penetration of Electronic Car Identification Systems (Percent)

Region	1993	1998	2000
Europe	0	8	12
Japan	0	6	15
North America	0	10	20
Asia/Pacific-ROW	0	3	5
Total	0	7	14

Source: Dataquest (April 1995 Estimates)

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Already, pilot trials are being conducted to develop this concept in a pre-competitive research environment. Although there are no real major supplier companies for car identification systems because the protocols and standards have not yet been established in Europe or the United States, Table 6-4 lists car manufacturing companies that are involved in this research and similar projects in the United States and Japan, as well as other major participants thatare suppliers, subcontract manufacturers, or partners to vehicle manufacturers and that have participated in the PROMETHEUS program.

Table 6-4
Companies Involved in the European PROMETHEUS Program

Car Manufacturers		Other Participating Companies
BMW	Mitsubishi	Celsius Technology
Chrysler	Nissan	DAIS
Daimler-Benz	Opel	Dräxlmaier
Fiat	Porsche	GEC-Marconi
Ford	PSA (Peugeot-Citroën)	HUSAT
General Motors	Renault	IBR
Honda	Saab	Leica
Jaguar	Toyota	Lucas
MAN	Volvo	Matra CAP
Mazda		Pilkington
		Robert Bosch
		Siemens Automotive
		TEMIC (Telefunken)
		Thomson

Source: Dataquest (April 1995)

Speech Recognition/Synthesizers

What Is Speech Recognition/Synthesis?

Speech recognition and speech synthesis use digital signal processing (DSP) techniques. Speech recognition uses DSP to filter analog signals into meaningful digital signals. Speech synthesis uses DSP to process digital signals to produce speech.

Existing solutions for speech recognition require large amounts of memory: EPROM and DRAM mostly (for software), and this makes the whole concept rather expensive for car applications. Software is a key component of speech recognition technology and until artificial intelligence software is developed further, then large volumes of memory capacity will remain associated with this application.

Volume applications for this technology have been pursued for nearly 20 years now. The primary objective is to develop an aural user interface that bypasses graphical user interfaces (GUIs). Currently, some limited applications exist, for access to program applications, especially for car telephones and other access applications such as door entry and car navigation systems. The use for this technology in these applications largely

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consists of voice-enabling or command functions. Speech recognition is mainly used to complement or replace other interface technologies.

Speech Recognition/Synthesizer Features

Current in-car applications use speech recognition as command- or voice-enabled functions mostly for carphone applications:

- Frequently used telephone numbers are stored in memory with a speech command assigned to dial them.
- It allows for absolute hands-free operation of car telephones or other in-car peripherals.
- It enhances driver safety by enabling voice-activated command input for non-safety-critical functions in car peripherals systems such as car radios, in-car phone/fax machines, and navigation systems.

The main problem areas for this kind of technology are analog noise cancellation for speech in a noisy environment.

Future car applications will require high-performance microphones to cancel out noise in the speech/command environment. Approaches to this technology for automotive applications require substantial amounts of processing capability, which makes it a very expensive solution.

To become successful in volume market applications, it must offer enhancements to existing technologies, or newly emerging applications to drive its use in the car. The main attractions for speech recognition in the car are a host of possible hands-free applications, allowing the driver to restrict hand use to other safety-critical areas such as steering and gear change. At its best, speech recognition offers the capability of "interactive-communication" with other car systems such as radio, traffic information networks and other such applications. Initially, this will not be suitable for safety-critical applications until the technology achieves higher standards of reliability.

First-generation speech synthesis systems have already been used in cars, but the concept of speech recognition is yet to appear in cars. To realize maximum appreciation of these technologies, newer systems will have to be interactive, combining both speech recognition and synthesis.

Against further implementation of this technology in the car is some very negative press reception, which is killing use of the systems even before they are designed into new cars. Most press reports describe the application as too "gimmicky" and impractical. European press coverage of earlier audio warning systems based on electronic speech synthesis (that constantly gave "doors open" warnings when they became faulty) discouraged early adopters and blemished any prospect for this technology in the car when, for example, it was first introduced in the 1980s by Rover. As a result, speech recognition has not been massively successful. Table 6-5 details current and forecast penetration of the technology worldwide.

Emerging speech recognition systems will be for interactive car radio, navigation systems, and other driver information systems.

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Table 6-5
Worldwide Automotive Market Penetration of Speech Recognition Systems (Percent)

Region	1993	1998	2000
Europe	0	2	10
Japan	1	2	10
North America	0	3	15
Asia/Pacific-ROW	0	0	5
Total	0	2	10

Source: Dataquest (April 1995 Estimates)

Companies producing speech recognition/synthesis hardware and software are as follows:

- Hardware
  - AT&T Microelectronics
  - Clarion
  - Ford
  - Fujitsu-TEN
  - General Motors
  - Hughes Network Systems
  - NEC
  - Nippondenso
  - Nokia
  - OKI
  - Sanyo
  - Sharp
  - Toshiba
  - Voice Control Systems Inc.
- Software
  - Lernout & Hauspie Speech Products, Belgium
  - Ricoh, Japan
  - Voice Control Systems, Dallas, Texas

Future Speech Recognition Applications

Some state-of-the-art car navigation systems developed in Japan already offer speech synthesis. It is currently more accepted in Japan because of poor road signs and severe traffic conditions in the urban areas. In Europe, market acceptance of speech recognition is poor. The failure of existing systems to reproduce accurate and human voice responses makes the whole concept appear even more gimmicky. Early systems handle non-safety-critical applications such as windows, mirrors, seats, central locking and heating and air-conditioning control.

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Secondary wireless application areas for speech recognition and interactive communication for automatic voice-activated hotel or restaurant reservations and other navigational aids may add value in other world regions for gradual market acceptance.

The proposed European standard for Traffic Message Channel protocol (for RDS-TMC) Alert-C offers a very structured digital language that has been developed to allow simple traffic information to be coded and transmitted to radio receivers equipped with a TMC decoder. The feature permits a user to receive traffic information in text form but in all the major European languages (English, French, German, Italian, and Spanish). This structure could also be easily formatted for speech synthesis in the car allowing audio interpretation of the code for any language. It is likely that the European Alert-C protocol may be adopted on a worldwide basis, to become a world standard as GSM is beginning to prove.

RDS-TMC provides other benefits through the car radio such as:

- Up-to-date traffic information from automatic traffic data collection and automated message paths
- Capability to be selective in information retrieval by criteria (for example, according to route)
- Constantly transmitted without interruption

Other applications in the car could include audible early warning systems such as low fuel, obstacle detection, and audio vehicle diagnostics. The enabling technologies for car applications are not yet widely available. Computer software houses and telecommunications companies are among the forerunners exploring this technology and its use, but the automotive industry itself may borrow from such vertical industries once applications become available.

Global Positioning Systems

What Is GPS?

The Global Positioning System (GPS) is one product of the cold war that could prove lucrative. Developed by the U.S. Department of Defense (DoD) as a strategic defense need, the Global Positioning System is a space-based satellite radio navigation system that provides a continuous source of three-dimensional positioning, velocity, and time. The GPS infrastructure consists of a "constellation" of 24 low earth orbiting (LEO) satellites (including 3 operative "spares") orbiting in a predetermined configuration at an altitude of approximately 10,900 nautical miles above earth.

A GPS receiver relies on the principle of triangulation to calculate its set of location coordinates, by measuring accurately its distance from 4 satellites that are in view (using a digital signal processor and a microprocessor). This is accomplished by measuring precisely the time taken for a radio transmission to travel from a GPS satellite to the GPS receiver. A receiver uses an internal database (called an Almanac), stored in a PROM chip, to look up the exact 3-D coordinates at a particular time of any of the 21 satellites in space. Thus, the GPS receiver relies on highly accurate time information provided by each satellite, and high degrees of computation in each GPS receiver.

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GPS Features

A GPS provides longitude, latitude, and altitude information (making it possible to calculate location anywhere in the world) while a navigation system provides more than just position information, but also route guidance and direction information.

Global Positioning Systems offer immense capabilities for navigation systems with their accurate location tracking systems. The accuracy of the location systems also make them very suitable for vehicle tracking applications, and they are therefore designed into fleet control systems and car security systems.

Consumer receivers cost as little as $500, but even that figure is dropping dramatically. If they are integrated into other types of system like navigation or security systems, then system prices, depending on features, range from $1,500 to $6,000. Car manufacturers expect that by the year 2010, virtually every vehicle will be tracked using an embedded GPS engine. About one-third of the world's established GPS hardware (engines) and software is made in California by such companies as Magnavox, Magellan Systems, Ashtech, Trimble Navigation, ESRI, and Rockwell International. Other manufacturers include the following:

- Ashtech
- Navstar (a Peek Company)
- Garmin
- New Japan Radio Company (JRC)
- GEC-Plessey Semiconductors
- NovAtel Communications
- Koden
- Sony
- Motorola
- Socket Communications Inc.

GPS applications in the car are mostly to aid dynamic driver navigation systems that use dead-reckoning. Although they have seen successful introduction on the Japanese aftermarket for nearly four years now, car manufacturers have only recently begun to offer them as an option. In Japan Honda, Toyota, Mazda, Mitsubishi, and Nissan are now offering GPS navigation systems with their top-of-the-range car models; while in the United States General Motors is leading with OEM installations of its Guidestar navigation system developed with Hughes Electronics; and in Europe BMW, Mercedes, and Jaguar (Ford) are emerging as pioneers for OEM installations of navigation and traffic information systems.

Dataquest believes that GPS navigation systems will begin to take off from the year 2000 onward (see Table 6-6). To date, the Japanese lead in aftermarket installation and car factory installations of GPS navigation systems. GPS navigation markets in Europe and the United States are only just beginning.

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Table 6-6
Worldwide Automotive Market Penetration of Global Positioning Systems (Percent)

Region	1993	1998	2000
Europe	0	20	30
Japan	2	40	50
North America	0	8	15
Asia/Pacific-ROW	0	6	10
Total	1	20	27

Source: Dataquest (April 1995 Estimates)

Suppliers of the systems are as follows:

- GPS-based car navigation systems:
  - Aisin (Japan)
  - Peek (United Kingdom)
  - Alpine (Japan)
  - Philips Car Systems (Germany)
  - Clarion (Japan)
  - Pioneer (Japan)
  - Delco (USA)
  - Robert Bosch/Blaupunkt (Germany)
  - Ford (USA)
  - Sagem (France)
  - Fujitsu-Ten (Japan)
  - Sanyo (Japan)
  - Gilardini/Fiat (Italy)
  - Siemens (Germany)
  - JVC (Japan)
  - Sony (Japan)
  - Kenwood (Japan)
  - Sumitomo Electric (Japan)
  - Mannesmann/VDO (Germany)
  - Toshiba (Japan)
  - Motorola (USA)
  - Xanavi (Japan)
  - Nippondenso (Japan)
  - Zexel (Japan)
  - Panasonic (Japan)

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- Major digital map suppliers:
  - Etak Technologies (News Corporation International subsidiary)
  - Road Scholar Inc. (PC map software company)
  - Robert Bosch (Germany)
  - European Geographic Technologies (EGT)
  - Personal Travel Technologies Inc. (with locations of hotels, restaurants, and so on)
  - Zenrin (Japan)

Navigation Systems

What Is a Navigation System?

Several different navigation systems are available for automotive use. They typically range from variants incorporating a liquid crystal display (LCD) that may be graphic, text, or alphanumeric, Azimuth sensors (for measuring coordinates), distance-travelled sensors, GPS, CD-ROM maps, FM radio data systems/traffic message channel (RDS-TMC), and GSM (Global System for Mobile Communications) voice/data telephony capability.

For most car navigation systems, the driver will key in the destination, with the system then guiding the driver to the selected destination. The methods of calculating and planning routes differ by type of navigation system. However, most electronic navigation systems embrace the basic method of finding your way to any destination using GPS and digital maps. State-of-the-art navigation systems in a car need to meet certain requirements:

- Ability to operate in a mobile environment
- Continuous operation mode for the duration of the journey
- Fast, clear, and concise display of information
- Provide "real-time" information
- Rationalize new roads/changes in road-direction flow

Navigation System Features

Earlier car navigation systems were simply electronic compasses. Navigation systems have advanced through map-based route guidance systems incorporating cathode ray tube (CRT) visual display units (VDUs) to intelligent dynamic navigation systems using satellites, LCDs, and digital CD-ROM maps. Some of the differentiating features among the several emerging platforms for car navigation systems are as follows:

- Gyroscopes/dead-reckoning/compass
- Global positioning satellites
- CD-ROM map-based navigation
- Traffic information processing
- UHF radio/GSM telephony

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Car navigation systems fall into three main categories – autonomous route guidance, interactive route guidance, and traffic information. Autonomous route guidance systems use a GPS receiver, CD-ROM and on-board computer, and sometimes an electronic compass or wheel distance sensors. These systems provide on-board route guidance to the driver without any use of real-time traffic information.

Interactive route guidance systems provide route planning information by receiving traffic information from FM-RDS stations or via GSM data communication channels. RDS information is received from the in-built radio. This traffic information is processed by the on-board computer to provide the most efficient route guidance for the selected destination. They may also use roadside beacons to communicate with the vehicle's on-board navigation system to receive traffic information in city centers.

Traffic information systems are real-time systems like the United Kingdom's "Trafficmaster," which provides traffic information collected using infrared beacons to detect vehicle speed (traffic flow) on motorways. The Trafficmaster also provides text information about traffic incidents and could be used as a radio pager. These systems give traffic information but with very limited navigation information.

Emerging application trends will incorporate the following:

- Audio: Car radio RDS-TMC (character LCDs)
- Visual: Information boards (in-car navigation systems – LCD VDU)
- Semi-interactive intelligent systems (DAB)
- Bidirectional and interactive communications and off-board digital maps (GSM)

Car navigation systems have existed for many years now, but the market for these systems has been very slow to develop (see the current and forecast penetration in Table 6-7), as these systems have taken longer to reach the development phase that exists today. In the early days, gyroscope positioning was the only available system to aid driver navigation and these devices had some major drawbacks in accuracy.

Table 6-7
Worldwide Automotive Market Penetration of Vehicle Navigation Systems (Percent)

Region	1993	1998	2000
Europe	0	3	7
Japan	2	20	40
North America	0	3	5
Asia/Pacific-ROW	0	1	5
Total	1	7	13

Source: Dataquest (April 1995 Estimates)

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CD-ROM maps were developed for use in second-generation systems, but these too were not entirely adequate. At the end of the cold war, global positioning technology became available and a combination of these three technologies is now widely acknowledged as offering the most reliable navigation techniques available for car navigation systems.

It is clear that navigation systems still have quite some way to go; for example, next-generation systems may not include CD-ROM maps as an integral part of the system. Digital mobile communication technologies will allow electronic maps to be transmitted to cars in the future.

Another product development trend is that most manufacturers of car navigation systems are the major car radio manufacturers. It is somewhat inevitable that navigation systems will become integrated with car radio. This will produce a more versatile driver information system with multimedia capability in the car.

Suppliers of car navigation systems include the following:

- Aisin (Japan)
- Panasonic (Japan)
- Alpine (Japan)
- Pagamatron (France)
- Clarion (Japan)
- Philips Car Systems (Germany)
- Delco (USA)
- Pioneer (Japan)
- Ford (USA)
- Robert Bosch/Blaupunkt (Germany)
- Fujitsu-Ten (Japan)
- Sagem (France)
- Gilardini/Fiat (Italy)
- Sanyo (Japan)
- JVC (Japan)
- Siemens (Germany)
- Kenwood (Japan)
- Sony (Japan)
- Mannesmann/VDO (Germany)
- Sumitomo Electric (Japan)
- Mazda (Japan)
- Toshiba (Japan)
- Motorola (USA)
- Toyota (Japan)

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- Nippondenso (Japan)
- Xanavi (Japan)
- Nissan (Japan)
- Zexel (Japan)

GSM

What Is GSM?

Global System for Mobile Communications (GSM), initially developed as a pan-European digital cellular telecommunications network, is fast becoming the world standard for digital cellular communications.The primary application of GSM in cars will be data-driven applications that fit into the advanced road transport telematics program. GSM offers bidirectional communication, while the FM radio RDS/TMC only offers one-way communication.

Future Applications and Features of GSM

As part of the EU SOCRATES program, research funding was made available to participants for exploring ways of utilizing GSM for a pan-European traffic information infrastructure. There are four projects developing SOCRATES: the Kernel project that coordinates the research and development; and pilot trials in three countries – London in the United Kingdom (APPLE pilot project), Frankfurt in Germany (RHAPIT pilot project), and Gothenburg in Sweden (TANGO pilot project). Major participating companies in SOCRATES projects are as follows:

- Adam Opel
- Philips Car Systems
- British Telecommunications plc (BT)
- Philips Kommunications Industrie AG
- CelsiusTech Systems
- RAC Enterprises
- Daimler-Benz
- Renault
- DeTeMobil
- Robert Bosch
- European Geographic Technologies
- Rover Group
- Expertel
- Saab Automobile
- Ford Motor Company
- Saab Mecel
- France Telecom Grands Comptes
- SEMA Group Telecom

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- GEC Marconi Transport Systems
- Telecom Securicor Cellular Radio
- Hessisches Landesampt für Stassenbau
- Telefónica
- Heusch Boesefeldt
- Telia Mobitel
- Kjessler and Mannerstraler
- Traffic Research Institute
- Lockheed IMS (UK) Ltd.
- Volvo Technological Department
- London Transport

Compared to analog cellular, GSM offers a superior spectrum efficiency that allows for speech clarity, provides improved communication security and eliminates some of the fading problems associated with analog cellular telephony. Initially developed for voice communication applications, GSM technology is rapidly beginning to provide a medium for data transmission. It is this capability that opens up new areas for automotive applications.

For driver information—road transport, traffic and navigation—purposes, GSM offers the capability to deliver data at 9 Kbps, which allows for immense flexibility for real-time information delivery. The most significant feature of GSM in automotive applications is the ability to provide bidirectional data exchange for off-board information processing. Precise position information could be sent via digital cellular communications, linked with an on-board GPS.

In future automotive applications, GSM will offer high-speed/high-density bidirectional data transfer capabilities; for example, GSM could be used in the following areas:

- **Digital road maps**: To deliver, digitally, electronic maps to subscribers of a GSM system, which will be temporarily stored for use with a car navigation system. This is especially valuable as freshly updated maps could be provided instantly without risk of being outdated.
- **Road tolling (cashless transaction processing)**: To provide data interchange for electronic cashless transactions for prepaid road tolling debiting. It could also be used to facilitate traffic control and information by utilizing data from such electronic tolling plazas or from roadside transponder networks.
- **Market information services**: GSM could be used for electronically paging customized traffic information, which is tailored to suit prespecified routes (such as tourism, trade, brief news, and diagnosis).
- **Security and emergency calling**: Automatic SOS calls giving the location of the vehicle with the use of a GPS navigation system to police, fire, ambulance, or recovery services.

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- **Traffic management (park and ride)**: Automatic booking and reservation of public car parking spaces in advance of reaching the destination. This feature extends to allow GSM for automatic reservations in other commercial applications like restaurants, cinemas, theatres, and other such applications.

Although at this time, government ministers have not yet approved GSM as an application for advanced telematics infrastructure, several car manufacturers and subsystem manufacturers have developed systems for this industry. OEMs of hardware include the following:

- Robert Bosch/Blaupunkt
- Nokia
- Dancall
- OKI
- Ericsson
- Orbitel
- Hagenuk/Cetelco
- Panasonic
- Matra-AEG
- Sony
- Mitsubishi
- Siemens
- Motorola
- Mannesmann/VDO
- NEC

Dataquest believes that navigation systems incorporating GSM will offer an abridged version of GSM technology offering just data communication. Car systems will have the option of integrating both data and voice at the customer's request. Automotive manufacturers will be looking at integrating these systems in the interior compartment design of future cars. Table 6-8 gives Dataquest's projections for penetration of these systems.

Table 6-8
Worldwide Automotive Market Penetration of Digital Mobile Communication Systems (Percent)

Region	1993	1998	2000
Europe	0	10	15
Japan	3	5	10
North America	0	1	5
Asia/Pacific-ROW	0	0	1
Total	1	5	9

Source: Dataquest (April 1995 Estimates)

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Digital Audio Broadcasting

What Is DAB?

Digital audio broadcasting (DAB) is the result of the seven-year Eureka project EU 147 (costing $110 million) to develop the standards for digital terrestrial radio. Digital audio broadcasting involves the newest audio broadcasting technology developed to replace existing analog broadcasting systems. Analog information (usually speech or music) is digitized and transmitted in digital format. The result is that it offers digital CD-like sound quality from radio broadcasts that is superior to the best FM radio can offer. Test transmissions are already broadcast in France, Germany, Italy, the Netherlands, Sweden, and the United Kingdom. Fully operational pilot trials and tests will begin from the second half of 1995 in several countries including most EU member states, and outside Europe in Canada and Australia.

DAB Features

DAB is especially suited to vehicle radio applications because it eliminates the noise problems associated with analog radio signals and offers constant, excellent reception quality. Distortion of FM radio signals caused by multipath propagation and other physical conditions are avoided by using a transmission method known as coded orthogonal frequency-division multiplex (COFDM). DAB also allows the transmission of data such as music/speech identification, program type identification, station name, and other such text data that could be transmitted with audio broadcasts.

Future DAB Applications in the Car

Largely because DAB (unlike GSM) is not a bidirectional communication medium, in the future, powerful data channels will allow specific information to be transmitted to closed user groups, opening up the possibility of "data broadcasts" and conditional access services alongside audio broadcasts. Examples of data broadcasting services for DAB include:

- Traffic message channel (character text-based)
- Paging systems
- Stock market news
- Real-time electronic maps for car navigation systems
- Weather information

Although the DAB market is not yet developed for commercial use (see Table 6-9 for current and forecast penetration), Dataquest believes that Germany will lead the world with its introduction. Nearly 40 percent of the Western European car radio market is in Germany, and car radio manufacturers will begin to switch production to DAB systems when the service becomes commercially available in Germany from 1997. The nearest single European car radio country market is less than 15 percent of the European market.

First-to-market OEMs of DAB radios include the following:

- Becker
- Philips

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Table 6-9
Worldwide Automotive Market Penetration of DAB Car Radios (Percent)

Region	1993	1998	2000
Europe	0	3	5
Japan	0	0	5
North America	0	1	3
Asia/Pacific-ROW	0	0	0
Total	0	1	4

Source: Dataquest (April 1995 Estimates)

- Clarion
- Robert Bosch (Blaupunkt)
- Delco
- Sony
- Grundig
- Thomson Consumer Electronics

Many of these OEMs currently have prototype test receivers available—which are too bulky for car dashboards. By September 1995 (in time for the Berlin IFA-*International Funkausstellung Berlin, 1995*), these manufacturers are expected to bring some prototype models to market, although the cost of these systems at that time will not be attractive for OEM factory installations. Market development for car DAB systems will take place when car manufacturers sign up for volume allocations that will bring component prices down.

Typically, it takes two years in a car manufacturer's design cycle for dashboard applications to appear on the market. With the introduction of DAB to the volume German market planned for 1997, we do not expect to see DAB car radios become factory-fitted until after 1998. Initial systems will likely be sold through aftermarket channels after the fourth quarter of 1996, although these will be insignificant volumes. We expect to see DAB volumes begin to have some slight effect on the semiconductor market by the year 2000. Since DAB will be simulcast with existing FM for at least 15 years, it will not be until around 2010 that the market will begin to take off.

Dataquest believes that these first systems will be hybrid systems capable of receiving both digital audio broadcast and analog broadcasts; thus, some hybrid radios will remain on the market for many years before the switch to full coverage of DAB takes place.

Head-Up Displays

What Is Head-Up Display?

For a number of reasons ranging from reduced night visibility through to dashboard instrument clutter, solutions are being sought to prevent momentary lowering of driver alertness. Head-up displays (HUDs) are

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seen as a technology to present essential information in the driver's field of view. Developments for future in-car applications have been borrowed from aircraft and military systems to improve road safety. HUDs use a display projector built into the car dashboard that projects images onto specially constructed windscreens. The special windscreen construction (using glass optics and projection techniques) allows projected virtual images to be viewed in light (day) or dark (night) conditions.

Future Application of HUDs

Head-up display technologies have now reached a stage of near commercial introduction into vehicles. In the United States and Japan car manufacturers such as Nissan and General Motors have introduced first-generation car models with HUDs for primary information display (dashboard warning signals). Future applications of HUDs include the following:

- Primary information display (speedometer, dashboard warning signals, and advance road/traffic warning information)
- Secondary information display (enhanced vision in fog, rain, and snow or at night)
- Tertiary information display (for example, early warning signalling of road conditions such as ice, snow, rain, and flood)

As part of the global research initiatives such as the equivalent of Europe's PROMETHEUS program in the United States and in Japan, car manufacturers are keen to prove that HUDs enhance driver alertness and improve driver focus on the road. However, the real barrier to the deployment of HUDs in cars is currently the cost of projection technology. DSP costs are still too high, and until such time that car manufacturers are convinced that customers will be willing to pay for these systems, they are likely to remain in research and development labs until around 2010.

The single most important market driver for HUDs is night vision enhancement, and this is the area where much of the current development is taking place. The key issues here are how to perfect a technology for image detection that is dazzle-proof. Image detection and projection in current solutions using infrared cameras and charge-coupled devices (CCDs) are affected by oncoming vehicle lights.

Another area for further development in HUD technology is to improve the image quality projected onto the windscreen for vision enhancement. Current systems that use ultraviolet technology for thermal image detection are not very good for image clarity or projection. Further technology development is required in this area to overcome this problem.

Although HUDs for speedometer and other dashboard applications are available, the market is very insignificant at the moment (see Table 6-10) as there is no real justification for this additional cost option item. Future systems will have capability for night vision enhancement, and this is the aspect of most interest to car manufacturers.

At present, General Motors has a HUD option available for its Oldsmobile Cutlass Supreme model and the Pontiac Bonneville models. These are

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Table 6-10
Worldwide Automotive Market Penetration of Head-Up Displays (Percent)

Region	1993	1998	2000
Europe	0	1	1
Japan	1	2	3
North America	0	2	2
Asia/Pacific-ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

cheaper, low-end HUD systems that cost $250 as a standalone option. Nissan also has a similar HUD system in its Sylvia car model built for the Japanese market only. Typical information displays of existing HUD systems include:

- Update of road signs
- Speed
- Fuel distance to empty
- Temperature (inside/outside)

HUD systems need a fairly sophisticated projection technology onto the windscreen. Some prototype systems use basic camera technology while for certain thermal image detection HUD systems, some fairly complex CCDs are used. Future applications for HUD will be for driver information purposes or warning signals to the driver such as the following:

- Enhanced night vision
- Warning of road conditions (black ice, oil spill, slippery surface, snow, rain, and so on)
- Advance warning of route traffic conditions
- Navigation/travel direction display

Although this technology is unlikely to appear in cars for many years, there appear to be two companies very active in HUD technology for automotive applications; many other companies that manufacture HUD systems for the military and aviation industry are also known to be developing low-cost HUD prototypes for automotive vision enhancement applications. Many of these prototypes are currently in development and by 2000, first-generation systems should begin to gain entry into the high-end automotive markets, commercial vehicles, and vehicles used by the emergency services such as the police, fire, vehicle/disaster recovery, and ambulance services.

Major automotive HUD technology developers include the following:

- BMW
- British Aerospace

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- Delco Electronics
- Fiat (Magneti-Marelli)
- Ford
- Libbys Owens Ford (LOF)
- Nissan
- Peugeot-Citroën
- Pilkington Glass and Jaguar Cars
- Renault
- Toyota

Near-Obstacle Detection

What Is Near-Obstacle Detection?

Near-obstacle detection (NOD) systems monitor objects that come within short-range view of vehicles and warn the driver about these obstacles. They work on a principle utilizing electronic sensors that may fit into rear-end light panels or vehicle bumpers. Current systems designed for the automotive industry use ultrasonic sensors or infrared sensors that monitor moving vehicles in the blind spot area. The most common application is for reversing assistance (when gear selection is in reverse).

Features of Near-Obstacle Detection

Near-obstacle detection uses sensors to detect obstacles in the path of view. Some systems deploy infrared sensors, radars (microwave/millimeter wave) or CCD cameras.

Typically, a basic NOD will deploy a sensor that will detect obstacles. The sensor could be infrared, radar, or microwave. The electronic control unit will receive signals from the sensor, and each time an obstacle is detected in the view of the sensor, a break in signal transmission will trigger the warning. Based on a camera principle, each sensor sends and receives focused infrared rays through a special optical system. The system can be activated only by setting the turning indicators. Any object up to a preset distance away from the sensor triggers the warning signal.

Vehicle manufacturers may configure the warning signal to provide audible, visual, or audio/visual warning signals. Price estimates of this kind of system range from around $50 and above, and it is anticipated that these systems will be first introduced for commercial vehicle applications before we see them in cars.

Convex and aspheric mirrors minimize the blind spot, but the scale differences easily confuse the driver as an estimation of the real distance of cars approaching from the back is almost impossible, especially at night.

Siemens Semiconductors and Autosense Ltd. of Denver, Colorado, have developed a system based on this principle that will indicate the presence of any vehicle in the blind spot area through warning lamps inside the car or at the outside mirror.

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Future systems could be integrated into active collision avoidance systems. Although existing systems are deployed by some commercial vehicle manufacturers, the use of these systems could become mandatory for commercial vehicles or vehicles with high driver cabins.

Table 6-11 gives Dataquest's current and projected penetration for near obstacle detection systems. Manufacturers and suppliers of the systems include the following:

- Delco Electronics
- HE Microwave
- Hitachi
- NEC Electronics
- Mitsubishi
- Sharp Electronics
- Siemens
- TEMIC (Telefunken)

Table 6-11
Worldwide Automotive Market Penetration of Near Obstacle Detection Systems (Percent)

Region	1993	1998	2000
Europe	0	1	5
Japan	2	7	15
North America	0	3	10
Asia/Pacific-ROW	0	0	3
Total	1	3	8

Source: Dataquest (April 1995 Estimates)

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Chapter 7
Powertrain Electronics

Although the rate of penetration for powertrain electronics is fast approaching maturity as a result of legislation to curb exhaust emissions to protect the global environment, further advances in electronics are very actively pursued in this area. Powertrain electronics is increasingly seen as the powerhouse of all vehicle electronics. This segment will expand to gain control of other areas of automotive electronics as the need to merge functions of individual electronic control systems becomes a reality.

The merging of electronic control systems will depend largely on developments in the data-bus area where multiplexed wiring technology is replacing the traditional vehicle wiring harness. Future powertrain applications will involve and control all aspects of vehicle motion dynamics ranging from total control of vehicle stability, steering control, suspension control, braking control, transmission and safety, to security controls. In achieving this purpose, larger packets of input data will be processed by the engine control unit and larger-size software programs will need to be developed to cope with the diversity of algorithms that will be calculated. Research efforts geared toward reaching these objectives are already in place at most major motor manufacturers' research and development divisions.

Parallel to these developments are newer forces driving further use of electronics to achieve widely diverging solutions but converging applications that have become established parameters for engine management systems such as:

- Fuel crisis and fuel efficiency drive
- Performance enhancement and vehicle safety
- Environmental pressure
- Vehicle security and insurance costs
- Vehicle diagnostics control
- IVHS and advanced traffic telematics

In examining the potential for these developments, this chapter of the report covers the aspects of powertrain electronics and all directly and indirectly related emerging systems that will play a role in reaching the goal of intelligent vehicles or the so-called "smart car" of the next decade. The following applications are explained in this chapter to identify the importance and the use of each system:

- TCS/traction control (and antiskid control/ASR)
- Electronic power steering
- Active suspension/adaptive suspension
- Intelligent/smart cruise control
- Electronic transmission: Tiptronic
- Electronic clutch

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- Electronic brakes (brake by wire)
- Collision avoidance
- Diesel electronic fuel injectors (electronics)
- Driving stability control and guidance system (DSC)

TCS/Traction Control (and Antiskid Control/ASR)

What Is Traction Control?

Traction control prevents the wheels from spinning by reducing engine speed, whereas ABS prevents wheels from locking by optimizing braking pressure. Traction control (sometimes referred to as ASR or antiskid control) was first developed for high-performance cars. Most traction control systems are integrated into an ABS and often share the same electronic control unit.

Features of Traction Control

Earlier-generation traction control systems reduced engine speed when wheel sensors detected wheel spin. The application for traction control in cars first became popular in the 1980s to aid performance in sports cars.

Nowadays, traction control is being developed as a safety application for traction control in adverse road conditions (snow, rain, black-ice, and so on). Thus, to prevent loss of traction in adverse road conditions, the focus is on developing sensors for detecting road conditions. This is the newly emerging area of development that will move traction control into the mass market. Like ABS, traction control helps to maintain vehicle traction and steering.

The electronic control unit deploys wheel speed sensors, engine speed sensors/throttle valve position sensors, a brake switch, and an on/off switch for the traction control system itself. Data from the wheel speed, engine speed/throttle valve position sensors, and brake switch state is processed by the electronic control system; output is fed through actuator control devices to the hydraulic brake valves, and the ABS pump relays and the electrical drive of the throttle valve. Thus, when a driving wheel slips it is braked by an active intervention of the brakes. In other extreme conditions, such as cornering on roads with reduced traction (wet roads), the processors decrease engine torque using the throttle valve actuator.

Like many safety critical electronics systems in cars, the electronic control unit uses multicontrollers and could have up to three microcontrollers (8-bit MCUs). One microcontroller is used for the main application, the second controller is a watchdog controller, and the third controller acts as a diagnostics and safety logic controller.

Future Traction Control Applications

Having first made its debut in racing cars, traction control has since gained entry for commercial vehicle applications. The next stage in the development of traction control systems is to advance the road condition sensor technology for this application to be deployed in the medium-size and small car markets.

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Dataquest forecasts that this application, when perfected, will eventually become a standard offering with ABS. Eventually where advanced car electronics are deployed, traction control may be attached to engine management for engine braking. Table 7-1 gives current and forecast penetration of these systems.

Table 7-1
Worldwide Automotive Market Penetration of Traction Control Systems (Percent)

Region	1993	1998	2000
Europe	5	30	35
Japan	5	20	35
North America	8	45	50
Asia/Pacific-ROW	1	5	10
Total	5	28	34

Source: Dataquest (April 1995 Estimates)

It is conceivable that traction control, ABS, and engine management systems connected with an active suspension system would provide an excellent solution for safer motoring and dynamic vehicle control. Driving stability control systems are themselves an extension of ABS and traction control.

Major suppliers of ABS and traction control systems include the following:

- Alfred Teves/ITT
- Allied Signal
- Bendix
- FAG Kugelfischer (Motorcyles)
- Kelsey-Hayes
- Lucas Braking Systems
- Nippon ABS
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes
- TEMIC (Telefunken)

Electronic Power Steering

What Is Electronic Power Steering?

Conventional power steering systems use a method of magnification to reduce the amount of effort used to turn the steering wheel. This method operates with a hydraulic power steering pump system. Power steering systems with fixed-magnification ratio have major drawbacks. If the

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system is designed to reduce the force needed to turn the wheel when the car is stationary, steering becomes too loose when the car is driven at greater speeds; this is where electronics are used.

Features of Electronic Power Steering

The application of electronics in this area is focused on controlling the degree of magnification to apply equal amounts of hydraulic force to compensate for variable speeds. To control hydraulic power steering, speed sensors, solenoid valves, hydraulic pumps, and a power steering gearbox are currently deployed by most of the emerging electronic power steering systems.

The only input to the electronic control unit for power steering is from the vehicle speed sensor. The output signal activates a linear solenoid valve (a solenoid valve that can be controlled at any arbitrary position depending on the average current). The solenoid valve is used to control the hydraulic power steering.

Newer developments in power steering are expected to shift away from hydraulic system to electronic power motors that can be controlled more efficiently and will drain less engine power, thus becoming more energy-/fuel-efficient. These types of power steering system are now in development (particularly for electric vehicles) and are expected to become widely available by 2005 (see Table 7-2 for the Dataquest forecast out to 2000).

Table 7-2
Worldwide Automotive Market Penetration of Electronic Power Steering Systems (Percent)

Region	1993	1998	2000
Europe	1	5	10
Japan	30	45	65
North America	4	9	15
Asia/Pacific-ROW	0	3	5
Total	9	16	23

Source: Dataquest (April 1995 Estimates)

Active Suspension

What Is Active Suspension?

The concept of suspension control covers a number of functions aimed at improving the overall stability and performance of a vehicle. The basic objective of suspension control is to reduce vehicle rocking, rolling, pitching, and yawing. A combination of driver-controlled actions such as steering, braking, and speeding often leads to instability.

Several techniques may be used to avoid vehicle instability from such driver actions. Active suspension is one method and is based on a principle of controlling dampers (shock absorbers) and springs while maintaining vehicle height to maximize stability. Softening the dampers reduces vehicle shock from jolts in road surfaces but increases springing, while

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vehicle shock from jolts in road surfaces but increases springing, while hardening the suspension stiffens springs. A compensating compromise needs to be achieved to sustain comfortable ride quality. This can only be done by electronic suspension control. The damper and spring control system is described as ride control or adaptive suspension. Active suspension combines height control to adaptive control techniques. The height control system relies on sensors that monitor and control each wheel height.

Features of Active Suspension Systems

The electronic control unit (ECU) of an active suspension system receives signals from a number of peripherals and sensors. A fully configured system will receive inputs from the following:

- A mode select switch (which selects the ride quality parameters)
- Steering sensors (to calculate damping rock/roll compensation for sharp steering/cornering)
- Braking light sensors (to prevent diving when braking hard)
- Throttle control—via the engine control unit (to minimize dipping of the rear end when accelerating)
- Vehicle speed sensor (to improve roadholding when the vehicle is travelling at high speed)
- Optional—automatic transmission neutral sensor (to monitor the vehicle's current travel status)
- Vehicle height control sensor (body to ground clearance sensors)—active suspension
- Diagnostic check system

How Does Active Suspension Work?

The electronic control unit processes signals from all the input sensors and outputs to actuators that control damping or suspension control. It uses algorithms that are developed to maintain optimal stability in all driving situations to aid vehicle control.

Active suspension systems are tailored for different types of vehicle as they incorporate specific algorithms related to vehicle weight/mass distribution and velocity metrics. The ECU sends signals to an actuator to select damping (shock absorber tensioning), an electronic DC motor, and a solenoid valve to control hydraulic pressure in the shock absorber. Typically, an 8-bit microcontroller is used for these functions.

For height control, the ECU receives signals from each wheel height sensor and applies the damping control to compensate for increases or decreases in height caused by loading. Maintaining vehicle height ensures vehicle stability and also minimizes changes in the optical axis of the headlamp illumination angle. Most active suspension systems use actuators for air or hydraulic springs to adjust vehicle height.

Active suspension emerged first in Formula 1 racing in the 1980s but has been slow to gain market acceptance by car manufacturers. As early as during the 1980s, Toyota and Nissan had been installing active suspension systems on their top-range cars as an option, but penetration remained

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Xantia car model and offered this model with a hydraulic active suspension system. Toyota is now offering active suspension systems with the top-range Lexus cars. The costs of developing these systems and the length of development time make them a very expensive solution for car applications. Newer systems such as driver stability control systems are emerging as more cost-effective ways of achieving similar results.

Major suppliers of active suspension and damping control systems are listed below, and Table 7-3 contains Dataquest's projections for penetration of these systems:

- Lotus Engineering
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Tokiko
- Valeo

Table 7-3
Worldwide Automotive Market Penetration of Active Suspension Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	1	3	5
North America	0	3	6
Asia/Pacific-ROW	0	0	1
Total	0	2	4

Source: Dataquest (April 1995 Estimates)

Intelligent/Smart Cruise Control

What Is Intelligent Cruise Control?

Cruise control or fixed-speed driving control is a system that allows drivers to travel at a constant fixed speed without using the accelerator pedal. The main benefit of cruise control is to reduce driver strain or fatigue during long motorway journeys. The earliest systems used analog circuitry but most current systems use digital circuitry.

Features of Intelligent Cruise Control

When cruising speed is set, the electronic control unit will calculate vehicle speed using signals from the speed sensor, and then maintain vehicle speed using a throttle control actuator. Fixed speed cruising is cancelled by a cancel signal, which can be set using the foot brake pedal, clutch, or parking brake switch. Most systems use a 4-bit or 8-bit micocontroller for this application, but this is becoming increasingly integrated with engine management control systems.

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Intelligent cruise control is the next-generation cruise control currently under development. Specifically designed to improve driver safety, intelligent cruise control can be set to adjust cruising speed with that of the vehicle in front of the driver. This is to avoid frontal collision when cruise control is set and the driver is lulled into a false sense of security. Intelligent cruise control will have more than one input signal and will take additional information from other obstacle detection sensors such as radar, microwave, and infrared sensors.

Most drivers of cars fitted with cruise control systems rarely use this feature, but it is becoming standard equipment with most automatic transmission cars. Intelligent cruise control is a major function of so-called "cooperative driving" where cars traveling toward a common destination on motorways are batched together in wireless chains. The collision avoidance technology is employed in the cooperative driving system and is proven to improve traffic efficiency.

Future systems will incorporate near-obstacle detection technology; consequently, it is likely that in the near future, newly developed systems will commonly be hybrid detection systems using both radar and infrared detection technology.

Table 7-4
Worldwide Automotive Market Penetration of Intelligent Cruise Control Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	3	5	10
North America	0	2	3
Asia/Pacific-ROW	0	0	1
Total	1	2	4

Source: Dataquest (April 1995 Estimates)

Major developers of intelligent cruise control systems are listed below, and Table 7-4 gives Dataquest's projections for current and future penetration of the systems:

- Delco
- Denshi Giken
- Jidosho Denki Kogyo
- Fujitsu Ten
- Motorola
- Nippondenso
- Robert Bosch
- Mercedes-Benz Research
- Mitsubishi Electric

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- Siemens Automotive
- TRW
- TEMIC (Telefunken)

Electronic Transmission: Adaptive Shift Pattern

What Is Electronic Transmission?

There are several different types of electronic transmission system, ranging from driving mode transmission control for automatics and continuous variable transmission (CVT) control systems and, ultimately, adaptive shift pattern (ASP) transmission. Most electronic automatic transmission control systems are programmed for economy and sport driving modes. ASP allows the driver to drive in three modes: manual, automatic, and a third metric automatic mode that allows the transmission system to adapt a number of driving patterns. Table 7-5 gives the worldwide forecast for electronic transmission.

An example of an ASP transmission system is Porsche's Tiptronic developed by Porsche and Bosch for the Le Mans Porsche 962 and Maclaren F1. Tiptronic first appeared in production Porsche cars during 1990. Today, BMW (Alpina), Audi (A8), and Saab also offer this system in their top-range cars. Nissan (Maxima) and Toyota (MFG super-performance sports-car) have a similar system.

Table 7-5
Worldwide Automotive Market Penetration of Electronic Transmission Systems (Percent)

Region	1993	1998	2000
Europe	0	5	10
Japan	0	4	15
North America	0	15	20
Asia/Pacific-ROW	0	1	3
Total	0	7	12

Source: Dataquest (April 1995 Estimates)

Features of Adaptive Shift Pattern Electronic Transmission

The major benefit of the ASP system is the ability to offer manual transmission driving in an automatic transmission car. The Porsche Tiptronic system receives input from eight sensors and interfaces with the ABS/traction control system and engine management systems:

- Engine speed sensors
- Lateral acceleration sensors
- Lateral deceleration sensors
- Road speed sensor
- Temperature sensors (engine)
- Throttle angle sensor

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- Throttle speed sensor
- Transmission sensors

Current first- and second-generation Tiptronic systems were designed around an 8-bit microcontroller, but the trend is toward using 32-bit controllers for newer transmission systems as the new designs eliminate mechanical function replacing mechanics with electronics—this requires more software and faster processing performance—making them smaller and lighter. The complexity of the controller is dependent on transmission technology and design of transmission system. The electronic control units outputs signals to solenoid valve actuators that control the transmission system and also to the engine management systems.

The ECU in the Tiptronic system monitors and learns driver behavior, while assessing environmental conditions. Depending on the results of these factors, it selects from five automatic electronic shift maps and adjusts torque, power, and speed (gear) accordingly. The five adaptive shift pattern algorithms contain programs that give optimal performance when driving uphill, for sporty driving, on bad road surfaces, in economy driving modes, and for city driving.

Electronic Clutch

What Is Electronic Clutch?

An electronic clutch involves a system of applying the clutch by using an electronic control unit to release gear-shift forks for manual transmission systems. This system has been used widely in Formula 1 racing for many years and is now beginning to appear in production vehicles. The first major debut in production cars was made in June 1994 by Renualt for the Twingo. In this car there are only two foot pedals: the brake and the accelerator pedal.

Features of Electronic Clutch Systems

An electronic clutch system deploys an electrical pump, a receiver, an electronic control unit, a gear shift lever sensor, an engine speed sensor, and a transmission sensor. The electronic control unit receives input from the gear shift lever sensor, engine speed/throttle sensors, door switch, and transmission sensors. When the driver puts his hand on the gear lever, the sensor transmits this information to the control unit; this activates the gear shift forks, which take over the maneuver to operate the clutch by means of a hydraulic circuit. The system relies on a conventional clutch system but uses a hydraulic gear shifter circuit to control the clutch system.

With cars fitted with electronic clutch systems, it is impossible to stall, jerk, or over-rev engines. Another benefit of the system is that it immobilizes the vehicle when the engine is switched off with a driving gear engaged.

Currently, Renualt offers the system with its Twingo car model and is expected to design the system into a new range of Clio cars. BMW's Rover subsidiary and Honda are also known to be evaluating the system in Europe. We expect to see some introductions in a range of vehicles including some sports cars, small vans, and light trucks by 1996 (Table 7-6 shows the forecast). The sole supplier for this type of system is Automotive

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Products (AP) Borg & Beck, but Dataquest believes that many other manufacturers of transmission and clutch systems will follow with introductions of similar systems over the next two years.

Table 7-6
Worldwide Automotive Market Penetration of Electronic Clutch Systems (Percent)

Region	1993	1998	2000
Europe	0	12	18
Japan	0	10	15
North America	0	15	20
Asia/Pacific-ROW	0	1	3
Total	0	11	15

Source: Dataquest (April 1995 Estimates)

Electronic Brakes (Brake by Wire)

What Is Electronic Brakes?

Electronic brakes are a new technology involving an electronic actuation system that will maximize braking performance of vehicles fitted with an ABS. Electronic braking systems apply maximum brake servo force, irrespective of the amount of pedal pressure from the driver. The system has an electronic control unit that detects emergency braking patterns and applies a booster to the brake servo.

Features of Electronic Brakes

The system deploys a four-wheel ABS system (traction control optional), an electronic control unit, position sensor, and solenoid valves. Electronic brakes use position sensors to detect emergency braking by measuring the speed of the application of the brake pedal. As soon as the speed of application of the brake pedal exceeds a predetermined critical value, the system is engaged – the sensor sends signals to an electronic control unit to engage an electronic actuation system, which applies the maximum possible servo force. The hydraulic pressure boost is applied to each wheel. This ensures that ABS is activated, bringing the car to a stop in the shortest possible distance while allowing the driver to steer.

Lucas and Mercedes-Benz have been developing such a system over the past few years, and this is expected to appear on some Mercedes cars from 1996 (see Table 7-7 for the worldwide forecast). Current systems will use a 16-bit microcontroller and typically share a module with the ABS and traction control units.

Future Electronic Braking Systems

Future developments of the electronic braking system will bring features such as:

- Active stability control and traction control (a driver stability control system)
- Hill-hold braking system

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Table 7-7
Worldwide Automotive Market Penetration of Electronic Brakes (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	0	1
North America	0	0	1
Asia/Pacific-ROW	0	0	0
Total	0	0	1

Source: Dataquest (April 1995 Estimates)

- Cruise control
- Autonomous intelligent cruise control (AICC)
- Constant pedal pressure (vehicle payload–dependent braking)

Several manufacturers of ABS and traction control systems are evaluating the use of hydraulic boosting of the braking force. The newest research in this area is examining ways of achieving proportional boost from the brake booster. This could allow the use of electronic brakes for the future development listed above at minimal cost. The system also allows for a less expensive ABS system, as ABS, traction control, AICC, and constant pedal pressure systems are integrated into one complete system.

Dataquest believes that electronic brake boosters will eventually become a functional feature of future ABS and traction control systems. The application of this type of brake assistance system is likely to be fitted to cars with automatic transmissions. Although these systems are now only just emerging, the future uptake will depend on the uptake and success of ABS systems penetration into new cars.

Diesel Electronic Fuel Injectors (Electronics)

What Is Electronic Diesel Control?

Tougher emissions requirements will soon lead to totally smoke-free diesels. Many car manufacturers are designing newer diesel engines to meet these emission requirements. As the next-generation high-speed direct injection (HSDI) engines begin to replace existing injection engines, diesel engine fuel pumps will be rapidly replaced by electronic diesel unit injector systems. These new diesel injector systems each have a high-speed fuel injection pump per fuel injector. Solenoid valves control fuel flow, and these valves are controlled by an electronic control unit.

Lucas has developed an electronic unit injector (EUI) that meets the Euro 3 emission standards due for introduction in 1996 and the U.S. Fed 98 legislation (a stricter requirement for exhaust emissions than the current emissions regulations). The objective is to develop a system that provides very high-pressure diesel injection into each engine cylinder. Currently, most diesel engines operate with injection pressure of 400-bar maximum. The new systems aim to deliver injection pressure rates of up to 2,000 bar. These systems will improve diesel fuel combustion; this provides a quieter diesel engine, with better performance and cleaner emissions.

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Features of Electronic Diesel Control

The electronic control unit receives information from accelerator pedal sensors, engine speed sensors, camshaft sensors, and air flow sensors. It uses this information to calculate the amount of fuel required per injection unit. Most diesel systems use a 16-bit MCU but are rapidly moving to 32-bit for commercial vehicles. However, the stricter U.S. CARB is pushing 32-bit electronics into diesel engines in meeting new engine diagnostics regulations enforceable with the U.S. Fed 98 legislation.

Major manufacturers of diesel engine electronics are listed below, while Table 7-8 gives the worldwide forecast for penetration of the systems:

- Delco
- Lucas
- Robert Bosch
- Nippondenso
- Nissan Diesel
- Toyota

Table 7-8
Worldwide Automotive Market Penetration of Diesel Engine Injector Control (Percent)

Region	1993	1998	2000
Europe	1	5	8
Japan	1	2	5
North America	1	2	3
Asia/Pacific-ROW	0	1	2
Total	0	3	5

Source: Dataquest (April 1995 Estimates)

Collision Avoidance

What Is Collision Avoidance?

Collision avoidance technology involves obstacle detection technology, which has been explained in some detail in the section on near-obstacle detection (page 42). In the automotive industry, wherever collision avoidance is discussed two issues arise: active (preventive) collision avoidance; and passive (detection) collision avoidance. The fundamental technology, however, remains the same and involves a combination of either ultrasonic sensors, or radar/microwave or infrared sensor-based detection systems.

Features of a Collision Avoidance System

Currently, there are no fully deployed collision avoidance systems, but many car manufacturers have developed prototype collision avoidance systems that could be deployed in passive or active systems. Typically, a passive system will give the driver advance warning of potential collision

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dangers, while active systems are configured with other electronic systems such as braking, transmission, cruise/engine control or, in extreme possibilities, steering control to actively avoid collision. Most of the research in collision avoidance technology is still under way, but we believe that first-generation systems will become available within the next few years (see Table 7-9 for the worldwide forecast).

Table 7-9
Worldwide Automotive Market Penetration of Collision Avoidance Systems (Percent)

Region	1993	1998	2000
Europe	0	5	8
Japan	0	5	7
North America	0	5	10
Asia/Pacific-ROW	0	1	5
Total	0	4	8

Source: Dataquest (April 1995 Estimates)

Future Applications of Collision Avoidance Systems

Active collision avoidance systems are designed to avoid collision. First-generation systems are already used in commercial vehicle applications for detecting objects in the drivers' blind spot areas. In the United States, Delco has developed a forward-looking radar warning system that is currently installed in Toyota's luxury Lexus range. Delco is also developing a full collision avoidance system integrated in an intelligent/active cruise control system.

Recent second-generation systems have been developed for use in cars to aid reversing and parking maneuvers. In Europe, BMW is already offering this system as an option for its cars; in Japan, Mitsubishi offers intelligent cruise control connected to throttle and transmission control on the top-range Diamante car model. Third-generation systems will likely be proactive systems linked to engine management and cruise control, braking systems, and, potentially, steering.

Major manufacturers developing collision avoidance systems include the following:

- Delco
- Kansei
- Mercedes-Benz
- Mitsubishi
- Nissan Diesel
- TEMIC (Telefunken)
- Toyota
- TRW

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Collision avoidance technology is a major function of so-called "cooperative driving" where cars traveling toward a common destination on motorways are batched together in wireless chains. The collision avoidance technology is deployed in the intelligent cruise control system (see earlier section) to facilitate a cooperative driving system that is proven in theory (simulation tests) to improve traffic efficiency.

Driving Stability Control Systems

What Is a Driving Stability Control System?

Driving stability control systems, known as DSC, are a new technology developed by Mercedes-Benz and Robert Bosch for next-generation, top-range Mercedes models. It involves a steering wheel angle sensor (optical sensor), a vehicle rotational speed sensor, acceleration sensors, wheel speed sensors, and yaw rate sensors; and deploys electronic steering with the ABS and traction control system. The main electronics of the DSC is integrated with the ABS and traction ECU. The objective of DSC is to monitor and maintain driver control of the vehicle to avoid loss of traction.

Features of Driving Stability Control

Driving stability control systems receive input from a steering wheel angle sensor, a mechanical magnetic vibration sensor (piezo-electric), wheel speed sensors, acceleration sensors and a yaw/rate sensor.

The system relies on a principle called "electronic brake force distribution," which governs the electronic system. Electronic brake force distribution applies a compensating brake force to diagonally opposite or adjacent wheels to counteract vehicle yawing and pitching. The system relies on many of the sensors in a traction control system and the ABS. The system processes data for rotational speed around the vertical axis and steering angle positioning for driver control analysis. DSC systems share the ABS and traction control actuators, and output data is fed from the control unit to the actuators.

The electronic control unit of this system uses a 16-bit MCU. The system applies braking to slow down a car if driving too fast on ice. Demonstrations of these systems in countries like Sweden and Norway have already received very good reviews in the automotive industry.

Driving stability control systems are now emerging in high-end cars and will begin to take off from 1997 onward (see Table 7-10 for the worldwide forecast). Mercedes-Benz will install this system on the new replacement E-class model. In Japan, Mitsubishi and Toyota are also evaluating a similar system for midrange vehicles.

The major ABS and traction control system manufacturers are leading in the development of driving stability control systems. Dataquest believes that by the end of the decade, driving stability systems will begin to appear in cars in all the major producing regions. Major manufacturers of driving stability control systems include the following:

- Allied Signal
- ITT Automotive (Teves)

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Table 7-10
Worldwide Automotive Market Penetration of Driving Stability Control Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	1	2
North America	0	1	2
Asia/Pacific-ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

- Kelsey-Hayes
- Lucas Braking Systems
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes

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Chapter 8
Body Control Electronics

Body control electronics includes all the electronics that control car body and chassis functions. Body control electronics improve vehicle comfort and convenience by making it easier to control body systems. They include such systems as central locking, sunroof, and memory seat controls.

As vehicle electronics in future systems begin to merge, many body control functions could be linked to other system controls such as powertrain management systems or dynamic vehicle control systems, which will include powertrain, suspension control, and steering control.

This chapter covers emerging applications that fall within vehicle body control areas such as the following, all of which will have a direct connection on the functionality of the vehicle's body electronics hardware:

- Tire pressure monitors
- Multiplexing systems
- Car computer (on-board diagnostics)
- Noise cancellation
- Accident recorders – automotive "black-box"

Tire Pressure Monitors

What Is a Tire Pressure Monitor?

Tire pressure monitors are not an entirely new concept but have been discussed in the automotive world for many years. A tire pressure sensor (electromechanical limit switches or semiconductor pressure sensors) is used to monitor each individual tire pressure, and sends an audible or visual warning signal to the driver reminding him to check air pressure. The sensor is actually located inside the rim of the wheel and is designed to withstand the high pressure of air in tires. An electronic receiver/decoder receives radiofrequency signal transmissions and outputs either a warning signal or the actual tire pressure of each individual tire.

In Europe alone, official statistics show that 50,000 people are killed in road accidents resulting from tire blowouts. Car manufacturers are keen to eliminate these fatalities by offering tire pressure monitors as a standard safety feature.

It is also proven that maintaining proper tire pressure improves tire wear and fuel efficiency. In underinflated tires, temperatures rise and this quickly deteriorates tread wear. Furthermore, underinflated tires can severely affect vehicle handling and steering, and this is potentially dangerous in built-up areas where pedestrians could be put at higher risk.

The trend is toward integrating tire pressure monitors with keyless entry systems using commonly shared RF receivers. Current pricing for tire pressure monitors range from $100 upwards to around $400. This makes it prohibitive for car manufacturers to fit them as standard on cars.

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Cheaper variations of tire pressure monitoring incorporated in antilock braking systems involve using the wheel speed sensors to track individual wheel rotation speeds. General Motors' Delco Electronics subsidiary is exploiting the theory that an underinflated tire has a smaller diameter, and therefore will have to rotate faster than a normally inflated tire. In theory, the fastest rotating wheel will have a lower pressure, but this theory is not always reliable and requires further development. Delco Electronics is one of the companies known to have been developing such a system.

Major manufacturers of tire pressure monitor systems are listed below, and Table 8-1 gives the worldwide forecast:

- Epic Technologies (USA)
- Schrader Automotive (USA)
- Robert Bosch (Germany)
- Delco Electronics
- Sentronics Limited (N. Ireland)

Table 8-1
Worldwide Automotive Market Penetration of Tire Pressure Monitors (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	1	2
North America	0	3	5
Asia/Pacific-ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

Dataquest believes that tire pressure monitors could be mandated for all vehicles in the next decade either through government legislation or from insurance companies. The technology is still too expensive for car manufacturers to justify, but with the uptake of RF keyless entry in vehicle immobilization systems, the potential remains for tire pressure monitors to be included.

Multiplexing Systems

What Is a Multiplexing System?

Multiplexing systems refer to the networked cabling and communications techniques designed to eliminate the multiplicity of wiring found in the typical vehicle, as brought on by the proliferation of electronic systems. Multiplexing technology allows the effective networked communications between linked electronic control units on the same data bus.

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Features of Multiplex Systems

Multiplexing generally is segmented into speed classes. One segmentation adopted by the US-based Society of Automotive Engineers (SAE) defines the speed classes as follows:

- Class A: Low-speed for body-wiring applications up to 10 Kbps
- Class B: Medium-speed for data-sharing applications, between 10 Kbps to 125 Kbps
- Class C: High-speed for local area networking, greater than 125 Kbps

At the moment, many car manufacturers are using the Class A–type multiplexing for door applications such as power windows, central door locking, alarm (car security), electric mirrors, and sunroof applications. Already, several standards are emerging from two major communication protocols, the J1850 and the ISO 9141. J1850 and ISO 9141 are the proposed protocols adapted for car diagnostics. Some car manufacturers are also developing their own proprietary communication protocols and standards. Table 8-2 lists some of the emerging systems.

Table 8-2
Emerging Multiplexing Systems

Standard	Diagnostic Data Link	Car Manufacturer
A-Bus	ISO 9141	Volkswagen
Basic CAN	ISO 9141	
CAN	ISO 9141	
C2D	J1850 or ISO 9141	
DLCS	J1850	General Motors
HBCC	J1850	Ford Motor Company
HSSD	J1850	Proposed U.S. high-speed standard
ISO 9141		
ISO 9141 CARB		(Meets U.S. CARB specification)
J1850		
PALMNET	J1850 or ISO 9141	Mazda
VAN	ISO 9141	PSA and Renault

Source: Dataquest (April 1995)

Benefits of Multiplexing

Probably the most measurable benefit of multiplexing technology is that it reduces the quantity of wiring harness in a vehicle. Each subsystem in the car will have a multiplex IC that acts as an interface chip with a defined I/O address and a priority rating for data processing and data management purposes on the data bus. This means that future systems will be easier to install as the wiring requirements will be greatly reduced.

From the point of view of the overall vehicle weight, a multiplexed data bus will reduce the weight of electrical wiring required for cars. This could also allow for more space in the vehicle body for additional electronics. The design of multiplexed wiring systems also eliminates wiring problems and difficulties associated with the already complex wiring harness

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of vehicles. The number of connectors required by existing wiring harness technology will also be reduced as a result of implementing this highly structured and hierarchical technology.

Overall, multiplexing technology contributes to integrating the vehicle's electronics and electrics by eliminating redundant sensors – sensors could be used more efficiently to feed input signals to one or more electronic control modules on the data bus. Likewise, multiplexed technology eliminates duplicate microcontroller functions by allowing more efficient use of microcontrollers in the same way as it allows the combination and integration of electronic control units.

Most importantly, this technology improves diagnostics as the communications systems and networks become integrated. This will speed up the processes of performing on-board diagnostic checks and off-board checks.

Future Multiplexing Systems

Future multiplexing systems will replace the complexities involved in contemporary vehicle wiring with potentially what will become a single "bus" (that is, one wire), using semiconductor interface chips as gateways. Low-speed multiplexing systems have been developed and are already in use by most car manufacturers for luxury cars. These systems operate such functions as windows, sunroof, door locking, and memory seat applications. Future developments will be for medium-speed and high-speed data bus systems.

Recently, the United States has approved the J1850 standard for Class B speeds. It incorporates many of the features that other U.S. vehicle manufacturers use in their proprietary standards. It appears, however, that vehicles made for the European market will be based on ISO 9141, while the North American market will use the J1850 protocol for diagnostic links. The Japanese and Korean manufacturers are likely to make all varieties to satisfy their overseas markets. Developments continue in the high-speed data bus area to develop the integration of engine management, suspension, power steering, braking, and transmission systems.

Major suppliers of multiplexing systems for automotive applications are listed below, and Table 8-3 gives the worldwide forecast:

- Chrysler
- Delco Electronics
- Ford Electronics
- Hella
- Nippondenso
- Robert Bosch
- Siemens Automotive
- TRW
- Valeo
- UK NSI

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Table 8-3
Automotive Market Penetration of Multiplexing Systems (Percent)

Region	1993	1998	2000
Europe	1	5	15
Japan	2	15	20
North America	3	20	25
Asia/Pacific-ROW	0	2	5
Total	2	11	17

Source: Dataquest (April 1995 Estimates)

Car Computer (On-Board Diagnostics)

What Is a Car Computer?

Car computer systems were first developed in the 1980s. It was during this same phase in automotive electronics that voice annunciators were being introduced into cars. Initially, car computers were designed to provide synthesized voice information giving warnings about engine oil pressure, fuel left in tank, door opened, temperature and other such information.

Features of Car Computer Systems

Newer systems include diagnostic check functions and are more sophisticated than the earlier-generation systems. The car computer system comprises a manually operated programmable input keyboard, LCD alphanumeric character display panel, and a microcomputer system. The keyboard acts as a driver interface with the system and the driver can set or obtain information including such functions as:

- Date, time (real time), and arrival time (estimated)
- Average fuel consumption
- Average speed
- Distance to destination
- Mileage conversions (miles to kilometers and kilometers to miles)
- Outside temperature
- Speed limit warning
- Stopwatch
- Timers (trip timers)
- Travel range

Input data is received and processed by the microcomputer from all other critical electronic systems such as:

- Actuators
- Airbag system
- Air-conditioning control

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- Alternator condition
- Antilock braking system
- Battery condition
- Door locks
- Engine management system
- Engine oil pressure
- Exhaust emission
- Fuel tank sensors
- Ignition control
- Lights
- Power steering
- Power supply
- Seat belts
- Speed
- Temperature (external/internal)
- Wiper control (windscreen and driving lamps)
- Wiring (short circuit detection)

All the above systems are tested by the microcomputer in a diagnostic check function by running programmed memory with test patterns for each system, which can be retrieved and used for comparisons. Each peripheral system has an address and the data and address buses are included in the system test routines. Sensors are tested for performance within specified limits while open and short circuits can also be detected.

Output data from the test results (diagnostics) is fed back to the car computer and displayed, or audible synthesized voice annunciation is made to communicate the results to the driver through the car speakers.

Newer systems being developed provide temporary software solutions to provide a "limp home" solution to engine problems or electrical problems. Sometimes the limp home solutions may, for example, involve disabling electronic systems that control faulty mechanical functions or actuators. Here, multiplexing technology and its protocols will vastly improve the prioritizing of data checks that are required for systems diagnostics; thus, a faulty electronic transmission system would be switched off by a car computer to allow full manual operation as a limp-home solution.

The application of car computer systems such as the fully diagnostic system described above is very low (see Table 8-4). The development costs of such systems are very high as for each new generation of electronic systems that are input sources to the computer, the diagnostic software often needs redevelopment.

This has sustained the high cost of these systems and, consequently, the low penetration rates. Trip computers are a scaled-back version of the car computer system, and these are gaining some significant penetration

rates. Dataquest believes, however, that future legislation and enforcement tactics of some car systems such as exhaust emissions may lead to increased use of such systems in cars and commercial vehicles.

Major players in car computer systems include the following:

- Delco Electronics
- Ford Electronics
- Magneti-Marelli
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Valeo
- VDO (Mannesmann)

Table 8-4
Worldwide Automotive Market Penetration of On-Board Car Computers (Percent)

Region	1993	1998	2000
Europe	4	15	20
Japan	5	12	20
North America	8	10	15
Asia/Pacific-ROW	1	3	5
Total	5	11	15

Source: Dataquest (April 1995 Estimates)

Active Noise Cancellation (ANC)

What Is Active Noise Cancellation?

Noise cancellation systems are designed to electronically cancel unwanted cabin noise and external noise from the engine and exhaust mufflers. The benefits extend beyond making vehicles quieter to making them also more energy-efficient. The concept of active noise cancellation involves two major sources of noise, namely cabin noise and engine noise.

Features of Active Noise Cancellation

Cabin noise (or passenger compartment noise) is usually amplified through the body of the car from materials that absorb and transport noise into the car. Primary contributors of noise are the engine, engine mounts, suspension (shock absorbers), and the car body itself. Noise cancellation technology relies on the application of DSP chips to control noise from engine mounts, electronic mufflers and interior quieting. The controller processes a cancellation algorithm, which is stored in the RAM of the DSP chip. The process of noise or vibration cancellation is performed by a signal that is its exact mirror image at the same noise/vibration amplitude but 180 degrees out of phase.

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Current development for active noise cancellation ECUs will initially be standalone, although they could become integrated in engine management system.

Future Applications of Active Noise Cancellation

The electronic control unit itself receives signal input from the throttle and tachometer to predict engine noise occurring from car acceleration. Other sensors include a microphone in the muffler, a microphone in the air vents, and an additional number of microphones in the passenger compartment. Each of these signals are processed by the electronic control unit, which then outputs command signals to actuators that control loudspeakers and exhaust flow modulation for the electronic mufflers, hydraulic dampers and noise dampening systems on the car body, and the interior compartment loudspeakers through the car stereo. This particular application is deemed to be most attractive for small cars, which tend to have very small amounts of sound insulation by the nature of small car construction.

A major and measurable financial benefit and justification for noise cancellation systems is that they could offer fuel savings to the driver. ANC allows control of engine vibrations, allowing smaller engines to idle at lower speeds, thus saving fuel.

Noise cancellation systems are in use by specialist car manufacturers especially in the sport of motor-racing. But commercial application of noise cancellation has been slow because the systems contribute very little benefit for larger vehicles, which have better insulation and, nowadays, highly refined engines that are quieter than earlier generations. Some commercial vehicle applications for exhaust mufflers have been established but with very limited success among commercial vehicle manufacturers.

In Europe and Japan, Fiat and Nissan have been reported as evaluating active noise cancellation systems for a new range of small cars planned for market introduction after 1998. Prototype small cars fitted with this technology drive very quietly, which gives a perception of being more expensive-sounding vehicles. Depending on the cost of future systems for small cars, these systems could appear in cars in a big way by the end of the century although at this point in time, we believe they are further away than that (see Table 8-5 for the worldwide forecast).

Table 8-5
Worldwide Automotive Market Penetration of Active Noise Cancellation (Percent)

Region	1993	1998	2000
Europe	0	10	15
Japan	1	5	10
North America	0	13	20
Asia/Pacific-ROW	0	2	5
Total	0	8	13

Source: Dataquest (April 1995 Estimates)

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Costs associated with DSP application are one of the major factors why introduction of these systems is being stalled. However, legislation against noise pollution from HGVs and commercial passenger buses could also affect the introduction of this technology in vehicles.

Companies developing active noise cancellation technology include the following:

- Calsonic (Tokyo)
- Digisonix (U.S. pioneer of ANC)
- Elesa (a Fiat-owned Magneti-Marelli subsidiary, and joint-venture company with Noise Cancellation Technologies Inc.)
- Lotus Engineering
- Lucas Automotive
- Nissan (Japanese Bluebird model ANC)
- Saab
- Ultra Electronics (developed Saab commuter aircraft ANC system)

Accident Data Recorders—"Automotive Black-Box"

What Is an Accident Data Recorder?

Accident data recorders (ADRs) or automotive black boxes are a technology descended from the aviation industry that is slowly finding a place in modern vehicles. The applications of black boxes in the aviation industry are most commonly for aircraft diagnostics and also for examination to determine the likely causes of air crashes.

There are many different variations of accident data recorders, but the most sophisticated systems have diagnostic systems that monitor performance algorithms of all the key electronic systems in a vehicle.

Features of Accident Data Recorders

Aircraft accident data recorder systems emerged from diagnostic monitoring systems. The technology of these systems is now modified for cars to track vehicle behavior before, during, and after an accident.

An accident data recorder receives input signals from diagnostic functions of car electronic subsystems. Typically, the ECU of the system has an 8- or 16-bit microcontroller, and a certain amount of memory buffer. The basic system receives input from the ignition switch, speedometer, brake light sensors, indicators (left/right), and lights. More sophisticated accident data recorders may receive signals from ABS/traction control (optional), airbag (including side impact airbags), navigation systems (optional), and engine management systems. All these systems include the following sensors that are constantly monitored by the ADR unit:

- Accelerometers
- Azimuth sensors
- Brake signals/sensors

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- GPS data
- Lateral sensors
- Longitudinal sensors
- Transmission sensors
- Vertical sensors

After an accident has occurred, the latest driver reactions before impact are digitally stored in the system. This data could be analyzed to prove cause of accident and performance of safety critical subsystems such as ABS, airbags, and electronic brakes.

Future ADR Systems

The ADR system has many benefits that could become attractive for a range of applications. Firstly, for the general public, effective marketing of these systems by car manufacturers will help raise consumer awareness. If these systems are not marketed properly, consumers could view them as hostile electronics that monitor their driving habits.

Secondly, fleet operators may easily justify installing ADR systems for their vehicles. Taxi companies, for example, may find that their insurance claims will be less when drivers know that their vehicles are fitted with ADRs.

Thirdly, insurance companies may influence the installation of ADRs in cars to speed up processing of accident claims and to reduce the rate of accidents among their own policyholders. In theory, if drivers know that their driving habits are being recorded, then they might be more cautious about avoiding careless driving, and this could reduce accident rates in favor of insurance companies.

Fourthly, ADRs could provide safety-critical system diagnostics for the driver to enhance the diagnostics already in place for each car system. This could be beneficial for drivers who frequently wish to feel secure in their cars before making long journeys.

However, for these systems to gain market acceptance, they may require legislative instruments to support the application of the data they provide. For example, laws pertaining to road use vary across Europe; certain standards of data gathering that meet national traffic regulations will need to be developed further.

Major suppliers of accident data recorders are listed below, and Table 8-6 gives the worldwide forecast:

- Bosch
- Mannesmann
- Valeo
- Sagem
- Siemens Automotive
- TEMIC (Telefunken)

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Table 8-6
Worldwide Automotive Market Penetration of Accident Data Recorders (Percent)

Region	1993	1998	2000
Europe	0	3	10
Japan	0	4	20
North America	0	5	20
Asia/Pacific-ROW	0	1	1
Total	0	4	13

Source: Dataquest (April 1995 Estimates)

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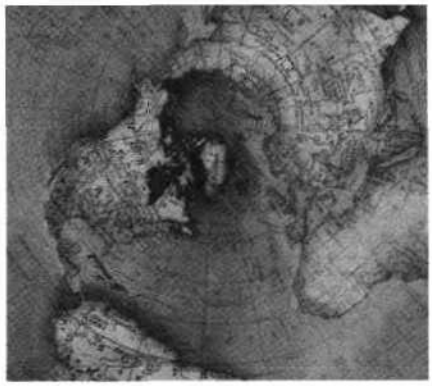
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Emerging Automotive Electronics Applications



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Emerging Automotive Electronics Applications



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Chapter 1
Executive Summary and Introduction

Executive Summary

The market for automotive electronics is now set for further growth as global issues begin to place even more emphasis on strict exhaust emission regulations for both petrol and diesel engines becoming enforceable over the next few years. Developments of advanced driver information and traffic control systems will keep this strong momentum into the new millennium.

Historically, powertrain electronics and safety electronics have been the growth drivers in this market segment. Dataquest estimates that growth in automotive electronics is reaching maturity for powertrain electronics, which now accounts for nearly 50 percent of the worldwide automotive electronics market. Safety applications such as antilock braking systems (ABS) and airbags have also emerged and will continue to grow into the next decade as factory installations and aftermarket opportunities increase.

Fresh new impetus for further growth is anticipated to come from newly emerging communications applications for road transport/traffic and vehicle systems. The European Union (EU) and the European automobile manufacturers have committed more than $1 billion in the PROMETHEUS research program, which aims to halve the EU's 50,000 road deaths a year by the year 2010 through greater use of in-car electronic information systems and other technological developments.

The new "smart" cars for the next decade will be intelligent cars that can:

- Illuminate long distances in the dark with infrared and ultraviolet headlights
- Cruise intelligently by automatically keeping pace with the vehicle in front
- Know exactly where they are, using satellite navigation
- Summon emergency services to the exact location of a breakdown or accident with or without any driver action

This report explores the implications of this future strategy for cars of the future – so-called "smart cars" – for the electronic components industry and provides an insight to developments in this area. The report identifies 25 newly emerging electronic applications for the intelligent cars of the future and identifies the opportunities for future electronics growth in this fast-growing market segment.

Introduction

Automotive electronics is a rather fragmented semiconductor application market, but all the automotive electronics systems will eventually become integrated. This integration will occur as multiplexing technology advances to allow each of the subsystems to be interconnected. Thus, it is conceivable that automobile electronics will become one of the top five

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global electronics markets for semiconductor and passive electronic components. As a single system application, the personal computer aside, automotive electronics is forecast to be one of the single most important "engines" for semiconductor components in the next century. Worldwide, the average semiconductor content of a vehicle is now estimated to be in excess of $100.

By the year 2000 average semiconductor content per vehicle will be nearly $200. Worldwide automotive semiconductor consumption in 1994 amounted to $5 billion. By 2000, the demand for semiconductors by cars and commercial vehicles is expected to at least double, exceeding nearly $10 billion.

Electronic applications in the car (specifically integrated circuits) first appeared in commercial volumes during the 1960s as voltage regulators for alternators and also ignition control. During the 1970s the world fuel crisis led to the introduction of electronic control for fuel injection and carburetor engines. The 1980s brought legislation in the United States for electronic engine control systems to curb engine exhaust pollution. By the 1990s electronics in the car was widespread in various automotive applications from engine management, air conditioning, dashboard, security systems, vehicle tracking devices, and safety applications such as airbags and ABS, and driver navigation systems for route planning and traffic information.

In the 1980s and 1990s, environmental factors were driving electronic penetration in cars. Recently (the late 1980s and early 1990s), electronics was used as a product differentiator among car manufacturers, and the use of electronics has now advanced past that stage, ushering in a new era where vehicle emission legislation and safety regulations account for growth. Nowadays, these metrics are taken for granted, and electronics is being used to improve vehicle safety and optimize vehicle functionality.

Current research indicates that electronics and vehicle electrics account for nearly 12 percent of the total cost of a midrange car; by 2005 this cost is forecast to exceed 25 percent of the cost of a new car. New factors are beginning to drive the use of electronics in cars. Virtual market forces (aside from legislation and regulation) are now emerging as, for example, insurance companies begin to mandate the use of electronics to enhance car security.

By the end of the decade social, political, and economic factors enforced by governments, and the entire fleet transportation industry, will begin to drive the use of electronics in cars. The millions of dollars spent on research and development for the transportation industry will also be expected to yield dividends for the commercial sector. At the end of 1994, the European Commission was publicly censured by automotive manufacturers for failing to honor its financial and strategic planning obligations under the joint industry and EU precompetitive research program.

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We have partitioned each emerging technology development in the report into three main sections:

- **Advanced driver information and communication systems (Chapter 6):** This looks at all the areas of development that contribute to increased driver awareness for road safety and road conditions.
- **Powertrain electronics (Chapter 7):** Covers all aspects in motor vehicles that affect the physical design of powertrain or motion aspects of the vehicle and include engine management, suspension control, and vehicle handling.
- **Body control electronics (Chapter 8):** Deals with the entire electronics infrastructure from door body control, windows, central locking, lights, wipers, and security systems.

Please note that in the tables showing worldwide penetration of electronic systems, penetration rates are shown as a proportion of annual car production volumes in each world region.

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Chapter 2
Factors Driving Demand for Emerging Automotive Electronics Applications

Because the automotive industry is a global industry, certain regional factors have a very strong impact on the global markets. Legislation, safety, security, and environmental issues have recently impacted automotive electronics applications in cars. Europe, the United States, and Japan are the three major car producing regions worldwide. Any future changes affecting this industry are mostly influenced by the issues and decisions of these major regions.

Emerging electronic automotive applications will be influenced by a combination of factors as car manufacturers, governments, and communities actively respond to curbing the rate of vehicle traffic congestion and the effect of global air pollution in major world cities. Figure 2-1 summarizes new areas for development toward the year 2000 and beyond. These plans are expected to result in increases in demand for electronics in automobiles.

In a regionally structured initiative, the major automotive markets worldwide—namely the United States, Europe, and Japan—have each formed research coordinating organizations aimed at achieving the above objectives. In the United States, the entire concept is referred to as IVHS (Intelligent Vehicle Highway Systems), and in Japan it is known as ARTS (Advanced Road Transport Telematics), while in Europe it is commonly referred to as RTI (Road Transport Informatics).

IVHS America is a coordinating organization set up by the federal government to pursue and advance the development of research programs, pilot trials, and precompetitive cooperative product development of infrastructure systems for road transport telematics. Participants of IVHS America are government agencies, companies allied to the automotive industry, and the information technology industries in the United States.

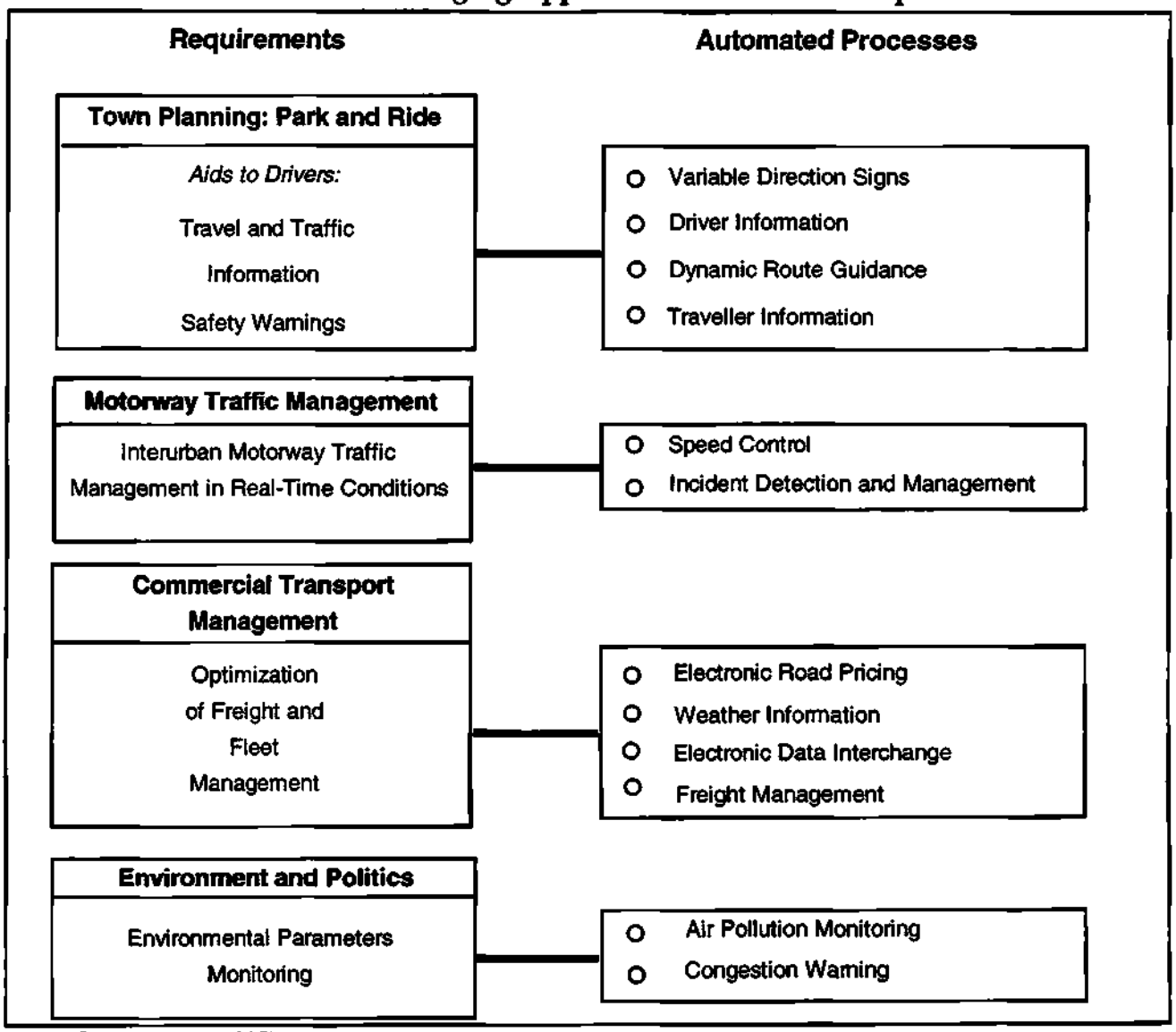
ARTS is the Japanese initiative which aims to coordinate a number of national and governmental research projects involving companies in the automotive industry (both manufacturers and suppliers) to achieve goals similar to the IVHS America initiative.

RTI is the active program in Europe to realize advanced road traffic systems under way across Europe. It coordinates, through a number of European Commission research projects, precompetitive cooperative research among competitor companies, car manufacturers, and government agencies.

Telematics refers to the merging of communications and computing technology making it possible for traffic information to become more widely accessible by motorists. Telematics is a central infrastructural requirement of the global IVHS efforts and will itself require yet more investment in certain infrastructure areas before implementation. Worldwide, the target date of 2010 set by IVHS America and Europe's PROMETHEUS program is steering the industry toward achieving these goals.

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Figure 2-1
Advanced Road Telematics: Emerging Applications from New Perspectives



Source: Dataquest (April 1995)

This report identifies future opportunities for automotive electronic penetration in vehicles that will make the European initiative achieve the 2010 objective. It also identifies the potential new semiconductor markets that will be generated as a result of this objective for the global automotive market.

Most microelectronics applications in cars improve the control or efficiency of existing mechanical systems. Consequently, the use of electronics is often perceived as additional cost. Nowadays, electronics addresses more than control and efficiency. It provides more accurate monitoring of the various parts of a car. From ignition, engine, transmission, through to braking control—start to stop—electronics are used to maintain optimal performance. Microcontrollers (MCUs) are used to control, monitor, and process analog signals from the mechanical operations of the car. Thus, most automotive systems have a microcontroller, voltage regulator, analog interface, and an I/O driver interface.

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Chapter 3
What Future for Microelectronics in the Car?

Future car microelectronics will be toward replacing some mechanical systems and permitting further integration of electronics and mechanics. Independent surveys of the automotive industry show that nearly 90 percent of all electrical faults that occur in vehicles are because of the connector. Therefore, in at least 90 percent of all electronic fault cases, the system itself is not responsible for failure.

Several companies have advanced research in system connectors. Specifically in Europe, BMW is among those that have advanced car electronic connector technology, and its patents are now being licensed to several German and European car manufacturers. But there is still more development ahead for integrated systems such as mechatronics.

A second area of equal importance and market potential for development is the use of silicon sensors. The automotive industry is now approaching certain requirements that can no longer rely on existing technology. Where existing technologies can meet these requirements, they are often too costly to implement and design-in.

Specifically for airbag applications, micromachined accelerometer sensors are required to further reduce the risk of false airbag trigger. In meeting the U.S. legislation for side impact protection, most manufacturers are seeking newer but lower-cost silicon sensors that predict crash impact. A combination of radar and optical sensors could be used for side impact detection but the limitations here are false airbag triggering, as some vehicle collision is avoided even after getting as close as two millimeters.

Mechatronics is the concept of integrating electronics and mechanical parts to form a completely integrated system. Antilock braking systems are a prime example of mechatronics, where brake plungers and electronic sensors are designed into mechanical components for controlling vehicle braking.

Many areas still remain to be resolved as car electronics (and car electrics to a lesser extent) is a relatively young technology in search of many solutions from the semiconductor industry. Furthermore, some of the technologies required for automotive application are not readily available as costs are still too high for automotive engineers to design-in such components. In the sensors area, for example, suppliers of military electronic systems that found their markets extinguished at the end of the cold war have attempted to diverge into the automotive segment. Here, new processes and technology are required to meet the automotive needs. The volume application potential for silicon sensors for automotive applications is very substantial.

Much still needs to be resolved as car electronics is a relatively new technology in search of many solutions from the semiconductor industry. New developments in the semiconductor industry itself present many automotive opportunities, and examples include integrated IC connectors, electronic packaging, wiring, multiplexing, and semiconductor technology for

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applications such as smart power, radiofrequency (RF), millimeter-wave sensors, piezo-electric sensors, and newer but cheaper accelerometer sensors.

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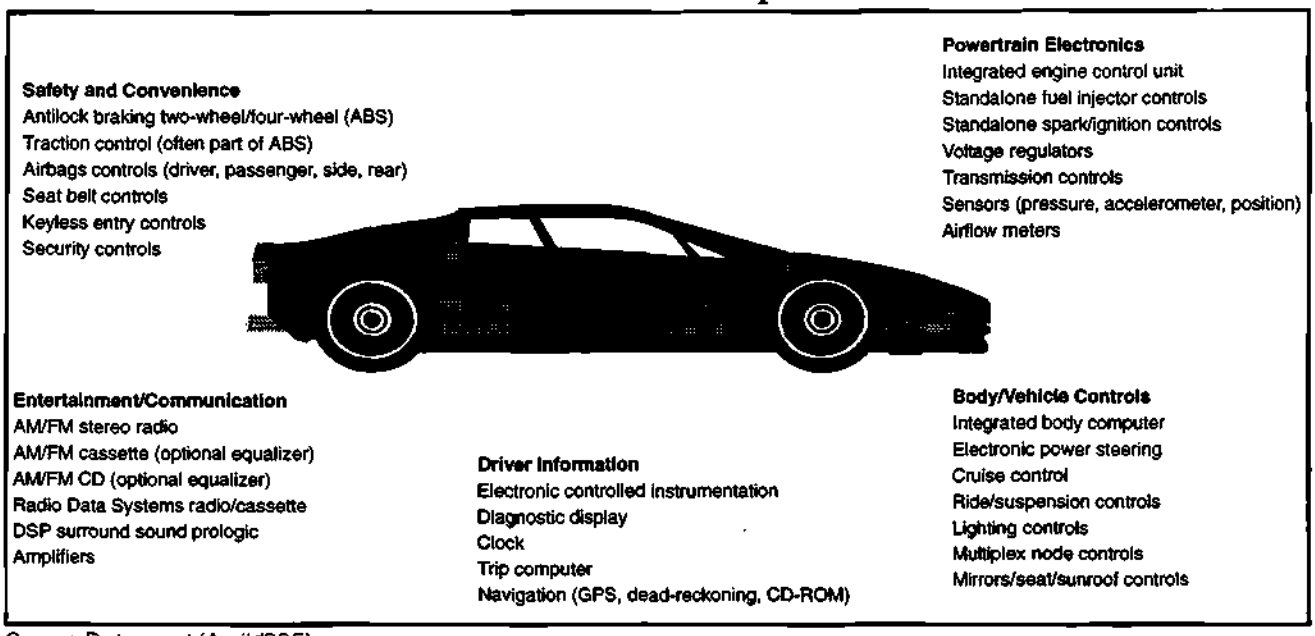
Chapter 4
Worldwide Automotive Electronic Markets

Figure 4-1 shows the current electronic systems that are available for automotive applications. Many of these systems are available as aftermarket systems that are not installed at the factory by the vehicle manufacturer. This report focuses on the new emerging applications (see Figure 5-2 in the next chapter). To bring the volume applications of these systems into perspective, Table 4-1 gives our current forecast for worldwide car production.

Europe is the leading manufacturer of cars worldwide, accounting for almost 35 percent of global car production. This pattern will likely change as the big emerging markets (BEMs) of Asia, central and eastern Europe, and Latin America begin to take shape. The final formation of car production demographics beyond the year 2000 is still quite uncertain as car ownership has a very strong correlation with economic gross domestic product (GDP). However, China represents the single car market with the largest potential and is likely to become an important producing country beyond 2000. Other important BEMs include eastern Europe and Latin America, although it is widely acknowledged that eastern Europe holds more prospects than the Latin American markets.

Dataquest believes that the major car manufacturers will continue to control car production globally and will retain the relationships of established suppliers rather than extending their supplier relationships with more suppliers. Already, automotive component procurement is being actively trimmed by most manufacturers in a drive to further cut manufacturing costs. Some car manufacturers are forming joint procurement groups to procure components with their competitors to drive down system costs.

Figure 4-1
Automotive Electronics—Standard Features and Options



Source: Dataquest (April 1995)

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Table 4-1
Worldwide Car Production Forecast
(Millions of Units)

Region	1993	1998	2000
North America	7.34	8.33	8.65
Light Trucks	5.83	7.47	7.80
Europe	11.33	11.84	13.53
Japan	8.50	9.29	10.29
Light Trucks	0.96	1.20	1.35
Asia/Pacific-ROW	3.97	5.15	7.24
Total Cars	31.14	34.61	39.71
Total*	37.93	43.28	48.86

*Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

Japanese car production is forecast to slow toward the year 2000 and will probably decline as production shifts away from Japan to Europe begin to gain momentum toward the end of the decade. U.S. car production will continue a healthy growth as favorable currency exchange rates continue to make U.S. cars competitive in the global markets. European car production will soar toward the year 2000 as eastern European manufacturing begins to ramp up and Japanese transplant manufacturing activities enter their final phase of production volume expansion.

Manufacturers from the Asia/Pacific region are expanding capacity and beginning to establish manufacturing sites outside their region. The region is dominated by the Korean vehicle manufacturers but there is also a sprinkling of minor car manufacturers serving countries in this region. The newest car manufacturing company is electronics conglomerate Samsung of Korea, which is working with Nissan Motors of Japan to start manufacturing cars.

Penetration of car electronics across all regions is forecast to grow rapidly toward the year 2000. The automotive industry in the 1990s is achieving goals of reducing car development cycles from five years to three years on average, and this is now rapidly approaching two years. Moreover, the automotive industry is experiencing some very radical market trends that will stimulate increased electronics penetration.

The latest trend shows that traditional market demographics of small, medium-size, and large car markets are moving to include more exotic vehicles. The new demography includes performance sport cars (ranging from high-performance roadsters to hatchback convertibles), four-wheel drive (4WD) vehicles (high-end, midrange, and low-end versions), and multipurpose vehicles (MPVs). Nowadays, the new vehicles are all fitted with standard electronic systems such as ABS, airbags, engine management controls, power windows/sunroof/roof (convertibles), central door locking, alarm systems and immobilizers, and RDS (Radio Data Systems) stereo radiocassette systems. On a worldwide basis about 100 new car models are introduced on the market each year. Each new car model

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announced ultimately increases the numbers of controllers, sensors, electric motors, actuators and general electronics in cars.

Automotive Electronics Systems Market Trends

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming 6 modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the powertrain area. A trend toward 32-bit microcontroller-based integrated modules is being stimulated by efficiencies needed for even stricter and tighter emission controls and fuel consumption requirements.
- Electronic-intensive antilock brakes and airbag controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (legislation in Europe) to be used in high-end and midrange cars.
- Driver-side airbags are becoming standard equipment on almost every vehicle. Passenger-side airbag versions have now entered the market, and rear passenger airbags (rear-seat and door/side impact) are emerging as an option. Strictly speaking, side-impact is being driven by legislation in the United States for side impact protection by 1998. Three versions are emerging: those installed in the door, seat, and car frame pillars.
- Europe is leading the world in the development of side-impact airbags. Volvo was first to come to market with side impact, quickly followed by Saab and BMW. Porsche, Mercedes, and Jaguar are planning introduction later this year for 1996 models. The European standard for side impact airbags is more rigorous than the U.S. standard: the European standard is based on deflection and force, while the U.S. standard is based on acceleration.
- Electronic suspension and steering are now beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information, and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry and light timers are proving popular options in an ever security-conscious world.
- Personalization features such as memory seats, memory mirror, and radio settings are now popular on high-end models, with future models extending personalized settings to include engine management, glove compartment locks, and fuel usage depending on driver code.
- Entertainment systems continue to be cassette-based today, with CD-based systems emerging at a modest rate. New digital compact cassette (DCC) and Mini-Disc (MD) systems have begun to find their way into 1994/1995 vehicles. Intelligent/distributed speaker systems (surround sound) are becoming more common.

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- Digital audio systems and technology for car radio is still developing rapidly with RDS now being introduced in the United States, and Japan likely to follow. RDS alerts the driver to traffic reports and will display radio station format and call letters. Digital audio broadcasting (DAB) for car radios is also set to emerge by the end of the century.
- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 multiplexing protocol has been adopted in the United States. This interface is heading toward serving the communication link between modules. Europe is settling on a standard called ISO 9141 and other proprietary standards like Intel's and Bosch's CAN, and the French VAN standard.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement for a 2 percent requirement on all vehicles sold in that state by 1998 (10 percent by 2003). Several manufacturers have chosen a minivan test platform. The most critical challenges are creating cost-effective battery technology and fast-charge batteries. Nickel metal hydride seems to be the leader at the moment. Electric vehicles currently cost about 50 percent more than the petrol versions. Battery life averages about three years; it costs the consumer $3,000 to replace them. Hybrid approaches are being considered including advanced flywheel technology.
- Navigation systems based on dead-reckoning technology and the Global Positioning by Satellite System (GPS) are becoming very popular in Japan and are now emerging as standard options in the United States and Europe. General Motors has introduced a $2,000 system that uses a PCMCIA format card for the map database and a Motorola-based 68EC020 processor for GPS and dead-reckoning processing (made by Zexel and Rockwell). BMW has chosen the Philips CARIN navigation system with dead-reckoning, GPS, and audio annunciation—it also doubles as an in-car television set.
- With the pressure on environmental cleanliness and fuel efficiency, diesel car sales are now on a rapid and steady growth curve. New diesel engine technology is allowing electronic diesel engine management systems to proliferate, achieving performances matching petrol cars and increasing fuel efficiency of traditional diesel engines. Diesel engines are also benefiting from the use of electronic engine control systems that help reduce the emission of harmful exhaust particulates.

World Automotive Electronics Production

Worldwide factory revenue of automotive electronic equipment production reached nearly $36 billion during 1994 (Table 4-2). The fastest-growing regions continued to be North America and Europe, with some growth also measured in the Asia/Pacific region specifically in Singapore and Korea.

During 1994, key market growth indicators from a global perspective include:

- **Powertrain electronics**: Engine management systems and diesel engine management systems
- **Safety and convenience electronics**: Airbags and ABS

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- **Body control**: Multiplex door wiring and car security systems
- **Security systems**: Immobilizers and car alarms
- **In-car entertainment**: CD players and navigation systems

Dataquest forecasts that first-generation systems for driver information systems such as integrated car navigation and traffic information systems will begin to appear on the market from 1988 onward. The market for these systems are forecast to begin to take off when infrastructure systems become available. Table 4-3 shows our worldwide forecast for automotive electronic production by end-application segment.

Table 4-2
Worldwide Automotive Electronics Production by Region, Factory Revenue (Millions of Dollars)

Region	1993	1994	1998	2000
North America*	9,458	11,311	15,022	16,824
Europe	8,558	9,953	15,763	17,313
Japan*	11,519	11,843	14,099	15,981
Asia/Pacific-ROW	2,676	2,922	4,596	6,994
Total*	32,211	36,029	47,480	57,112

*Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

Table 4-3
Worldwide Automotive Electronic Production by End-Application Segment, Factory Revenue (Millions of Dollars)

Segment	1993	1994	1998	2000
Entertainment	5,871	6,191	8,452	9,652
Body Control	3,077	3,495	5,532	6,594
Driver Information	5,464	5,893	7,584	9,068
Powertrain	10,607	11,929	16,425	18,541
Safety and Convenience	7,193	8,521	11,486	13,257
Total	32,211	36,029	49,480	57,112

Source: Dataquest (April 1995 Estimates)

We have projected a conservative forecast for the overall automotive electronics market to reach more than $57 billion by the year 2000. Powertrain electronics and safety and convenience electronics are forecast to dominate as requirements for increased security functions and tighter regulations governing emissions take off. A number of factors such as legislation, pressure from insurance companies and, ultimately, demand for further electronics could push up the demand for automotive electronics even more.

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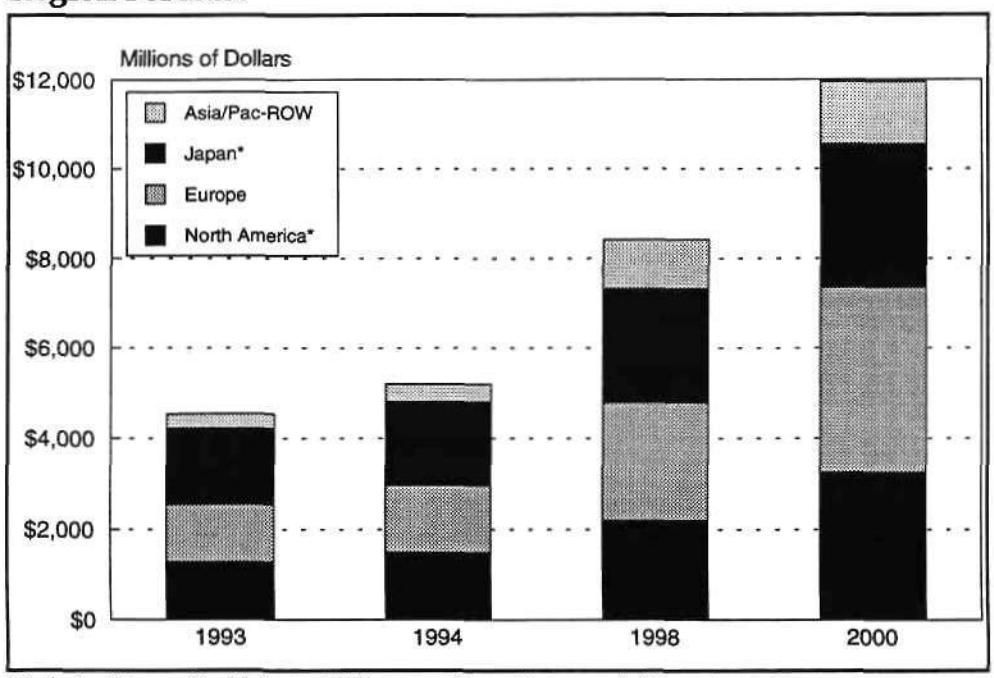
Chapter 5
Worldwide Automotive Semiconductor Markets

Dataquest estimates that the worldwide semiconductor market for automotive applications reached $5.2 billion in 1994. By the year 2000, worldwide semiconductor demand for automotive applications is forecast to reach nearly $10.2 billion (Figure 5-1). By that time, the fastest-growing regional market for automotive semiconductor components will be the Asia/Pacific region. However, as a result of global component procurement, just-in-time deliveries, and flexible but shorter cyclical R&D requirements for local automotive production, Dataquest forecasts that by 2000, Europe will account for 40 percent of the worldwide semiconductor consumption, and Japan and the United States will account for 24 percent and 32 percent, respectively.

In North America the factors driving growth are tighter emission controls with more sophisticated engine control units being developed as well as safety applications like airbags to meet side-impact protection legislation in the United States from 1997.

European automotive semiconductor growth has been spurred by growth in electronic engine immobilizer systems and car security systems, in addition to airbags, ABS and engine control units. Diesel engine management systems are also taking off in Europe—already nearly 25 percent of cars sold in Europe are diesel engine cars. Toward the year 2000, we anticipate that digital audio broadcast receivers will begin to appear in car radios and driving stability guidance systems (an extension of ABS and traction control).

Figure 5-1
Preliminary Worldwide Automotive Semiconductor Markets by Region Forecast



* Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

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The Japanese automotive segment is driven by the entertainment and driver information systems markets. Car navigation systems are proving very popular in Japan and are forecast to maintain this growth momentum toward 2000, by which time many Japanese car manufacturers will be fitting these systems into cars at the factory.

Growth in the Asia/Pacific region is coming from demand by Korean car manufacturers such as Hyundai, Kia, and Daewoo, and Malaysian car manufacturer Proton, which are ramping up manufacturing capacity to match demand coming from both western and eastern European countries. This means that they now have to meet the emission control legislation in these markets and therefore fit more engine management systems and catalytic converters to their cars.

Overall, by end-application market segment (see Table 5-1), powertrain electronics represents nearly 50 percent of the automotive semiconductor total available market (TAM). Safety and convenience applications now account for nearly 25 percent of the automotive semiconductor market. The remainder of the market is mostly in-car entertainment electronics.

Table 5-1
Preliminary Worldwide Automotive Semiconductor Markets by End-Application Segment (Millions of U.S. Dollars)

Segment	1993	1994	1998	2000
Entertainment	681	727	1,262	1,793
Body Control	545	519	842	1,195
Driver Information	363	416	505	956
Powertrain	2,044	2,389	3,871	5,258
Safety and Convenience	909	1,143	1,936	2,749
Total	4,543	5,194	8,416	11,950

Source: Dataquest (April 1995 Estimates)

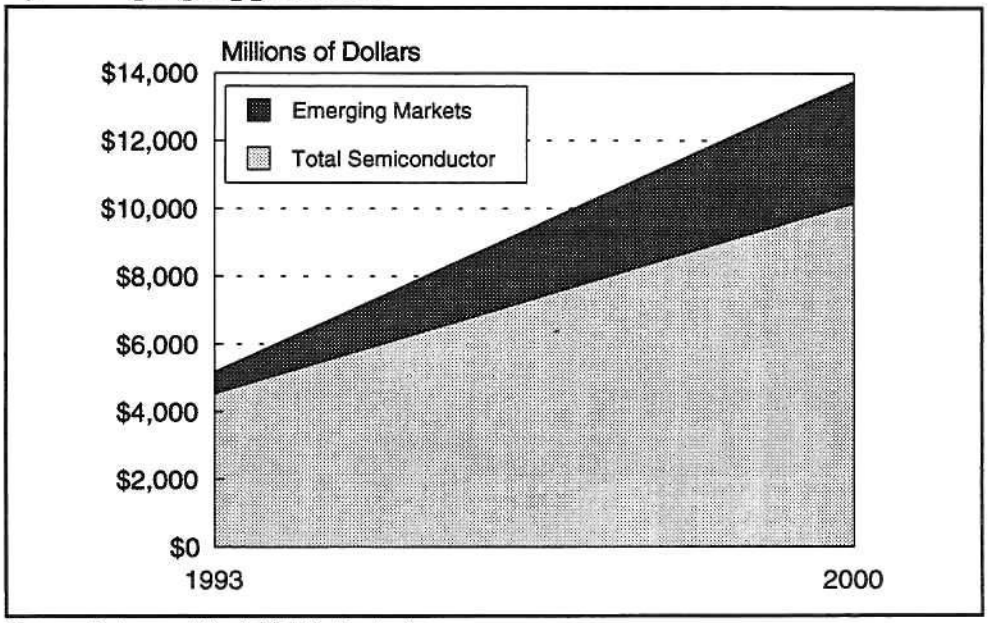
Emerging applications highlighted in this report are mostly driver entertainment, powertrain, and body control electronics. This could add an additional 10 to 50 percent of semiconductor business to the worldwide automotive segment alone. This report identifies the additional electronics business potential for emerging automotive applications shown in the top layer of Dataquest's forecast for worldwide automotive semiconductor markets in Figure 5-2.

Product Trends of Existing Automotive Electronic Systems in the Car

Cost sensitivity in automotive electronics affects product trends of existing systems. Car electronic systems are continually being upgraded, improved, and refined. In many nonsafety or nonlegislated application areas, the automotive industry itself cannot justify development costs. Often, economies of scale in other related electronics markets, such as communications and consumer electronics, drive down technology costs before they appear in the car. Figure 5-3 illustrates the systems included in the so-called "smart car" of the future.

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Figure 5-2
Contribution to Worldwide Automotive Semiconductor Growth by Emerging Applications



Source: Dataquest (April 1995 Estimates)

In the driver entertainment area, new technologies have enhanced car stereo systems as developments in audio technology have migrated from the home into cars. Examples are compact disc players, digital audio tapes (DAT)—albeit not very successful to date—digital compact cassettes, Mini-Discs, and in the near future, digital audio broadcasting. The evolution of in-car entertainment continues with the pace of development in consumer entertainment markets.

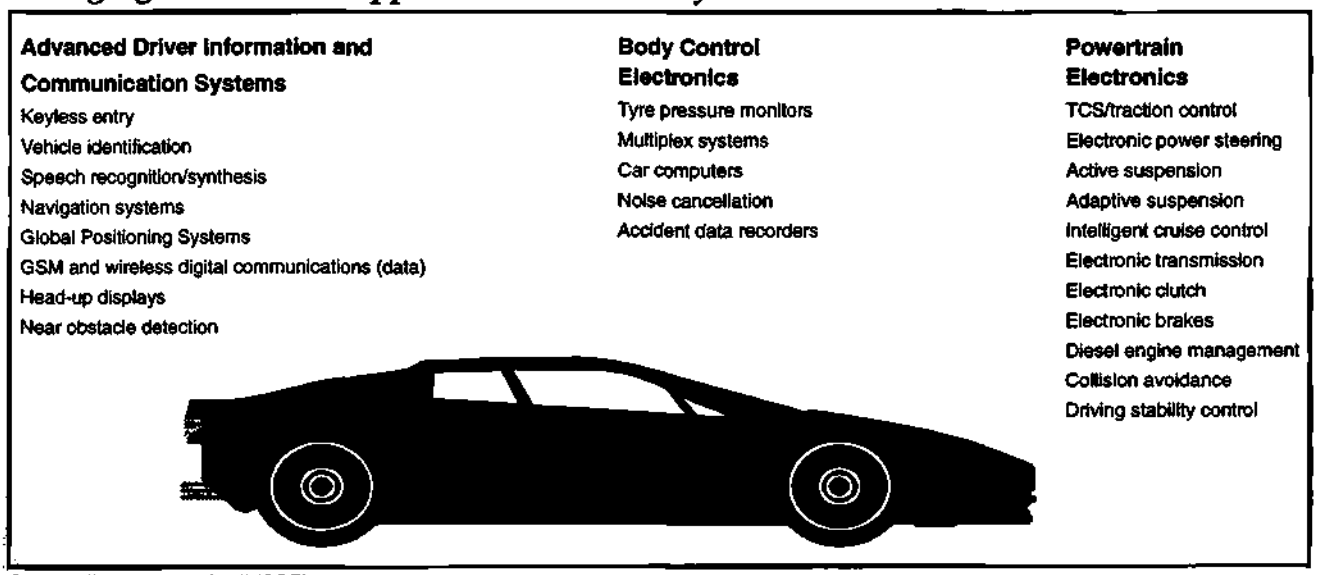
Other factors such as environmental pressures continue to affect development in areas such as ignition and engine control systems: fuel shortages of the 1970s led to the introduction of fuel injection engines and electronic injection control systems. Environmental pressure has resulted in the growth in the sales of diesel cars, and now more electronic development is being applied to meet new tighter emission control regulations aimed at reducing dirty and harmful particulates from diesel exhaust emission.

Additionally, heightened driver awareness has stimulated demand and growth in automotive safety applications such as antilock braking systems, antiskid, traction control, and airbags. Each new era in the car electronics evolution is creating further demand for electronics, and in some cases newer electronic systems and technology are being sought.

As an example, in the current airbag phase, where legislation for side-impact protection and full frontal protection is required in the United States from 1998, car manufacturers are seeking newer collision detector sensors at low cost to sense side-impact collision. Electronic solutions for the automotive business seem to be endless, restrained only by costs.

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Figure 5-3
Emerging Automotive Applications—Future Systems



Source: Dataquest (April 1995)

However, the automotive industry has one major constraint, and that is the customers. It is often customer needs that dictate the level of electronic sophistication the cars have—in the end the customer has to pay for all the car electronics.

The Automotive Environment

The automotive environment is often described as very harsh with most electronics expected to reach the level of military specifications for semiconductor device qualification. Compared with other electronic devices, this is a valid perception. The following are some of the factors that have to be tolerated when designing-in semiconductor devices for automotive applications:

- Dust-proof
- Electromagnetic compatibility (EMC)
- Humidity (including sudden changes in humidity from air conditioners)
- Oil and fuel resistant
- Shock and vibration resistant
- Short-circuit-proof
- Surge voltage resistant
- Temperature resistant (possible low temperatures of -50°C.)
- Voltage changes
- Waterproof
- Proof against polarity reversal

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As a guide, Table 5-2 provides some basic conditions that are currently applicable as conditions for electronic components in automotive applications.

Minimum operating temperatures for most of these systems are set by regional automotive electronics bodies like the Society of Automotive Engineers (SAE) in the United States, JASO in Japan, and in Europe by the various national governments' transport department. But most car manufacturers generally tend to apply the extreme limits of specification for electronic systems in order to qualify for exports to all countries.

Table 5-2
Semiconductor Device Temperature Thresholds for Automotive Applications

Location		Maximum Temperature (°C)
Chassis	Overall vehicle chassis	85
	Near heat sources	121
	Oil chassis	175
Body	Outside	121
Engine Compartment	Engine walls	140
	Engine surfaces	150
	Choke surface	205
	Starter cable (near exhaust pipes)	205
	Exhaust manifold	650
Passenger Compartment	Floor surface	85
	Real parcel shelf	107
	Instrument panel (surface)	113
	Instrument Panel (general)	85
Boot/Trunk		85

Source: Dataquest (April 1995)

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Chapter 6
Advanced Driver Information and Communication Systems

Driver Information in the Technology Evolution Process

For many years driver information systems have graduated from crude generations of roadside signs through to advanced, electronically controlled active matrix roadside information boards. Roadside information networks have advanced to a stage where most developed countries now have a computerized information control room that displays relevant traffic information on specific road routes. This infrastructure development has occurred mostly over the last decade.

Along with roadside information boards are car radios, which have also undergone quite substantial advances in technology. Microelectronics has developed the car radio to provide more information than what is audible. Text-based information is also transmitted to modern car radios using the RDS channel on FM analog radios.

Communication systems in the car have also advanced with the introduction of cellular telephony, which is now making a further advancement from analog cellular communication systems to digital cellular communications. These developments have occurred largely as a result of a market need for mobile communication systems. The introduction of digital telephony offers a new dimension to road users as it is now possible to transmit data (in addition to voice) over the digital networks by using a relatively simple data interface.

Global Positioning by Satellite Systems have also emerged as a viable technology for automotive applications. The applications for GPS in the automotive segment range from car navigation, security (vehicle movement tracking), through to very accurate clock-timing precision.

Dataquest predicts that car radios will become the hub for future driver information systems that will incorporate digital cellular communications, navigation and route guidance systems, and digital audio broadcast. The car radio is currently going through a technology evolution that will change the way these systems are used in the future, and this chapter looks at parallel developments in driver information systems that will shape future in-car driver information systems.

This chapter covers the following emerging technology areas that will have roles to play in future driver information systems:

- Keyless entry
- Vehicle identification
- Speech recognition – audio, entry, carphones, navigation
- Global Positioning Systems – alternative identification/location
- Navigation systems

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- GSM/wireless communications
- Digital audio broadcast: car radio/cassettes (versus RDS/TMC/EON)
- Head-up displays
- Near-obstacle detection (NODs)/blind-spot camera/mirrors

Keyless Entry

What Is Keyless Entry?

Keyless entry at its lowest specification allows door locks to be locked or unlocked without using the traditional car key. The most common implementation uses a remote control key-fob or "plip." More sophisticated models will have intelligent functions that may automatically lock doors once the engine is started (for security or safety purposes).

Current applications use infrared remote controls with trends toward integrating technology. The RF technology holds a unique code, which is transmitted to a receiver that controls the engine management system (EMS). The codes activate either the fuel pump relays, or the EMS itself.

Keyless Entry Features

Keyless entry improves existing car security and safety as it is also possible to configure the system to switch on or off inside/courtesy lights, alarms, and immobilizers, and quickens entry into the car by the driver (especially in dark places). RF adds additional security to EMS. The level of security required to combat vandals, joy riders, car theft, and higher insurance premiums are currently best addressed using electronics. Future keyless entry systems will use more sophisticated software to increase electronic security. Further integration of the modulator/demodulator unit into the engine management system, for example, will expand the application possibilities of keyless entry.

Table 6-1 shows the anticipated level of demand in each major world region. Although Europe is the largest car-producing region, keyless entry systems have been slower to reach the market compared with the North American region. Japan has the second-highest penetration rates for keyless entry systems because of the volume of exports to other world regions where these systems are sold or installed by respective regional car dealers through aftermarket channels.

Table 6-1
Worldwide Automotive Market Penetration of Keyless Entry Systems (Percent)

Region	1993	1998	2000
Europe	10	65	80
Japan	15	75	97
North America	15	30	40
Asia/Pacific–ROW	5	15	30
Total	12	50	64

Source: Dataquest (April 1995 Estimates)

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Future Keyless Entry Applications

Wireless communication itself as an enabling technology will in future allow linkage of engine management, transmission, and braking system for immobilization. Future RF keys could offer more processing power on-chip to increase the security level by implementing rolling codes or ciphering on-chip, thus permitting new application capabilities for keyless entry (wireless) offering customized keys for each family member that will, for example, automatically reset:

- Driver seat/mirror to memory position
- Restrict driver speed (depending on preset key priorities)
- Restrict the distance travelled (mileage), or fuel usage (for garage mechanics)
- Restrict access to boot or glove compartment
- Reset driver preferences for preset-radio, CD, and so on

Current EU vehicle type approval is for door lock, antitheft steering column lock, and transmission. Although there is no regulation in place for keyless entry, it will become mandated for EU vehicle type approval when it becomes fully implemented as a high-security door lock.

The major supplier companies of ignition keys, car alarms, engine management, and engine immobilizers will continue to work toward the development of keyless entry systems. Major original equipment manufacturers (OEMs) active in this area are shown in Table 6-2.

Table 6-2
Major OEMs of Keyless Entry Systems

Company	Country
AB Electronics	United Kingdom
Ford Electronics	United Kingdom
GM-Delco	Kokomo, Indiana, U.S.A.
Kiekert	Germany
Kokusan	Japan
Lucas	United Kingdom
Magneti-Marelli	Italy
Nippondenso	Japan
Omron	Japan
Valeo	France

Source: Dataquest (April 1995)

Because these systems are addressing the mass production car markets, all the major volume car manufacturers are evaluating keys that enhance vehicle security. A further addition to keyless entry is RF transponder keys. Ford of Europe pioneered this application in Europe by introducing Texas Instruments' TIRIS RF key across the entire entry-level car range,

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resulting in new insurance ratings for the Fiesta and Escort models. Other major end-user market customers include the following:

- BMW
- Chrysler
- Delco Electronics
- Ford
- GM (Adam Opel/Vauxhall)
- Honda
- Jaguar
- Mercedes-Benz
- Mitsubishi
- Nissan
- Porsche
- PSA Group (Peugeot/Citroën)
- Renault
- Subaru
- Toyota

Vehicle Identification

What Is Vehicle Identification?

Current EU vehicle type approval regulations for vehicle identification specify serial Vehicle Identification Numbers (VIN) to be etched into a vehicle identification plate that is affixed onto the car body and the car engine.

Global efforts to develop world standards for smart cars and highways using computers, wireless communications, and electronic traffic control systems have resulted in a need for electronic vehicle identification. Research and development are being coordinated in the United States through the IVHS program, in Europe through the EU's PROMETHEUS program, and in Japan through the government's Info-Mobility projects.

Although there may be no world standards for vehicle identification, the various research efforts being undertaken will develop common standards to address the main aspects of electronic vehicle identification. The generic feature for all these systems requires wireless vehicle identification systems that may be designed around radiofrequency identification (RF/ID): radar, infrared, or digital cellular communication technologies.

RF/ID is a method of electronically tracking items using embedded tags or transponders, stationary or mobile readers, data input devices, and system software. In low-frequency passive systems, usually 30 kHz to 500 kHz, a reader transmits a signal to an embedded or attached tag, charging the transponder and sending back a signal identifying the tagged item's unique code.

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Low-frequency devices work best at a range of a few feet or less and transmit at 20 miles per hour. High-frequency systems, in the 900-MHz to 2.5-GHz range, are capable of transmitting a greater amount of information over a wider geographic area. High-frequency devices can be used at distances of 250 feet and at speeds of more than 150 miles per hour. In Europe some systems have been developed to operate within the 5.8-GHz range specifically for road-tolling applications.

Vehicle Identification Features

Electronic vehicle identification improves existing vehicle security and traffic/vehicle monitoring/control. It offers the capability of transmitting vehicle identification for specific applications such as prepaid road-tolling systems.

Current proposals for prepaid road-tolling systems are mostly smart card-based so that older cars can benefit. However, future systems may use an integrated car identification system that will hold the car owner's details. This could offer some added benefits for car security when the "intelligent highway" concept becomes a reality. For example, access to future transaction services (such as booking car parking spaces) may be accessed more easily electronically as VIN effectively provides a user address.

Other features driving future growth for vehicle identification include:

- Road tolling (debiting/crediting transactions)
- Ability to restrict access of certain vehicle categories to road lanes
- Control and monitor road access
- Prebooking parking space at destination
- Fleet transport movement control and antitheft applications

Future Car Identification Applications

With an electronic vehicle identification system linked to cruise control and collision avoidance systems, it is possible that cars traveling to the same destination could be chained together in a train. Such a combination is believed to control traffic speed and ease traffic flow, potentially making road traffic conditions safer. This concept is known as cooperative driving in the EU PROMETHEUS program. Future development starts in 1995 for what is known as medium-range preinformation systems that will involve cooperative driving, autonomous intelligent cruise control, and automatic emergency calling. Table 6-3 gives Dataquest's forecast for these systems.

Table 6-3
Worldwide Automotive Market Penetration of Electronic Car Identification Systems (Percent)

Region	1993	1998	2000
Europe	0	8	12
Japan	0	6	15
North America	0	10	20
Asia/Pacific-ROW	0	3	5
Total	0	7	14

Source: Dataquest (April 1995 Estimates)

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Already, pilot trials are being conducted to develop this concept in a pre-competitive research environment. Although there are no real major supplier companies for car identification systems because the protocols and standards have not yet been established in Europe or the United States, Table 6-4 lists car manufacturing companies that are involved in this research and similar projects in the United States and Japan, as well as other major participants thatare suppliers, subcontract manufacturers, or partners to vehicle manufacturers and that have participated in the PROMETHEUS program.

Table 6-4
Companies Involved in the European PROMETHEUS Program

Car Manufacturers		Other Participating Companies
BMW	Mitsubishi	Celsius Technology
Chrysler	Nissan	DAIS
Daimler-Benz	Opel	Dräxlmaier
Fiat	Porsche	GEC-Marconi
Ford	PSA (Peugeot-Citroën)	HUSAT
General Motors	Renault	IBR
Honda	Saab	Leica
Jaguar	Toyota	Lucas
MAN	Volvo	Matra CAP
Mazda		Pilkington
		Robert Bosch
		Siemens Automotive
		TEMIC (Telefunken)
		Thomson

Source: Dataquest (April 1995)

Speech Recognition/Synthesizers

What Is Speech Recognition/Synthesis?

Speech recognition and speech synthesis use digital signal processing (DSP) techniques. Speech recognition uses DSP to filter analog signals into meaningful digital signals. Speech synthesis uses DSP to process digital signals to produce speech.

Existing solutions for speech recognition require large amounts of memory: EPROM and DRAM mostly (for software), and this makes the whole concept rather expensive for car applications. Software is a key component of speech recognition technology and until artificial intelligence software is developed further, then large volumes of memory capacity will remain associated with this application.

Volume applications for this technology have been pursued for nearly 20 years now. The primary objective is to develop an aural user interface that bypasses graphical user interfaces (GUIs). Currently, some limited applications exist, for access to program applications, especially for car telephones and other access applications such as door entry and car navigation systems. The use for this technology in these applications largely

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consists of voice-enabling or command functions. Speech recognition is mainly used to complement or replace other interface technologies.

Speech Recognition/Synthesizer Features

Current in-car applications use speech recognition as command- or voice-enabled functions mostly for carphone applications:

- Frequently used telephone numbers are stored in memory with a speech command assigned to dial them.
- It allows for absolute hands-free operation of car telephones or other in-car peripherals.
- It enhances driver safety by enabling voice-activated command input for non-safety-critical functions in car peripherals systems such as car radios, in-car phone/fax machines, and navigation systems.

The main problem areas for this kind of technology are analog noise cancellation for speech in a noisy environment.

Future car applications will require high-performance microphones to cancel out noise in the speech/command environment. Approaches to this technology for automotive applications require substantial amounts of processing capability, which makes it a very expensive solution.

To become successful in volume market applications, it must offer enhancements to existing technologies, or newly emerging applications to drive its use in the car. The main attractions for speech recognition in the car are a host of possible hands-free applications, allowing the driver to restrict hand use to other safety-critical areas such as steering and gear change. At its best, speech recognition offers the capability of "interactive-communication" with other car systems such as radio, traffic information networks and other such applications. Initially, this will not be suitable for safety-critical applications until the technology achieves higher standards of reliability.

First-generation speech synthesis systems have already been used in cars, but the concept of speech recognition is yet to appear in cars. To realize maximum appreciation of these technologies, newer systems will have to be interactive, combining both speech recognition and synthesis.

Against further implementation of this technology in the car is some very negative press reception, which is killing use of the systems even before they are designed into new cars. Most press reports describe the application as too "gimmicky" and impractical. European press coverage of earlier audio warning systems based on electronic speech synthesis (that constantly gave "doors open" warnings when they became faulty) discouraged early adopters and blemished any prospect for this technology in the car when, for example, it was first introduced in the 1980s by Rover. As a result, speech recognition has not been massively successful. Table 6-5 details current and forecast penetration of the technology worldwide.

Emerging speech recognition systems will be for interactive car radio, navigation systems, and other driver information systems.

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Table 6-5
Worldwide Automotive Market Penetration of Speech Recognition Systems (Percent)

Region	1993	1998	2000
Europe	0	2	10
Japan	1	2	10
North America	0	3	15
Asia/Pacific-ROW	0	0	5
Total	0	2	10

Source: Dataquest (April 1995 Estimates)

Companies producing speech recognition/synthesis hardware and software are as follows:

- Hardware
  - AT&T Microelectronics
  - Clarion
  - Ford
  - Fujitsu-TEN
  - General Motors
  - Hughes Network Systems
  - NEC
  - Nippondenso
  - Nokia
  - OKI
  - Sanyo
  - Sharp
  - Toshiba
  - Voice Control Systems Inc.
- Software
  - Lernout & Hauspie Speech Products, Belgium
  - Ricoh, Japan
  - Voice Control Systems, Dallas, Texas

Future Speech Recognition Applications

Some state-of-the-art car navigation systems developed in Japan already offer speech synthesis. It is currently more accepted in Japan because of poor road signs and severe traffic conditions in the urban areas. In Europe, market acceptance of speech recognition is poor. The failure of existing systems to reproduce accurate and human voice responses makes the whole concept appear even more gimmicky. Early systems handle non-safety-critical applications such as windows, mirrors, seats, central locking and heating and air-conditioning control.

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Secondary wireless application areas for speech recognition and interactive communication for automatic voice-activated hotel or restaurant reservations and other navigational aids may add value in other world regions for gradual market acceptance.

The proposed European standard for Traffic Message Channel protocol (for RDS-TMC) Alert-C offers a very structured digital language that has been developed to allow simple traffic information to be coded and transmitted to radio receivers equipped with a TMC decoder. The feature permits a user to receive traffic information in text form but in all the major European languages (English, French, German, Italian, and Spanish). This structure could also be easily formatted for speech synthesis in the car allowing audio interpretation of the code for any language. It is likely that the European Alert-C protocol may be adopted on a worldwide basis, to become a world standard as GSM is beginning to prove.

RDS-TMC provides other benefits through the car radio such as:

- Up-to-date traffic information from automatic traffic data collection and automated message paths
- Capability to be selective in information retrieval by criteria (for example, according to route)
- Constantly transmitted without interruption

Other applications in the car could include audible early warning systems such as low fuel, obstacle detection, and audio vehicle diagnostics. The enabling technologies for car applications are not yet widely available. Computer software houses and telecommunications companies are among the forerunners exploring this technology and its use, but the automotive industry itself may borrow from such vertical industries once applications become available.

Global Positioning Systems

What Is GPS?

The Global Positioning System (GPS) is one product of the cold war that could prove lucrative. Developed by the U.S. Department of Defense (DoD) as a strategic defense need, the Global Positioning System is a space-based satellite radio navigation system that provides a continuous source of three-dimensional positioning, velocity, and time. The GPS infrastructure consists of a "constellation" of 24 low earth orbiting (LEO) satellites (including 3 operative "spares") orbiting in a predetermined configuration at an altitude of approximately 10,900 nautical miles above earth.

A GPS receiver relies on the principle of triangulation to calculate its set of location coordinates, by measuring accurately its distance from 4 satellites that are in view (using a digital signal processor and a microprocessor). This is accomplished by measuring precisely the time taken for a radio transmission to travel from a GPS satellite to the GPS receiver. A receiver uses an internal database (called an Almanac), stored in a PROM chip, to look up the exact 3-D coordinates at a particular time of any of the 21 satellites in space. Thus, the GPS receiver relies on highly accurate time information provided by each satellite, and high degrees of computation in each GPS receiver.

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GPS Features

A GPS provides longitude, latitude, and altitude information (making it possible to calculate location anywhere in the world) while a navigation system provides more than just position information, but also route guidance and direction information.

Global Positioning Systems offer immense capabilities for navigation systems with their accurate location tracking systems. The accuracy of the location systems also make them very suitable for vehicle tracking applications, and they are therefore designed into fleet control systems and car security systems.

Consumer receivers cost as little as $500, but even that figure is dropping dramatically. If they are integrated into other types of system like navigation or security systems, then system prices, depending on features, range from $1,500 to $6,000. Car manufacturers expect that by the year 2010, virtually every vehicle will be tracked using an embedded GPS engine. About one-third of the world's established GPS hardware (engines) and software is made in California by such companies as Magnavox, Magellan Systems, Ashtech, Trimble Navigation, ESRI, and Rockwell International. Other manufacturers include the following:

- Ashtech
- Navstar (a Peek Company)
- Garmin
- New Japan Radio Company (JRC)
- GEC-Plessey Semiconductors
- NovAtel Communications
- Koden
- Sony
- Motorola
- Socket Communications Inc.

GPS applications in the car are mostly to aid dynamic driver navigation systems that use dead-reckoning. Although they have seen successful introduction on the Japanese aftermarket for nearly four years now, car manufacturers have only recently begun to offer them as an option. In Japan Honda, Toyota, Mazda, Mitsubishi, and Nissan are now offering GPS navigation systems with their top-of-the-range car models; while in the United States General Motors is leading with OEM installations of its Guidestar navigation system developed with Hughes Electronics; and in Europe BMW, Mercedes, and Jaguar (Ford) are emerging as pioneers for OEM installations of navigation and traffic information systems.

Dataquest believes that GPS navigation systems will begin to take off from the year 2000 onward (see Table 6-6). To date, the Japanese lead in aftermarket installation and car factory installations of GPS navigation systems. GPS navigation markets in Europe and the United States are only just beginning.

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Table 6-6
Worldwide Automotive Market Penetration of Global Positioning Systems (Percent)

Region	1993	1998	2000
Europe	0	20	30
Japan	2	40	50
North America	0	8	15
Asia/Pacific-ROW	0	6	10
Total	1	20	27

Source: Dataquest (April 1995 Estimates)

Suppliers of the systems are as follows:

- GPS-based car navigation systems:
  - Aisin (Japan)
  - Peek (United Kingdom)
  - Alpine (Japan)
  - Philips Car Systems (Germany)
  - Clarion (Japan)
  - Pioneer (Japan)
  - Delco (USA)
  - Robert Bosch/Blaupunkt (Germany)
  - Ford (USA)
  - Sagem (France)
  - Fujitsu-Ten (Japan)
  - Sanyo (Japan)
  - Gilardini/Fiat (Italy)
  - Siemens (Germany)
  - JVC (Japan)
  - Sony (Japan)
  - Kenwood (Japan)
  - Sumitomo Electric (Japan)
  - Mannesmann/VDO (Germany)
  - Toshiba (Japan)
  - Motorola (USA)
  - Xanavi (Japan)
  - Nippondenso (Japan)
  - Zexel (Japan)
  - Panasonic (Japan)

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- Major digital map suppliers:
  - Etak Technologies (News Corporation International subsidiary)
  - Road Scholar Inc. (PC map software company)
  - Robert Bosch (Germany)
  - European Geographic Technologies (EGT)
  - Personal Travel Technologies Inc. (with locations of hotels, restaurants, and so on)
  - Zenrin (Japan)

Navigation Systems

What Is a Navigation System?

Several different navigation systems are available for automotive use. They typically range from variants incorporating a liquid crystal display (LCD) that may be graphic, text, or alphanumeric, Azimuth sensors (for measuring coordinates), distance-travelled sensors, GPS, CD-ROM maps, FM radio data systems/traffic message channel (RDS-TMC), and GSM (Global System for Mobile Communications) voice/data telephony capability.

For most car navigation systems, the driver will key in the destination, with the system then guiding the driver to the selected destination. The methods of calculating and planning routes differ by type of navigation system. However, most electronic navigation systems embrace the basic method of finding your way to any destination using GPS and digital maps. State-of-the-art navigation systems in a car need to meet certain requirements:

- Ability to operate in a mobile environment
- Continuous operation mode for the duration of the journey
- Fast, clear, and concise display of information
- Provide "real-time" information
- Rationalize new roads/changes in road-direction flow

Navigation System Features

Earlier car navigation systems were simply electronic compasses. Navigation systems have advanced through map-based route guidance systems incorporating cathode ray tube (CRT) visual display units (VDUs) to intelligent dynamic navigation systems using satellites, LCDs, and digital CD-ROM maps. Some of the differentiating features among the several emerging platforms for car navigation systems are as follows:

- Gyroscopes/dead-reckoning/compass
- Global positioning satellites
- CD-ROM map-based navigation
- Traffic information processing
- UHF radio/GSM telephony

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Car navigation systems fall into three main categories – autonomous route guidance, interactive route guidance, and traffic information. Autonomous route guidance systems use a GPS receiver, CD-ROM and on-board computer, and sometimes an electronic compass or wheel distance sensors. These systems provide on-board route guidance to the driver without any use of real-time traffic information.

Interactive route guidance systems provide route planning information by receiving traffic information from FM-RDS stations or via GSM data communication channels. RDS information is received from the in-built radio. This traffic information is processed by the on-board computer to provide the most efficient route guidance for the selected destination. They may also use roadside beacons to communicate with the vehicle's on-board navigation system to receive traffic information in city centers.

Traffic information systems are real-time systems like the United Kingdom's "Trafficmaster," which provides traffic information collected using infrared beacons to detect vehicle speed (traffic flow) on motorways. The Trafficmaster also provides text information about traffic incidents and could be used as a radio pager. These systems give traffic information but with very limited navigation information.

Emerging application trends will incorporate the following:

- Audio: Car radio RDS-TMC (character LCDs)
- Visual: Information boards (in-car navigation systems – LCD VDU)
- Semi-interactive intelligent systems (DAB)
- Bidirectional and interactive communications and off-board digital maps (GSM)

Car navigation systems have existed for many years now, but the market for these systems has been very slow to develop (see the current and forecast penetration in Table 6-7), as these systems have taken longer to reach the development phase that exists today. In the early days, gyroscope positioning was the only available system to aid driver navigation and these devices had some major drawbacks in accuracy.

Table 6-7
Worldwide Automotive Market Penetration of Vehicle Navigation Systems (Percent)

Region	1993	1998	2000
Europe	0	3	7
Japan	2	20	40
North America	0	3	5
Asia/Pacific-ROW	0	1	5
Total	1	7	13

Source: Dataquest (April 1995 Estimates)

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CD-ROM maps were developed for use in second-generation systems, but these too were not entirely adequate. At the end of the cold war, global positioning technology became available and a combination of these three technologies is now widely acknowledged as offering the most reliable navigation techniques available for car navigation systems.

It is clear that navigation systems still have quite some way to go; for example, next-generation systems may not include CD-ROM maps as an integral part of the system. Digital mobile communication technologies will allow electronic maps to be transmitted to cars in the future.

Another product development trend is that most manufacturers of car navigation systems are the major car radio manufacturers. It is somewhat inevitable that navigation systems will become integrated with car radio. This will produce a more versatile driver information system with multimedia capability in the car.

Suppliers of car navigation systems include the following:

- Aisin (Japan)
- Panasonic (Japan)
- Alpine (Japan)
- Pagamatron (France)
- Clarion (Japan)
- Philips Car Systems (Germany)
- Delco (USA)
- Pioneer (Japan)
- Ford (USA)
- Robert Bosch/Blaupunkt (Germany)
- Fujitsu-Ten (Japan)
- Sagem (France)
- Gilardini/Fiat (Italy)
- Sanyo (Japan)
- JVC (Japan)
- Siemens (Germany)
- Kenwood (Japan)
- Sony (Japan)
- Mannesmann/VDO (Germany)
- Sumitomo Electric (Japan)
- Mazda (Japan)
- Toshiba (Japan)
- Motorola (USA)
- Toyota (Japan)

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- Nippondenso (Japan)
- Xanavi (Japan)
- Nissan (Japan)
- Zexel (Japan)

GSM

What Is GSM?

Global System for Mobile Communications (GSM), initially developed as a pan-European digital cellular telecommunications network, is fast becoming the world standard for digital cellular communications.The primary application of GSM in cars will be data-driven applications that fit into the advanced road transport telematics program. GSM offers bidirectional communication, while the FM radio RDS/TMC only offers one-way communication.

Future Applications and Features of GSM

As part of the EU SOCRATES program, research funding was made available to participants for exploring ways of utilizing GSM for a pan-European traffic information infrastructure. There are four projects developing SOCRATES: the Kernel project that coordinates the research and development; and pilot trials in three countries—London in the United Kingdom (APPLE pilot project), Frankfurt in Germany (RHAPIT pilot project), and Gothenburg in Sweden (TANGO pilot project). Major participating companies in SOCRATES projects are as follows:

- Adam Opel
- Philips Car Systems
- British Telecommunications plc (BT)
- Philips Kommunications Industrie AG
- CelsiusTech Systems
- RAC Enterprises
- Daimler-Benz
- Renault
- DeTeMobil
- Robert Bosch
- European Geographic Technologies
- Rover Group
- Expertel
- Saab Automobile
- Ford Motor Company
- Saab Mecel
- France Telecom Grands Comptes
- SEMA Group Telecom

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- GEC Marconi Transport Systems
- Telecom Securicor Cellular Radio
- Hessisches Landesampt für Stassenbau
- Telefónica
- Heusch Boesefeldt
- Telia Mobitel
- Kjessler and Mannerstraler
- Traffic Research Institute
- Lockheed IMS (UK) Ltd.
- Volvo Technological Department
- London Transport

Compared to analog cellular, GSM offers a superior spectrum efficiency that allows for speech clarity, provides improved communication security and eliminates some of the fading problems associated with analog cellular telephony. Initially developed for voice communication applications, GSM technology is rapidly beginning to provide a medium for data transmission. It is this capability that opens up new areas for automotive applications.

For driver information—road transport, traffic and navigation—purposes, GSM offers the capability to deliver data at 9 Kbps, which allows for immense flexibility for real-time information delivery. The most significant feature of GSM in automotive applications is the ability to provide bidirectional data exchange for off-board information processing. Precise position information could be sent via digital cellular communications, linked with an on-board GPS.

In future automotive applications, GSM will offer high-speed/high-density bidirectional data transfer capabilities; for example, GSM could be used in the following areas:

- **Digital road maps**: To deliver, digitally, electronic maps to subscribers of a GSM system, which will be temporarily stored for use with a car navigation system. This is especially valuable as freshly updated maps could be provided instantly without risk of being outdated.
- **Road tolling (cashless transaction processing)**: To provide data interchange for electronic cashless transactions for prepaid road tolling debiting. It could also be used to facilitate traffic control and information by utilizing data from such electronic tolling plazas or from roadside transponder networks.
- **Market information services**: GSM could be used for electronically paging customized traffic information, which is tailored to suit prespecified routes (such as tourism, trade, brief news, and diagnosis).
- **Security and emergency calling**: Automatic SOS calls giving the location of the vehicle with the use of a GPS navigation system to police, fire, ambulance, or recovery services.

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- **Traffic management (park and ride)**: Automatic booking and reservation of public car parking spaces in advance of reaching the destination. This feature extends to allow GSM for automatic reservations in other commercial applications like restaurants, cinemas, theatres, and other such applications.

Although at this time, government ministers have not yet approved GSM as an application for advanced telematics infrastructure, several car manufacturers and subsystem manufacturers have developed systems for this industry. OEMs of hardware include the following:

- Robert Bosch/Blaupunkt
- Nokia
- Dancall
- OKI
- Ericsson
- Orbitel
- Hagenuk/Cetelco
- Panasonic
- Matra-AEG
- Sony
- Mitsubishi
- Siemens
- Motorola
- Mannesmann/VDO
- NEC

Dataquest believes that navigation systems incorporating GSM will offer an abridged version of GSM technology offering just data communication. Car systems will have the option of integrating both data and voice at the customer's request. Automotive manufacturers will be looking at integrating these systems in the interior compartment design of future cars. Table 6-8 gives Dataquest's projections for penetration of these systems.

Table 6-8
Worldwide Automotive Market Penetration of Digital Mobile Communication Systems (Percent)

Region	1993	1998	2000
Europe	0	10	15
Japan	3	5	10
North America	0	1	5
Asia/Pacific-ROW	0	0	1
Total	1	5	9

Source: Dataquest (April 1995 Estimates)

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Digital Audio Broadcasting

What Is DAB?

Digital audio broadcasting (DAB) is the result of the seven-year Eureka project EU 147 (costing $110 million) to develop the standards for digital terrestrial radio. Digital audio broadcasting involves the newest audio broadcasting technology developed to replace existing analog broadcasting systems. Analog information (usually speech or music) is digitized and transmitted in digital format. The result is that it offers digital CD-like sound quality from radio broadcasts that is superior to the best FM radio can offer. Test transmissions are already broadcast in France, Germany, Italy, the Netherlands, Sweden, and the United Kingdom. Fully operational pilot trials and tests will begin from the second half of 1995 in several countries including most EU member states, and outside Europe in Canada and Australia.

DAB Features

DAB is especially suited to vehicle radio applications because it eliminates the noise problems associated with analog radio signals and offers constant, excellent reception quality. Distortion of FM radio signals caused by multipath propagation and other physical conditions are avoided by using a transmission method known as coded orthogonal frequency-division multiplex (COFDM). DAB also allows the transmission of data such as music/speech identification, program type identification, station name, and other such text data that could be transmitted with audio broadcasts.

Future DAB Applications in the Car

Largely because DAB (unlike GSM) is not a bidirectional communication medium, in the future, powerful data channels will allow specific information to be transmitted to closed user groups, opening up the possibility of "data broadcasts" and conditional access services alongside audio broadcasts. Examples of data broadcasting services for DAB include:

- Traffic message channel (character text-based)
- Paging systems
- Stock market news
- Real-time electronic maps for car navigation systems
- Weather information

Although the DAB market is not yet developed for commercial use (see Table 6-9 for current and forecast penetration), Dataquest believes that Germany will lead the world with its introduction. Nearly 40 percent of the Western European car radio market is in Germany, and car radio manufacturers will begin to switch production to DAB systems when the service becomes commercially available in Germany from 1997. The nearest single European car radio country market is less than 15 percent of the European market.

First-to-market OEMs of DAB radios include the following:

- Becker
- Philips

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Table 6-9
Worldwide Automotive Market Penetration of DAB Car Radios (Percent)

Region	1993	1998	2000
Europe	0	3	5
Japan	0	0	5
North America	0	1	3
Asia/Pacific-ROW	0	0	0
Total	0	1	4

Source: Dataquest (April 1995 Estimates)

- Clarion
- Robert Bosch (Blaupunkt)
- Delco
- Sony
- Grundig
- Thomson Consumer Electronics

Many of these OEMs currently have prototype test receivers available—which are too bulky for car dashboards. By September 1995 (in time for the Berlin IFA-*International Funkausstellung Berlin, 1995*), these manufacturers are expected to bring some prototype models to market, although the cost of these systems at that time will not be attractive for OEM factory installations. Market development for car DAB systems will take place when car manufacturers sign up for volume allocations that will bring component prices down.

Typically, it takes two years in a car manufacturer's design cycle for dashboard applications to appear on the market. With the introduction of DAB to the volume German market planned for 1997, we do not expect to see DAB car radios become factory-fitted until after 1998. Initial systems will likely be sold through aftermarket channels after the fourth quarter of 1996, although these will be insignificant volumes. We expect to see DAB volumes begin to have some slight effect on the semiconductor market by the year 2000. Since DAB will be simulcast with existing FM for at least 15 years, it will not be until around 2010 that the market will begin to take off.

Dataquest believes that these first systems will be hybrid systems capable of receiving both digital audio broadcast and analog broadcasts; thus, some hybrid radios will remain on the market for many years before the switch to full coverage of DAB takes place.

Head-Up Displays

What Is Head-Up Display?

For a number of reasons ranging from reduced night visibility through to dashboard instrument clutter, solutions are being sought to prevent momentary lowering of driver alertness. Head-up displays (HUDs) are

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seen as a technology to present essential information in the driver's field of view. Developments for future in-car applications have been borrowed from aircraft and military systems to improve road safety. HUDs use a display projector built into the car dashboard that projects images onto specially constructed windscreens. The special windscreen construction (using glass optics and projection techniques) allows projected virtual images to be viewed in light (day) or dark (night) conditions.

Future Application of HUDs

Head-up display technologies have now reached a stage of near commercial introduction into vehicles. In the United States and Japan car manufacturers such as Nissan and General Motors have introduced first-generation car models with HUDs for primary information display (dashboard warning signals). Future applications of HUDs include the following:

- Primary information display (speedometer, dashboard warning signals, and advance road/traffic warning information)
- Secondary information display (enhanced vision in fog, rain, and snow or at night)
- Tertiary information display (for example, early warning signalling of road conditions such as ice, snow, rain, and flood)

As part of the global research initiatives such as the equivalent of Europe's PROMETHEUS program in the United States and in Japan, car manufacturers are keen to prove that HUDs enhance driver alertness and improve driver focus on the road. However, the real barrier to the deployment of HUDs in cars is currently the cost of projection technology. DSP costs are still too high, and until such time that car manufacturers are convinced that customers will be willing to pay for these systems, they are likely to remain in research and development labs until around 2010.

The single most important market driver for HUDs is night vision enhancement, and this is the area where much of the current development is taking place. The key issues here are how to perfect a technology for image detection that is dazzle-proof. Image detection and projection in current solutions using infrared cameras and charge-coupled devices (CCDs) are affected by oncoming vehicle lights.

Another area for further development in HUD technology is to improve the image quality projected onto the windscreen for vision enhancement. Current systems that use ultraviolet technology for thermal image detection are not very good for image clarity or projection. Further technology development is required in this area to overcome this problem.

Although HUDs for speedometer and other dashboard applications are available, the market is very insignificant at the moment (see Table 6-10) as there is no real justification for this additional cost option item. Future systems will have capability for night vision enhancement, and this is the aspect of most interest to car manufacturers.

At present, General Motors has a HUD option available for its Oldsmobile Cutlass Supreme model and the Pontiac Bonneville models. These are

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Table 6-10
Worldwide Automotive Market Penetration of Head-Up Displays (Percent)

Region	1993	1998	2000
Europe	0	1	1
Japan	1	2	3
North America	0	2	2
Asia/Pacific-ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

cheaper, low-end HUD systems that cost $250 as a standalone option. Nissan also has a similar HUD system in its Sylvia car model built for the Japanese market only. Typical information displays of existing HUD systems include:

- Update of road signs
- Speed
- Fuel distance to empty
- Temperature (inside/outside)

HUD systems need a fairly sophisticated projection technology onto the windscreen. Some prototype systems use basic camera technology while for certain thermal image detection HUD systems, some fairly complex CCDs are used. Future applications for HUD will be for driver information purposes or warning signals to the driver such as the following:

- Enhanced night vision
- Warning of road conditions (black ice, oil spill, slippery surface, snow, rain, and so on)
- Advance warning of route traffic conditions
- Navigation/travel direction display

Although this technology is unlikely to appear in cars for many years, there appear to be two companies very active in HUD technology for automotive applications; many other companies that manufacture HUD systems for the military and aviation industry are also known to be developing low-cost HUD prototypes for automotive vision enhancement applications. Many of these prototypes are currently in development and by 2000, first-generation systems should begin to gain entry into the high-end automotive markets, commercial vehicles, and vehicles used by the emergency services such as the police, fire, vehicle/disaster recovery, and ambulance services.

Major automotive HUD technology developers include the following:

- BMW
- British Aerospace

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- Delco Electronics
- Fiat (Magneti-Marelli)
- Ford
- Libbys Owens Ford (LOF)
- Nissan
- Peugeot-Citroën
- Pilkington Glass and Jaguar Cars
- Renault
- Toyota

Near-Obstacle Detection

What Is Near-Obstacle Detection?

Near-obstacle detection (NOD) systems monitor objects that come within short-range view of vehicles and warn the driver about these obstacles. They work on a principle utilizing electronic sensors that may fit into rear-end light panels or vehicle bumpers. Current systems designed for the automotive industry use ultrasonic sensors or infrared sensors that monitor moving vehicles in the blind spot area. The most common application is for reversing assistance (when gear selection is in reverse).

Features of Near-Obstacle Detection

Near-obstacle detection uses sensors to detect obstacles in the path of view. Some systems deploy infrared sensors, radars (microwave/millimeter wave) or CCD cameras.

Typically, a basic NOD will deploy a sensor that will detect obstacles. The sensor could be infrared, radar, or microwave. The electronic control unit will receive signals from the sensor, and each time an obstacle is detected in the view of the sensor, a break in signal transmission will trigger the warning. Based on a camera principle, each sensor sends and receives focused infrared rays through a special optical system. The system can be activated only by setting the turning indicators. Any object up to a preset distance away from the sensor triggers the warning signal.

Vehicle manufacturers may configure the warning signal to provide audible, visual, or audio/visual warning signals. Price estimates of this kind of system range from around $50 and above, and it is anticipated that these systems will be first introduced for commercial vehicle applications before we see them in cars.

Convex and aspheric mirrors minimize the blind spot, but the scale differences easily confuse the driver as an estimation of the real distance of cars approaching from the back is almost impossible, especially at night.

Siemens Semiconductors and Autosense Ltd. of Denver, Colorado, have developed a system based on this principle that will indicate the presence of any vehicle in the blind spot area through warning lamps inside the car or at the outside mirror.

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Future systems could be integrated into active collision avoidance systems. Although existing systems are deployed by some commercial vehicle manufacturers, the use of these systems could become mandatory for commercial vehicles or vehicles with high driver cabins.

Table 6-11 gives Dataquest's current and projected penetration for near obstacle detection systems. Manufacturers and suppliers of the systems include the following:

- Delco Electronics
- HE Microwave
- Hitachi
- NEC Electronics
- Mitsubishi
- Sharp Electronics
- Siemens
- TEMIC (Telefunken)

Table 6-11
Worldwide Automotive Market Penetration of Near Obstacle Detection Systems (Percent)

Region	1993	1998	2000
Europe	0	1	5
Japan	2	7	15
North America	0	3	10
Asia/Pacific-ROW	0	0	3
Total	1	3	8

Source: Dataquest (April 1995 Estimates)

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Chapter 7
Powertrain Electronics

Although the rate of penetration for powertrain electronics is fast approaching maturity as a result of legislation to curb exhaust emissions to protect the global environment, further advances in electronics are very actively pursued in this area. Powertrain electronics is increasingly seen as the powerhouse of all vehicle electronics. This segment will expand to gain control of other areas of automotive electronics as the need to merge functions of individual electronic control systems becomes a reality.

The merging of electronic control systems will depend largely on developments in the data-bus area where multiplexed wiring technology is replacing the traditional vehicle wiring harness. Future powertrain applications will involve and control all aspects of vehicle motion dynamics ranging from total control of vehicle stability, steering control, suspension control, braking control, transmission and safety, to security controls. In achieving this purpose, larger packets of input data will be processed by the engine control unit and larger-size software programs will need to be developed to cope with the diversity of algorithms that will be calculated. Research efforts geared toward reaching these objectives are already in place at most major motor manufacturers' research and development divisions.

Parallel to these developments are newer forces driving further use of electronics to achieve widely diverging solutions but converging applications that have become established parameters for engine management systems such as:

- Fuel crisis and fuel efficiency drive
- Performance enhancement and vehicle safety
- Environmental pressure
- Vehicle security and insurance costs
- Vehicle diagnostics control
- IVHS and advanced traffic telematics

In examining the potential for these developments, this chapter of the report covers the aspects of powertrain electronics and all directly and indirectly related emerging systems that will play a role in reaching the goal of intelligent vehicles or the so-called "smart car" of the next decade. The following applications are explained in this chapter to identify the importance and the use of each system:

- TCS/traction control (and antiskid control/ASR)
- Electronic power steering
- Active suspension/adaptive suspension
- Intelligent/smart cruise control
- Electronic transmission: Tiptronic
- Electronic clutch

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- Electronic brakes (brake by wire)
- Collision avoidance
- Diesel electronic fuel injectors (electronics)
- Driving stability control and guidance system (DSC)

TCS/Traction Control (and Antiskid Control/ASR)

What Is Traction Control?

Traction control prevents the wheels from spinning by reducing engine speed, whereas ABS prevents wheels from locking by optimizing braking pressure. Traction control (sometimes referred to as ASR or antiskid control) was first developed for high-performance cars. Most traction control systems are integrated into an ABS and often share the same electronic control unit.

Features of Traction Control

Earlier-generation traction control systems reduced engine speed when wheel sensors detected wheel spin. The application for traction control in cars first became popular in the 1980s to aid performance in sports cars.

Nowadays, traction control is being developed as a safety application for traction control in adverse road conditions (snow, rain, black-ice, and so on). Thus, to prevent loss of traction in adverse road conditions, the focus is on developing sensors for detecting road conditions. This is the newly emerging area of development that will move traction control into the mass market. Like ABS, traction control helps to maintain vehicle traction and steering.

The electronic control unit deploys wheel speed sensors, engine speed sensors/throttle valve position sensors, a brake switch, and an on/off switch for the traction control system itself. Data from the wheel speed, engine speed/throttle valve position sensors, and brake switch state is processed by the electronic control system; output is fed through actuator control devices to the hydraulic brake valves, and the ABS pump relays and the electrical drive of the throttle valve. Thus, when a driving wheel slips it is braked by an active intervention of the brakes. In other extreme conditions, such as cornering on roads with reduced traction (wet roads), the processors decrease engine torque using the throttle valve actuator.

Like many safety critical electronics systems in cars, the electronic control unit uses multicontrollers and could have up to three microcontrollers (8-bit MCUs). One microcontroller is used for the main application, the second controller is a watchdog controller, and the third controller acts as a diagnostics and safety logic controller.

Future Traction Control Applications

Having first made its debut in racing cars, traction control has since gained entry for commercial vehicle applications. The next stage in the development of traction control systems is to advance the road condition sensor technology for this application to be deployed in the medium-size and small car markets.

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Dataquest forecasts that this application, when perfected, will eventually become a standard offering with ABS. Eventually where advanced car electronics are deployed, traction control may be attached to engine management for engine braking. Table 7-1 gives current and forecast penetration of these systems.

Table 7-1
Worldwide Automotive Market Penetration of Traction Control Systems (Percent)

Region	1993	1998	2000
Europe	5	30	35
Japan	5	20	35
North America	8	45	50
Asia/Pacific-ROW	1	5	10
Total	5	28	34

Source: Dataquest (April 1995 Estimates)

It is conceivable that traction control, ABS, and engine management systems connected with an active suspension system would provide an excellent solution for safer motoring and dynamic vehicle control. Driving stability control systems are themselves an extension of ABS and traction control.

Major suppliers of ABS and traction control systems include the following:

- Alfred Teves/ITT
- Allied Signal
- Bendix
- FAG Kugelfischer (Motorcyles)
- Kelsey-Hayes
- Lucas Braking Systems
- Nippon ABS
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes
- TEMIC (Telefunken)

Electronic Power Steering

What Is Electronic Power Steering?

Conventional power steering systems use a method of magnification to reduce the amount of effort used to turn the steering wheel. This method operates with a hydraulic power steering pump system. Power steering systems with fixed-magnification ratio have major drawbacks. If the

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system is designed to reduce the force needed to turn the wheel when the car is stationary, steering becomes too loose when the car is driven at greater speeds; this is where electronics are used.

Features of Electronic Power Steering

The application of electronics in this area is focused on controlling the degree of magnification to apply equal amounts of hydraulic force to compensate for variable speeds. To control hydraulic power steering, speed sensors, solenoid valves, hydraulic pumps, and a power steering gearbox are currently deployed by most of the emerging electronic power steering systems.

The only input to the electronic control unit for power steering is from the vehicle speed sensor. The output signal activates a linear solenoid valve (a solenoid valve that can be controlled at any arbitrary position depending on the average current). The solenoid valve is used to control the hydraulic power steering.

Newer developments in power steering are expected to shift away from hydraulic system to electronic power motors that can be controlled more efficiently and will drain less engine power, thus becoming more energy-/fuel-efficient. These types of power steering system are now in development (particularly for electric vehicles) and are expected to become widely available by 2005 (see Table 7-2 for the Dataquest forecast out to 2000).

Table 7-2
Worldwide Automotive Market Penetration of Electronic Power Steering Systems (Percent)

Region	1993	1998	2000
Europe	1	5	10
Japan	30	45	65
North America	4	9	15
Asia/Pacific-ROW	0	3	5
Total	9	16	23

Source: Dataquest (April 1995 Estimates)

Active Suspension

What Is Active Suspension?

The concept of suspension control covers a number of functions aimed at improving the overall stability and performance of a vehicle. The basic objective of suspension control is to reduce vehicle rocking, rolling, pitching, and yawing. A combination of driver-controlled actions such as steering, braking, and speeding often leads to instability.

Several techniques may be used to avoid vehicle instability from such driver actions. Active suspension is one method and is based on a principle of controlling dampers (shock absorbers) and springs while maintaining vehicle height to maximize stability. Softening the dampers reduces vehicle shock from jolts in road surfaces but increases springing, while

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vehicle shock from jolts in road surfaces but increases springing, while hardening the suspension stiffens springs. A compensating compromise needs to be achieved to sustain comfortable ride quality. This can only be done by electronic suspension control. The damper and spring control system is described as ride control or adaptive suspension. Active suspension combines height control to adaptive control techniques. The height control system relies on sensors that monitor and control each wheel height.

Features of Active Suspension Systems

The electronic control unit (ECU) of an active suspension system receives signals from a number of peripherals and sensors. A fully configured system will receive inputs from the following:

- A mode select switch (which selects the ride quality parameters)
- Steering sensors (to calculate damping rock/roll compensation for sharp steering/cornering)
- Braking light sensors (to prevent diving when braking hard)
- Throttle control—via the engine control unit (to minimize dipping of the rear end when accelerating)
- Vehicle speed sensor (to improve roadholding when the vehicle is travelling at high speed)
- Optional—automatic transmission neutral sensor (to monitor the vehicle's current travel status)
- Vehicle height control sensor (body to ground clearance sensors)—active suspension
- Diagnostic check system

How Does Active Suspension Work?

The electronic control unit processes signals from all the input sensors and outputs to actuators that control damping or suspension control. It uses algorithms that are developed to maintain optimal stability in all driving situations to aid vehicle control.

Active suspension systems are tailored for different types of vehicle as they incorporate specific algorithms related to vehicle weight/mass distribution and velocity metrics. The ECU sends signals to an actuator to select damping (shock absorber tensioning), an electronic DC motor, and a solenoid valve to control hydraulic pressure in the shock absorber. Typically, an 8-bit microcontroller is used for these functions.

For height control, the ECU receives signals from each wheel height sensor and applies the damping control to compensate for increases or decreases in height caused by loading. Maintaining vehicle height ensures vehicle stability and also minimizes changes in the optical axis of the headlamp illumination angle. Most active suspension systems use actuators for air or hydraulic springs to adjust vehicle height.

Active suspension emerged first in Formula 1 racing in the 1980s but has been slow to gain market acceptance by car manufacturers. As early as during the 1980s, Toyota and Nissan had been installing active suspension systems on their top-range cars as an option, but penetration remained

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Xantia car model and offered this model with a hydraulic active suspension system. Toyota is now offering active suspension systems with the top-range Lexus cars. The costs of developing these systems and the length of development time make them a very expensive solution for car applications. Newer systems such as driver stability control systems are emerging as more cost-effective ways of achieving similar results.

Major suppliers of active suspension and damping control systems are listed below, and Table 7-3 contains Dataquest's projections for penetration of these systems:

- Lotus Engineering
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Tokiko
- Valeo

Table 7-3
Worldwide Automotive Market Penetration of Active Suspension Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	1	3	5
North America	0	3	6
Asia/Pacific-ROW	0	0	1
Total	0	2	4

Source: Dataquest (April 1995 Estimates)

Intelligent/Smart Cruise Control

What Is Intelligent Cruise Control?

Cruise control or fixed-speed driving control is a system that allows drivers to travel at a constant fixed speed without using the accelerator pedal. The main benefit of cruise control is to reduce driver strain or fatigue during long motorway journeys. The earliest systems used analog circuitry but most current systems use digital circuitry.

Features of Intelligent Cruise Control

When cruising speed is set, the electronic control unit will calculate vehicle speed using signals from the speed sensor, and then maintain vehicle speed using a throttle control actuator. Fixed speed cruising is cancelled by a cancel signal, which can be set using the foot brake pedal, clutch, or parking brake switch. Most systems use a 4-bit or 8-bit micocontroller for this application, but this is becoming increasingly integrated with engine management control systems.

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Intelligent cruise control is the next-generation cruise control currently under development. Specifically designed to improve driver safety, intelligent cruise control can be set to adjust cruising speed with that of the vehicle in front of the driver. This is to avoid frontal collision when cruise control is set and the driver is lulled into a false sense of security. Intelligent cruise control will have more than one input signal and will take additional information from other obstacle detection sensors such as radar, microwave, and infrared sensors.

Most drivers of cars fitted with cruise control systems rarely use this feature, but it is becoming standard equipment with most automatic transmission cars. Intelligent cruise control is a major function of so-called "cooperative driving" where cars traveling toward a common destination on motorways are batched together in wireless chains. The collision avoidance technology is employed in the cooperative driving system and is proven to improve traffic efficiency.

Future systems will incorporate near-obstacle detection technology; consequently, it is likely that in the near future, newly developed systems will commonly be hybrid detection systems using both radar and infrared detection technology.

Table 7-4
Worldwide Automotive Market Penetration of Intelligent Cruise Control Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	3	5	10
North America	0	2	3
Asia/Pacific–ROW	0	0	1
Total	1	2	4

Source: Dataquest (April 1995 Estimates)

Major developers of intelligent cruise control systems are listed below, and Table 7-4 gives Dataquest's projections for current and future penetration of the systems:

- Delco
- Denshi Giken
- Jidosho Denki Kogyo
- Fujitsu Ten
- Motorola
- Nippondenso
- Robert Bosch
- Mercedes-Benz Research
- Mitsubishi Electric

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- Siemens Automotive
- TRW
- TEMIC (Telefunken)

Electronic Transmission: Adaptive Shift Pattern

What Is Electronic Transmission?

There are several different types of electronic transmission system, ranging from driving mode transmission control for automatics and continuous variable transmission (CVT) control systems and, ultimately, adaptive shift pattern (ASP) transmission. Most electronic automatic transmission control systems are programmed for economy and sport driving modes. ASP allows the driver to drive in three modes: manual, automatic, and a third metric automatic mode that allows the transmission system to adapt a number of driving patterns. Table 7-5 gives the worldwide forecast for electronic transmission.

An example of an ASP transmission system is Porsche's Tiptronic developed by Porsche and Bosch for the Le Mans Porsche 962 and Maclaren F1. Tiptronic first appeared in production Porsche cars during 1990. Today, BMW (Alpina), Audi (A8), and Saab also offer this system in their top-range cars. Nissan (Maxima) and Toyota (MFG super-performance sports-car) have a similar system.

Table 7-5
Worldwide Automotive Market Penetration of Electronic Transmission Systems (Percent)

Region	1993	1998	2000
Europe	0	5	10
Japan	0	4	15
North America	0	15	20
Asia/Pacific-ROW	0	1	3
Total	0	7	12

Source: Dataquest (April 1995 Estimates)

Features of Adaptive Shift Pattern Electronic Transmission

The major benefit of the ASP system is the ability to offer manual transmission driving in an automatic transmission car. The Porsche Tiptronic system receives input from eight sensors and interfaces with the ABS/traction control system and engine management systems:

- Engine speed sensors
- Lateral acceleration sensors
- Lateral deceleration sensors
- Road speed sensor
- Temperature sensors (engine)
- Throttle angle sensor

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- Throttle speed sensor
- Transmission sensors

Current first- and second-generation Tiptronic systems were designed around an 8-bit microcontroller, but the trend is toward using 32-bit controllers for newer transmission systems as the new designs eliminate mechanical function replacing mechanics with electronics—this requires more software and faster processing performance—making them smaller and lighter. The complexity of the controller is dependent on transmission technology and design of transmission system. The electronic control units outputs signals to solenoid valve actuators that control the transmission system and also to the engine management systems.

The ECU in the Tiptronic system monitors and learns driver behavior, while assessing environmental conditions. Depending on the results of these factors, it selects from five automatic electronic shift maps and adjusts torque, power, and speed (gear) accordingly. The five adaptive shift pattern algorithms contain programs that give optimal performance when driving uphill, for sporty driving, on bad road surfaces, in economy driving modes, and for city driving.

Electronic Clutch

What Is Electronic Clutch?

An electronic clutch involves a system of applying the clutch by using an electronic control unit to release gear-shift forks for manual transmission systems. This system has been used widely in Formula 1 racing for many years and is now beginning to appear in production vehicles. The first major debut in production cars was made in June 1994 by Renualt for the Twingo. In this car there are only two foot pedals: the brake and the accelerator pedal.

Features of Electronic Clutch Systems

An electronic clutch system deploys an electrical pump, a receiver, an electronic control unit, a gear shift lever sensor, an engine speed sensor, and a transmission sensor. The electronic control unit receives input from the gear shift lever sensor, engine speed/throttle sensors, door switch, and transmission sensors. When the driver puts his hand on the gear lever, the sensor transmits this information to the control unit; this activates the gear shift forks, which take over the maneuver to operate the clutch by means of a hydraulic circuit. The system relies on a conventional clutch system but uses a hydraulic gear shifter circuit to control the clutch system.

With cars fitted with electronic clutch systems, it is impossible to stall, jerk, or over-rev engines. Another benefit of the system is that it immobilizes the vehicle when the engine is switched off with a driving gear engaged.

Currently, Renualt offers the system with its Twingo car model and is expected to design the system into a new range of Clio cars. BMW's Rover subsidiary and Honda are also known to be evaluating the system in Europe. We expect to see some introductions in a range of vehicles including some sports cars, small vans, and light trucks by 1996 (Table 7-6 shows the forecast). The sole supplier for this type of system is Automotive

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Products (AP) Borg & Beck, but Dataquest believes that many other manufacturers of transmission and clutch systems will follow with introductions of similar systems over the next two years.

Table 7-6
Worldwide Automotive Market Penetration of Electronic Clutch Systems (Percent)

Region	1993	1998	2000
Europe	0	12	18
Japan	0	10	15
North America	0	15	20
Asia/Pacific-ROW	0	1	3
Total	0	11	15

Source: Dataquest (April 1995 Estimates)

Electronic Brakes (Brake by Wire)

What Is Electronic Brakes?

Electronic brakes are a new technology involving an electronic actuation system that will maximize braking performance of vehicles fitted with an ABS. Electronic braking systems apply maximum brake servo force, irrespective of the amount of pedal pressure from the driver. The system has an electronic control unit that detects emergency braking patterns and applies a booster to the brake servo.

Features of Electronic Brakes

The system deploys a four-wheel ABS system (traction control optional), an electronic control unit, position sensor, and solenoid valves. Electronic brakes use position sensors to detect emergency braking by measuring the speed of the application of the brake pedal. As soon as the speed of application of the brake pedal exceeds a predetermined critical value, the system is engaged – the sensor sends signals to an electronic control unit to engage an electronic actuation system, which applies the maximum possible servo force. The hydraulic pressure boost is applied to each wheel. This ensures that ABS is activated, bringing the car to a stop in the shortest possible distance while allowing the driver to steer.

Lucas and Mercedes-Benz have been developing such a system over the past few years, and this is expected to appear on some Mercedes cars from 1996 (see Table 7-7 for the worldwide forecast). Current systems will use a 16-bit microcontroller and typically share a module with the ABS and traction control units.

Future Electronic Braking Systems

Future developments of the electronic braking system will bring features such as:

- Active stability control and traction control (a driver stability control system)
- Hill-hold braking system

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Table 7-7
Worldwide Automotive Market Penetration of Electronic Brakes (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	0	1
North America	0	0	1
Asia/Pacific-ROW	0	0	0
Total	0	0	1

Source: Dataquest (April 1995 Estimates)

- Cruise control
- Autonomous intelligent cruise control (AICC)
- Constant pedal pressure (vehicle payload-dependent braking)

Several manufacturers of ABS and traction control systems are evaluating the use of hydraulic boosting of the braking force. The newest research in this area is examining ways of achieving proportional boost from the brake booster. This could allow the use of electronic brakes for the future development listed above at minimal cost. The system also allows for a less expensive ABS system, as ABS, traction control, AICC, and constant pedal pressure systems are integrated into one complete system.

Dataquest believes that electronic brake boosters will eventually become a functional feature of future ABS and traction control systems. The application of this type of brake assistance system is likely to be fitted to cars with automatic transmissions. Although these systems are now only just emerging, the future uptake will depend on the uptake and success of ABS systems penetration into new cars.

Diesel Electronic Fuel Injectors (Electronics)

What Is Electronic Diesel Control?

Tougher emissions requirements will soon lead to totally smoke-free diesels. Many car manufacturers are designing newer diesel engines to meet these emission requirements. As the next-generation high-speed direct injection (HSDI) engines begin to replace existing injection engines, diesel engine fuel pumps will be rapidly replaced by electronic diesel unit injector systems. These new diesel injector systems each have a high-speed fuel injection pump per fuel injector. Solenoid valves control fuel flow, and these valves are controlled by an electronic control unit.

Lucas has developed an electronic unit injector (EUI) that meets the Euro 3 emission standards due for introduction in 1996 and the U.S. Fed 98 legislation (a stricter requirement for exhaust emissions than the current emissions regulations). The objective is to develop a system that provides very high-pressure diesel injection into each engine cylinder. Currently, most diesel engines operate with injection pressure of 400-bar maximum. The new systems aim to deliver injection pressure rates of up to 2,000 bar. These systems will improve diesel fuel combustion; this provides a quieter diesel engine, with better performance and cleaner emissions.

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Features of Electronic Diesel Control

The electronic control unit receives information from accelerator pedal sensors, engine speed sensors, camshaft sensors, and air flow sensors. It uses this information to calculate the amount of fuel required per injection unit. Most diesel systems use a 16-bit MCU but are rapidly moving to 32-bit for commercial vehicles. However, the stricter U.S. CARB is pushing 32-bit electronics into diesel engines in meeting new engine diagnostics regulations enforceable with the U.S. Fed 98 legislation.

Major manufacturers of diesel engine electronics are listed below, while Table 7-8 gives the worldwide forecast for penetration of the systems:

- Delco
- Lucas
- Robert Bosch
- Nippondenso
- Nissan Diesel
- Toyota

Table 7-8
Worldwide Automotive Market Penetration of Diesel Engine Injector Control (Percent)

Region	1993	1998	2000
Europe	1	5	8
Japan	1	2	5
North America	1	2	3
Asia/Pacific-ROW	0	1	2
Total	0	3	5

Source: Dataquest (April 1995 Estimates)

Collision Avoidance

What Is Collision Avoidance?

Collision avoidance technology involves obstacle detection technology, which has been explained in some detail in the section on near-obstacle detection (page 42). In the automotive industry, wherever collision avoidance is discussed two issues arise: active (preventive) collision avoidance; and passive (detection) collision avoidance. The fundamental technology, however, remains the same and involves a combination of either ultrasonic sensors, or radar/microwave or infrared sensor-based detection systems.

Features of a Collision Avoidance System

Currently, there are no fully deployed collision avoidance systems, but many car manufacturers have developed prototype collision avoidance systems that could be deployed in passive or active systems. Typically, a passive system will give the driver advance warning of potential collision

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dangers, while active systems are configured with other electronic systems such as braking, transmission, cruise/engine control or, in extreme possibilities, steering control to actively avoid collision. Most of the research in collision avoidance technology is still under way, but we believe that first-generation systems will become available within the next few years (see Table 7-9 for the worldwide forecast).

Table 7-9
Worldwide Automotive Market Penetration of Collision Avoidance Systems (Percent)

Region	1993	1998	2000
Europe	0	5	8
Japan	0	5	7
North America	0	5	10
Asia/Pacific-ROW	0	1	5
Total	0	4	8

Source: Dataquest (April 1995 Estimates)

Future Applications of Collision Avoidance Systems

Active collision avoidance systems are designed to avoid collision. First-generation systems are already used in commercial vehicle applications for detecting objects in the drivers' blind spot areas. In the United States, Delco has developed a forward-looking radar warning system that is currently installed in Toyota's luxury Lexus range. Delco is also developing a full collision avoidance system integrated in an intelligent/active cruise control system.

Recent second-generation systems have been developed for use in cars to aid reversing and parking maneuvers. In Europe, BMW is already offering this system as an option for its cars; in Japan, Mitsubishi offers intelligent cruise control connected to throttle and transmission control on the top-range Diamante car model. Third-generation systems will likely be proactive systems linked to engine management and cruise control, braking systems, and, potentially, steering.

Major manufacturers developing collision avoidance systems include the following:

- Delco
- Kansei
- Mercedes-Benz
- Mitsubishi
- Nissan Diesel
- TEMIC (Telefunken)
- Toyota
- TRW

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Collision avoidance technology is a major function of so-called "cooperative driving" where cars traveling toward a common destination on motorways are batched together in wireless chains. The collision avoidance technology is deployed in the intelligent cruise control system (see earlier section) to facilitate a cooperative driving system that is proven in theory (simulation tests) to improve traffic efficiency.

Driving Stability Control Systems

What Is a Driving Stability Control System?

Driving stability control systems, known as DSC, are a new technology developed by Mercedes-Benz and Robert Bosch for next-generation, top-range Mercedes models. It involves a steering wheel angle sensor (optical sensor), a vehicle rotational speed sensor, acceleration sensors, wheel speed sensors, and yaw rate sensors; and deploys electronic steering with the ABS and traction control system. The main electronics of the DSC is integrated with the ABS and traction ECU. The objective of DSC is to monitor and maintain driver control of the vehicle to avoid loss of traction.

Features of Driving Stability Control

Driving stability control systems receive input from a steering wheel angle sensor, a mechanical magnetic vibration sensor (piezo-electric), wheel speed sensors, acceleration sensors and a yaw/rate sensor.

The system relies on a principle called "electronic brake force distribution," which governs the electronic system. Electronic brake force distribution applies a compensating brake force to diagonally opposite or adjacent wheels to counteract vehicle yawing and pitching. The system relies on many of the sensors in a traction control system and the ABS. The system processes data for rotational speed around the vertical axis and steering angle positioning for driver control analysis. DSC systems share the ABS and traction control actuators, and output data is fed from the control unit to the actuators.

The electronic control unit of this system uses a 16-bit MCU. The system applies braking to slow down a car if driving too fast on ice. Demonstrations of these systems in countries like Sweden and Norway have already received very good reviews in the automotive industry.

Driving stability control systems are now emerging in high-end cars and will begin to take off from 1997 onward (see Table 7-10 for the worldwide forecast). Mercedes-Benz will install this system on the new replacement E-class model. In Japan, Mitsubishi and Toyota are also evaluating a similar system for midrange vehicles.

The major ABS and traction control system manufacturers are leading in the development of driving stability control systems. Dataquest believes that by the end of the decade, driving stability systems will begin to appear in cars in all the major producing regions. Major manufacturers of driving stability control systems include the following:

- Allied Signal
- ITT Automotive (Teves)

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Table 7-10
Worldwide Automotive Market Penetration of Driving Stability Control Systems (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	1	2
North America	0	1	2
Asia/Pacific–ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

- Kelsey-Hayes
- Lucas Braking Systems
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes

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Chapter 8
Body Control Electronics

Body control electronics includes all the electronics that control car body and chassis functions. Body control electronics improve vehicle comfort and convenience by making it easier to control body systems. They include such systems as central locking, sunroof, and memory seat controls.

As vehicle electronics in future systems begin to merge, many body control functions could be linked to other system controls such as powertrain management systems or dynamic vehicle control systems, which will include powertrain, suspension control, and steering control.

This chapter covers emerging applications that fall within vehicle body control areas such as the following, all of which will have a direct connection on the functionality of the vehicle's body electronics hardware:

- Tire pressure monitors
- Multiplexing systems
- Car computer (on-board diagnostics)
- Noise cancellation
- Accident recorders – automotive "black-box"

Tire Pressure Monitors

What Is a Tire Pressure Monitor?

Tire pressure monitors are not an entirely new concept but have been discussed in the automotive world for many years. A tire pressure sensor (electromechanical limit switches or semiconductor pressure sensors) is used to monitor each individual tire pressure, and sends an audible or visual warning signal to the driver reminding him to check air pressure. The sensor is actually located inside the rim of the wheel and is designed to withstand the high pressure of air in tires. An electronic receiver/decoder receives radiofrequency signal transmissions and outputs either a warning signal or the actual tire pressure of each individual tire.

In Europe alone, official statistics show that 50,000 people are killed in road accidents resulting from tire blowouts. Car manufacturers are keen to eliminate these fatalities by offering tire pressure monitors as a standard safety feature.

It is also proven that maintaining proper tire pressure improves tire wear and fuel efficiency. In underinflated tires, temperatures rise and this quickly deteriorates tread wear. Furthermore, underinflated tires can severely affect vehicle handling and steering, and this is potentially dangerous in built-up areas where pedestrians could be put at higher risk.

The trend is toward integrating tire pressure monitors with keyless entry systems using commonly shared RF receivers. Current pricing for tire pressure monitors range from $100 upwards to around $400. This makes it prohibitive for car manufacturers to fit them as standard on cars.

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Cheaper variations of tire pressure monitoring incorporated in antilock braking systems involve using the wheel speed sensors to track individual wheel rotation speeds. General Motors' Delco Electronics subsidiary is exploiting the theory that an underinflated tire has a smaller diameter, and therefore will have to rotate faster than a normally inflated tire. In theory, the fastest rotating wheel will have a lower pressure, but this theory is not always reliable and requires further development. Delco Electronics is one of the companies known to have been developing such a system.

Major manufacturers of tire pressure monitor systems are listed below, and Table 8-1 gives the worldwide forecast:

- Epic Technologies (USA)
- Schrader Automotive (USA)
- Robert Bosch (Germany)
- Delco Electronics
- Sentronics Limited (N. Ireland)

Table 8-1
Worldwide Automotive Market Penetration of Tire Pressure Monitors (Percent)

Region	1993	1998	2000
Europe	0	1	2
Japan	0	1	2
North America	0	3	5
Asia/Pacific-ROW	0	0	0
Total	0	1	2

Source: Dataquest (April 1995 Estimates)

Dataquest believes that tire pressure monitors could be mandated for all vehicles in the next decade either through government legislation or from insurance companies. The technology is still too expensive for car manufacturers to justify, but with the uptake of RF keyless entry in vehicle immobilization systems, the potential remains for tire pressure monitors to be included.

Multiplexing Systems

What Is a Multiplexing System?

Multiplexing systems refer to the networked cabling and communications techniques designed to eliminate the multiplicity of wiring found in the typical vehicle, as brought on by the proliferation of electronic systems. Multiplexing technology allows the effective networked communications between linked electronic control units on the same data bus.

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Features of Multiplex Systems

Multiplexing generally is segmented into speed classes. One segmentation adopted by the US-based Society of Automotive Engineers (SAE) defines the speed classes as follows:

- Class A: Low-speed for body-wiring applications up to 10 Kbps
- Class B: Medium-speed for data-sharing applications, between 10 Kbps to 125 Kbps
- Class C: High-speed for local area networking, greater than 125 Kbps

At the moment, many car manufacturers are using the Class A-type multiplexing for door applications such as power windows, central door locking, alarm (car security), electric mirrors, and sunroof applications. Already, several standards are emerging from two major communication protocols, the J1850 and the ISO 9141. J1850 and ISO 9141 are the proposed protocols adapted for car diagnostics. Some car manufacturers are also developing their own proprietary communication protocols and standards. Table 8-2 lists some of the emerging systems.

Table 8-2
Emerging Multiplexing Systems

Standard	Diagnostic Data Link	Car Manufacturer
A-Bus	ISO 9141	Volkswagen
Basic CAN	ISO 9141	
CAN	ISO 9141	
C2D	J1850 or ISO 9141	
DLCS	J1850	General Motors
HBCC	J1850	Ford Motor Company
HSSD	J1850	Proposed U.S. high-speed standard
ISO 9141		
ISO 9141 CARB		(Meets U.S. CARB specification)
J1850		
PALMNET	J1850 or ISO 9141	Mazda
VAN	ISO 9141	PSA and Renault

Source: Dataquest (April 1995)

Benefits of Multiplexing

Probably the most measurable benefit of multiplexing technology is that it reduces the quantity of wiring harness in a vehicle. Each subsystem in the car will have a multiplex IC that acts as an interface chip with a defined I/O address and a priority rating for data processing and data management purposes on the data bus. This means that future systems will be easier to install as the wiring requirements will be greatly reduced.

From the point of view of the overall vehicle weight, a multiplexed data bus will reduce the weight of electrical wiring required for cars. This could also allow for more space in the vehicle body for additional electronics. The design of multiplexed wiring systems also eliminates wiring problems and difficulties associated with the already complex wiring harness

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of vehicles. The number of connectors required by existing wiring harness technology will also be reduced as a result of implementing this highly structured and hierarchical technology.

Overall, multiplexing technology contributes to integrating the vehicle's electronics and electrics by eliminating redundant sensors—sensors could be used more efficiently to feed input signals to one or more electronic control modules on the data bus. Likewise, multiplexed technology eliminates duplicate microcontroller functions by allowing more efficient use of microcontrollers in the same way as it allows the combination and integration of electronic control units.

Most importantly, this technology improves diagnostics as the communications systems and networks become integrated. This will speed up the processes of performing on-board diagnostic checks and off-board checks.

Future Multiplexing Systems

Future multiplexing systems will replace the complexities involved in contemporary vehicle wiring with potentially what will become a single "bus" (that is, one wire), using semiconductor interface chips as gateways. Low-speed multiplexing systems have been developed and are already in use by most car manufacturers for luxury cars. These systems operate such functions as windows, sunroof, door locking, and memory seat applications. Future developments will be for medium-speed and high-speed data bus systems.

Recently, the United States has approved the J1850 standard for Class B speeds. It incorporates many of the features that other U.S. vehicle manufacturers use in their proprietary standards. It appears, however, that vehicles made for the European market will be based on ISO 9141, while the North American market will use the J1850 protocol for diagnostic links. The Japanese and Korean manufacturers are likely to make all varieties to satisfy their overseas markets. Developments continue in the high-speed data bus area to develop the integration of engine management, suspension, power steering, braking, and transmission systems.

Major suppliers of multiplexing systems for automotive applications are listed below, and Table 8-3 gives the worldwide forecast:

- Chrysler
- Delco Electronics
- Ford Electronics
- Hella
- Nippondenso
- Robert Bosch
- Siemens Automotive
- TRW
- Valeo
- UK NSI

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Table 8-3
Automotive Market Penetration of Multiplexing Systems (Percent)

Region	1993	1998	2000
Europe	1	5	15
Japan	2	15	20
North America	3	20	25
Asia/Pacific-ROW	0	2	5
Total	2	11	17

Source: Dataquest (April 1995 Estimates)

Car Computer (On-Board Diagnostics)

What Is a Car Computer?

Car computer systems were first developed in the 1980s. It was during this same phase in automotive electronics that voice annunciators were being introduced into cars. Initially, car computers were designed to provide synthesized voice information giving warnings about engine oil pressure, fuel left in tank, door opened, temperature and other such information.

Features of Car Computer Systems

Newer systems include diagnostic check functions and are more sophisticated than the earlier-generation systems. The car computer system comprises a manually operated programmable input keyboard, LCD alphanumeric character display panel, and a microcomputer system. The keyboard acts as a driver interface with the system and the driver can set or obtain information including such functions as:

- Date, time (real time), and arrival time (estimated)
- Average fuel consumption
- Average speed
- Distance to destination
- Mileage conversions (miles to kilometers and kilometers to miles)
- Outside temperature
- Speed limit warning
- Stopwatch
- Timers (trip timers)
- Travel range

Input data is received and processed by the microcomputer from all other critical electronic systems such as:

- Actuators
- Airbag system
- Air-conditioning control

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- Alternator condition
- Antilock braking system
- Battery condition
- Door locks
- Engine management system
- Engine oil pressure
- Exhaust emission
- Fuel tank sensors
- Ignition control
- Lights
- Power steering
- Power supply
- Seat belts
- Speed
- Temperature (external/internal)
- Wiper control (windscreen and driving lamps)
- Wiring (short circuit detection)

All the above systems are tested by the microcomputer in a diagnostic check function by running programmed memory with test patterns for each system, which can be retrieved and used for comparisons. Each peripheral system has an address and the data and address buses are included in the system test routines. Sensors are tested for performance within specified limits while open and short circuits can also be detected.

Output data from the test results (diagnostics) is fed back to the car computer and displayed, or audible synthesized voice annunciation is made to communicate the results to the driver through the car speakers.

Newer systems being developed provide temporary software solutions to provide a "limp home" solution to engine problems or electrical problems. Sometimes the limp home solutions may, for example, involve disabling electronic systems that control faulty mechanical functions or actuators. Here, multiplexing technology and its protocols will vastly improve the prioritizing of data checks that are required for systems diagnostics; thus, a faulty electronic transmission system would be switched off by a car computer to allow full manual operation as a limp-home solution.

The application of car computer systems such as the fully diagnostic system described above is very low (see Table 8-4). The development costs of such systems are very high as for each new generation of electronic systems that are input sources to the computer, the diagnostic software often needs redevelopment.

This has sustained the high cost of these systems and, consequently, the low penetration rates. Trip computers are a scaled-back version of the car computer system, and these are gaining some significant penetration

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rates. Dataquest believes, however, that future legislation and enforcement tactics of some car systems such as exhaust emissions may lead to increased use of such systems in cars and commercial vehicles.

Major players in car computer systems include the following:

- Delco Electronics
- Ford Electronics
- Magneti-Marelli
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Valeo
- VDO (Mannesmann)

Table 8-4
Worldwide Automotive Market Penetration of On-Board Car Computers (Percent)

Region	1993	1998	2000
Europe	4	15	20
Japan	5	12	20
North America	8	10	15
Asia/Pacific-ROW	1	3	5
Total	5	11	15

Source: Dataquest (April 1995 Estimates)

Active Noise Cancellation (ANC)

What Is Active Noise Cancellation?

Noise cancellation systems are designed to electronically cancel unwanted cabin noise and external noise from the engine and exhaust mufflers. The benefits extend beyond making vehicles quieter to making them also more energy-efficient. The concept of active noise cancellation involves two major sources of noise, namely cabin noise and engine noise.

Features of Active Noise Cancellation

Cabin noise (or passenger compartment noise) is usually amplified through the body of the car from materials that absorb and transport noise into the car. Primary contributors of noise are the engine, engine mounts, suspension (shock absorbers), and the car body itself. Noise cancellation technology relies on the application of DSP chips to control noise from engine mounts, electronic mufflers and interior quieting. The controller processes a cancellation algorithm, which is stored in the RAM of the DSP chip. The process of noise or vibration cancellation is performed by a signal that is its exact mirror image at the same noise/vibration amplitude but 180 degrees out of phase.

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Current development for active noise cancellation ECUs will initially be standalone, although they could become integrated in engine management system.

Future Applications of Active Noise Cancellation

The electronic control unit itself receives signal input from the throttle and tachometer to predict engine noise occurring from car acceleration. Other sensors include a microphone in the muffler, a microphone in the air vents, and an additional number of microphones in the passenger compartment. Each of these signals are processed by the electronic control unit, which then outputs command signals to actuators that control loudspeakers and exhaust flow modulation for the electronic mufflers, hydraulic dampers and noise dampening systems on the car body, and the interior compartment loudspeakers through the car stereo. This particular application is deemed to be most attractive for small cars, which tend to have very small amounts of sound insulation by the nature of small car construction.

A major and measurable financial benefit and justification for noise cancellation systems is that they could offer fuel savings to the driver. ANC allows control of engine vibrations, allowing smaller engines to idle at lower speeds, thus saving fuel.

Noise cancellation systems are in use by specialist car manufacturers especially in the sport of motor-racing. But commercial application of noise cancellation has been slow because the systems contribute very little benefit for larger vehicles, which have better insulation and, nowadays, highly refined engines that are quieter than earlier generations. Some commercial vehicle applications for exhaust mufflers have been established but with very limited success among commercial vehicle manufacturers.

In Europe and Japan, Fiat and Nissan have been reported as evaluating active noise cancellation systems for a new range of small cars planned for market introduction after 1998. Prototype small cars fitted with this technology drive very quietly, which gives a perception of being more expensive-sounding vehicles. Depending on the cost of future systems for small cars, these systems could appear in cars in a big way by the end of the century although at this point in time, we believe they are further away than that (see Table 8-5 for the worldwide forecast).

Table 8-5
Worldwide Automotive Market Penetration of Active Noise Cancellation (Percent)

Region	1993	1998	2000
Europe	0	10	15
Japan	1	5	10
North America	0	13	20
Asia/Pacific-ROW	0	2	5
Total	0	8	13

Source: Dataquest (April 1995 Estimates)

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Costs associated with DSP application are one of the major factors why introduction of these systems is being stalled. However, legislation against noise pollution from HGVs and commercial passenger buses could also affect the introduction of this technology in vehicles.

Companies developing active noise cancellation technology include the following:

- Calsonic (Tokyo)
- Digisonix (U.S. pioneer of ANC)
- Elesa (a Fiat-owned Magneti-Marelli subsidiary, and joint-venture company with Noise Cancellation Technologies Inc.)
- Lotus Engineering
- Lucas Automotive
- Nissan (Japanese Bluebird model ANC)
- Saab
- Ultra Electronics (developed Saab commuter aircraft ANC system)

Accident Data Recorders—"Automotive Black-Box"

What Is an Accident Data Recorder?

Accident data recorders (ADRs) or automotive black boxes are a technology descended from the aviation industry that is slowly finding a place in modern vehicles. The applications of black boxes in the aviation industry are most commonly for aircraft diagnostics and also for examination to determine the likely causes of air crashes.

There are many different variations of accident data recorders, but the most sophisticated systems have diagnostic systems that monitor performance algorithms of all the key electronic systems in a vehicle.

Features of Accident Data Recorders

Aircraft accident data recorder systems emerged from diagnostic monitoring systems. The technology of these systems is now modified for cars to track vehicle behavior before, during, and after an accident.

An accident data recorder receives input signals from diagnostic functions of car electronic subsystems. Typically, the ECU of the system has an 8- or 16-bit microcontroller, and a certain amount of memory buffer. The basic system receives input from the ignition switch, speedometer, brake light sensors, indicators (left/right), and lights. More sophisticated accident data recorders may receive signals from ABS/traction control (optional), airbag (including side impact airbags), navigation systems (optional), and engine management systems. All these systems include the following sensors that are constantly monitored by the ADR unit:

- Accelerometers
- Azimuth sensors
- Brake signals/sensors

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- GPS data
- Lateral sensors
- Longitudinal sensors
- Transmission sensors
- Vertical sensors

After an accident has occurred, the latest driver reactions before impact are digitally stored in the system. This data could be analyzed to prove cause of accident and performance of safety critical subsystems such as ABS, airbags, and electronic brakes.

Future ADR Systems

The ADR system has many benefits that could become attractive for a range of applications. Firstly, for the general public, effective marketing of these systems by car manufacturers will help raise consumer awareness. If these systems are not marketed properly, consumers could view them as hostile electronics that monitor their driving habits.

Secondly, fleet operators may easily justify installing ADR systems for their vehicles. Taxi companies, for example, may find that their insurance claims will be less when drivers know that their vehicles are fitted with ADRs.

Thirdly, insurance companies may influence the installation of ADRs in cars to speed up processing of accident claims and to reduce the rate of accidents among their own policyholders. In theory, if drivers know that their driving habits are being recorded, then they might be more cautious about avoiding careless driving, and this could reduce accident rates in favor of insurance companies.

Fourthly, ADRs could provide safety-critical system diagnostics for the driver to enhance the diagnostics already in place for each car system. This could be beneficial for drivers who frequently wish to feel secure in their cars before making long journeys.

However, for these systems to gain market acceptance, they may require legislative instruments to support the application of the data they provide. For example, laws pertaining to road use vary across Europe; certain standards of data gathering that meet national traffic regulations will need to be developed further.

Major suppliers of accident data recorders are listed below, and Table 8-6 gives the worldwide forecast:

- Bosch
- Mannesmann
- Valeo
- Sagem
- Siemens Automotive
- TEMIC (Telefunken)

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Table 8-6
Worldwide Automotive Market Penetration of Accident Data Recorders (Percent)

Region	1993	1998	2000
Europe	0	3	10
Japan	0	4	20
North America	0	5	20
Asia/Pacific-ROW	0	1	1
Total	0	4	13

Source: Dataquest (April 1995 Estimates)

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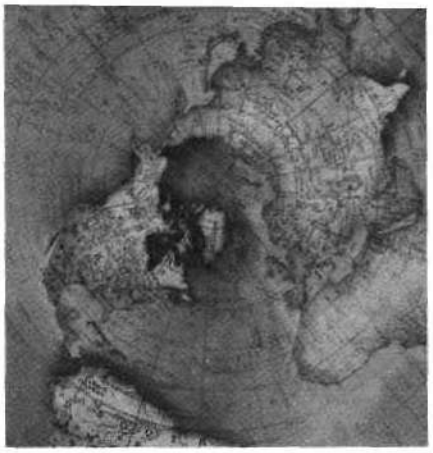
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Personal Communications Services (PCS): Wireless Renaissance or Brave New PCS World?



Focus Report

Program: Semiconductor Application Markets Worldwide
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Chapter 1
PCS: A Communications Utopia?

For visionaries, personal communications services (PCS) represents the dawning of a new era that will eventually lead to a wireless digital communications utopia. Beginning with basic "cellularlike" voice services and limited two-way voice and data paging services, PCS service providers will soon offer subscribers enhanced data services including advanced messaging, information access, commercial transaction, "bulletin board" interaction, and entertainment services. Innovative technologies and services being developed will add advanced intelligence to software, networks, and subscriber terminals that will allow subscribers to actively manage their communications in an efficient manner. Technologies that enable capabilities such as "one number/one person" will allow true communication between individuals instead of between specific devices or locations. It is anticipated that wireless video and multimedia services will eventually be possible.

PCS services could add rocket fuel to a wireless industry that is already exploding. Traditional methods of measuring the potential wireless communications market need to be re-evaluated because of new factors introduced by the concept of PCS. What is the wireless voice communications penetration in the United States today? Based on the cellular market, the typical answer would be less than 10 percent—more than 20 million subscribers out of about 250 million potential users. However, service providers make their money based on minutes of use. If the total wireless minutes of use is divided by the total of wireline minutes of use plus wireless minutes of use, the actual wireless voice penetration is less than 1 percent and data services penetration is practically 0 percent. Reduced pricing for wireless services and devices based on increased PCS competition and new technologies has the potential to greatly expand wireless penetration in this different perspective.

Manufacturers of wireless communications subscriber equipment such as cellular handsets and pagers have the potential to reach a much larger market than the traditional corded telephone manufacturers. The penetration of wireline telephone service into U.S. households is approaching 100 percent today (95 percent to 98 percent, according to different surveys). This means that there is about one access line per household, with an average of 2.6 people per house. The PCS concept of 100 percent penetration—one or more communications devices for every person—would mean a doubling or tripling of the handsets supplied to the PCS market, compared to the traditional wireline market.

However, this new PCS world is not for the faint of heart. The challenges that face companies desiring to compete in this market have caused even powerful and seasoned wireless industry veterans to carefully evaluate the resources, costs, and commitment that will be required for success. Major alliances, mergers, and acquisitions have resulted as companies seek to pool resources, leverage strengths, share risks, and develop strategic advantages in this new wireless arena.

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The creation of the PCS market in North America has also brought the deliberate introduction of increased competition to the wireless communications industry. This competition is expected to drive down prices for wireless devices and services so that they will be accessible to a much larger business and consumer market. In light of the risks and costs presented by the PCS market, many question the opportunity it offers to earn a reasonable return on their investment. Although prospective participants in the PCS competition seek the rewards to be reaped by the victorious, they cannot escape the sobering realization that the heat of battle will most certainly leave many vanquished foes on this new playing field. However, the risk/reward calculations of current wireless industry players has prompted them to pursue active participation in the PCS market. These calculations have also attracted a large number of companies seeking a new path of entrance to the wireless industry through the PCS market.

Potential service providers, manufacturers of infrastructure and subscriber terminal equipment, and semiconductor manufacturers must deal with a host of uncertainties and risks surrounding the PCS market. This report will address many of the key issues and events impacting the PCS market, such as the ongoing auctions, the battle between the proposed technical standards, the costs of developing a new wireless infrastructure, and the challenge of providing services in a timely manner. To provide a balanced perspective, Chapter 2 will present an overview of current and emerging wireless devices and services for general consumer and business applications. Chapter 2 will also provide some helpful definitions of terms used in the wireless industry. Finally, this report will outline the major equipment and semiconductor manufacturers competing in this market, present key technical trends, and discuss semiconductor opportunities presented by the emerging PCS market.

Project Analyst: Dale Ford

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Chapter 2
Overview of Current and Emerging Wireless Products and Services

A wireless communications renaissance is sweeping the world with a host of new technologies enabling a number of new wireless communications products and services. This chapter provides some perspective on where PCS fits in the overall wireless picture for consumer and general business applications by providing a brief description of current and emerging wireless products and services.

The following is a summary of these wireless communications products and services:

Current Wireless Products and Services

- Voice
  - Analog cordless (local)
  - Analog cellular
- Data
  - Point-to-point and diffuse infrared (local)
  - Pager radio
  - Circuit switched cellular

Emerging Wireless Products and Services

- Voice
  - Digital cordless (local)
- Data
  - Analog cellular with cellular digital packet data (CDPD)
  - Wireless local area networks (WLAN) (local)
  - Digital packet data radio
    - RAM
    - ARDIS
    - RadioMail
- Voice and data
  - Digital cellular
  - Enhanced specialized mobile radio (ESMR)
    - Nextel
  - Satellite communications
  - Personal communications services (PCS)
    - Unlicensed
    - Narrowband
    - Broadband

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Wireless Communication Today

Two technologies now are used for wireless voice communications, and two for transmitting data wirelessly over wide areas. Analog cordless telephones commonly are used for wireless communications within a small radius in homes and businesses, while analog cellular telephones are used in mobile wireless communications applications. Pager radio and circuit-switched cellular, which uses the cellular voice channels to transmit data, are employed for wireless data communications.

Analog Cordless Telephones

Until the early 1990s, all commercially available cordless telephones used analog technology and analog modulation techniques for the radio transmission between the handset and the base station. The base station provides the wireline connection to the public switched telephone network (PSTN) or private branch exchanges (PBXs). The primary market driver of cordless telephones has been the residential market. Analog cordless telephones have achieved a 49 percent household penetration rate in the United States.

Characteristics of analog cordless telephones are as follows:

- Two-way voice communications with limited area of coverage
- No roaming capability between base stations
- Some models incorporating tape-based or digital answering machines
- Suffers from poor speech quality, channel interference, poor propagation of signal, and lack of privacy
- OEMs continue to make improvements, including move to 3V technology, to reduce battery requirements and weight and size of handsets

Analog Cellular Telephones

Analog cellular services provide mobile, wireless communications between a handset and a base station that interfaces to the public switched telephone network (PSTN). The ability to perform a high-speed hand-off of a call from one base station to another enables users to communicate while traveling in a car. A number of different regional analog cellular standards have been established since the commercial launch of cellular in the early 1980s. The most common standard is the Advanced Mobile Phone System (AMPS).

Cellular services in the United States are provided by two operators in each of 306 metropolitan statistical areas (MSA) and 428 rural service areas (RSA). The number of cellular subscribers in the United States passed 20 million in 1994. As the number of cellular subscribers increases, the capacity of the existing cellular infrastructure in densely populated areas is becoming increasingly inadequate. Some interim solutions such as narrowband-AMPS (N-AMPS) have been developed, but long-term solutions will require the use of digital technologies.

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Characteristics of analog cellular include the following:

- Two-way voice communication and two-way data communication employing circuit-switched cellular or CDPD (an emerging technology) as described in the sections covering wireless data communications later in this chapter
- Subscriber receivers ranging in size from car-mounted units to micro handsets that fit in a pocket
- Limited channel capacity
- Problems with voice quality, dropped calls, and privacy
- Limited talk time and stand-by operation because of high power consumption and limited battery life

Infrared Communication

Point-to-Point (Serial Infrared)

Characteristics of point-to-point infrared are as follows:

- Devices exchanging information must be line-of-site
- Cannot operate through physical barriers
- Operates at a distance of about 10 feet or less
- Appropriate for applications that require small amounts of data to be exchanged between two devices
- Data transmission rates of about 115 Kbps

Diffuse Infrared (Infrared LAN)

Characteristics of diffuse infrared are as follows:

- Does not require line-of-sight use
- Can operate around but not through physical barriers
- Data transmission range to about 60 feet
- Applications include workgroup data exchange within a room, local client/server network, and local data exchange that requires a high level of security
- Data transfer rates at about 1 Mbps

Pager Radio

Wide area paging transmission involves the use of satellites to relay messages to transmission sites across the country. Paging technology can be used to deliver a message to a single recipient or to broadcast a message to many recipients.

With its Electronic Mail Broadcast to a Roaming Computer (EMBARC) system, Motorola offers a service that uses pager/receivers to download messages and information to a portable computer. SkyTel, a division of Mtel, also offers messaging services to a pager that connects to devices such as the HP95LX or HP100LX computer.

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Paging has its advantages in that it is inexpensive to send short messages, either to an individual or a group (broadcast), and information services are becoming available. In its current form, paging is severely limited in its capability because it is a one-way messaging technology.

Circuit-Switched Cellular Data Transmission

Characteristics of circuit-switched cellular include the following:

- Uses a cellular modem attached to a portable device, which is then plugged into a cellular phone
- Synchronous data transmission over cellular voice channels
- Device must be connected through the entire data transfer process
- Error-correction can drastically reduce the rates of data transfer, which optimally is 14.4 Kbps for most cellular modems
- Requires much battery power
- Two-way communication

Individual end users can buy a portable cellular telephone and an intelligent data interface for a portable computer for less than $700. The data interface is built-in with some portable computers, but the user must add the cellular phone. An intelligent interface will allow the computer or fax machine to dial and establish the connection, providing the advantage of unattended operation. But a key disadvantage of circuit-switched cellular is the inability to "store and forward," which is important for fax and messaging applications. The store-and-forward function allows a message to be stored and re-sent at a later time automatically. This type of service will be made obsolete by other technologies.

Emerging Wireless Communication

Wireless communications technologies in the planning, development, testing, or early implementation phases include: digital cordless telephones (900 MHz), Cellular Digital Packet Data (CDPD) over analog cellular telephones, wireless local area networks (WLAN), digital packet data radio, digital cellular, specialized mobile radio (SMR), satellite communications, and unlicensed, narrowband, and broadband PCS.

Digital Cordless Telephones (900 MHz)

The next-generation digital cordless telephones (DCTs) take advantage of many of the technologies developed for digital cellular telephones. The common standard for these telephones in North America is 900-MHz DCT. Because of their improvements in speech quality, range and propagation capabilities, and privacy, they are beginning to displace analog cordless telephones. Digital handsets will represent more than 50 percent of cordless sales by 1998.

Characteristics of DCTs are as follows:

- Two-way voice communication within 100 meters of a base station
- No roaming capability between base stations
- Significant improvement over analog versions in speech quality, size, weight, and battery use

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- Some models incorporating digital answering machines
- New capabilities creating additional opportunities for use in business environments with wireless PBX/key systems

WLANs

In 1985, the U.S. Federal Communications Commission (FCC) approved frequency bands for unlicensed use of spread spectrum radio technology in commercial environments. This technology, more than diffuse infrared, will comprise the majority of the market for wireless LANs.

The first applications for this technology were in vertical markets, but spread spectrum radio technology is being used to create wireless LANs for horizontal applications by several companies.

Characteristics of WLANs are as follows:

- Can penetrate walls
- Data transmission range of up to 500 feet in a typical office setting
- Data transfer rates up to about 9.5 Mbps
- Designed as extensions to existing wired LANs
- Expensive per node (relative to infrared)

CDPD over Analog Cellular

CDPD is based on a data-only analog technique for sending packets of data either by dedicated channels or by sharing idle time on voice cellular channels. CDPD initially was endorsed by nine cellular carriers, many of which conducted full-scale testing in 1993. Implementation of CDPD beyond initial test locations has been plagued by numerous delays that have caused loud murmuring throughout the telecommunications industry. However, CDPD still enjoys support from major players that want to establish it as a standard. The key CDPD technology for sharing idle time on voice channels is called CelluPlan II and was developed by IBM. Specification 1.0 was released in July 1993 for digital packet-switched data transmission sequencing, flow and error control, and encryption.

Characteristics of CDPD include the following:

- Uses a CDPD modem (offered by Cincinnati Microwave, PCSI, and Sierra Wireless Inc.)
- Packet data transmission over cellular voice channels
- Store-and-forward capability
- Better for short transmissions or transactions
- Users of CDPD also will be able to use circuit-switched cellular data transmission
- Requires much battery power
- Two-way communication

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Digital Packet Data Radio

Packet data radio involves the use of a packet-switched network, but instead of wires as the means of transmitting the data, it is done with radio waves. To provide national coverage, RAM Mobile Data and ARDIS have licensed 10 to 30 channels per major metropolitan area that they cover. The most difficult challenge is to put up the transmitters nationwide that are required for nationwide coverage. By the end of 1993, both RAM and ARDIS provided coverage for major metropolitan areas in addition to smaller cities, giving access to, based on RAM's estimates, more than 90 percent of U.S. businesses. But they are both missing full geographic coverage.

Characteristics of packet data radio include:

- Wide area coverage
- Two-way messaging
- The use of a special two-way modem, currently offered from L.M. Ericsson (Mobidem), Motorola (InfoTAC), and Intel (AT-command set Mobidem)
- Motorola recently introduced a new personal digital assistant (PDA) called Marco, which operates on the ARDIS network and will work on the RAM network and digital cellular networks in the future
- Supports roaming

The RadioMail Corporation (San Mateo, California) provides public gateway services to RAM and ARDIS subscribers. With RadioMail, messages sent on the RAM or ARDIS network have a gateway to public and private networks; without RadioMail, RAM or ARDIS subscribers would have been severely limited to sending e-mail only to other subscribers of their proprietary network.

Digital Cellular

Next-generation digital cellular telephones provide the solution to the limited channel capacity of the analog systems and enable the creation of new voice and data services. Digital cellular telephones based on the Global Standard for Mobile Communications (GSM) represent the large majority of digital cellular handsets on a worldwide basis. The adoption of GSM as a common European standard has fueled its early growth. Two standards are battling for market acceptance in the United States: IS-54, a time-division multiple access (TDMA)-based technology; and IS-95, a code-division multiple access (CDMA)-based technology. An enhanced version of IS-95, originally called Revision C, was recently introduced. This new TDMA standard is now called IS-136. Markets for digital telephones based on these standards are expected to experience rapid growth in the United States, with dual-mode analog/digital cellular telephones representing the majority of the market by 1998.

Characteristics of digital cellular include the following:

- Two-way voice communication and two-way data communication
- Subscriber receivers range in size from car-mounted units to micro handsets that fit in a pocket

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- Smaller cell sizes with greater channel capacity
- Enhanced voice quality, elimination of dropped calls, and encryption capability
- Improved talk time and stand-by operation because of power-management designs
- Initial service availability in limited markets today
- Handsets more expensive to produce, compared to analog cellular telephones

As the pending competition with wireless handsets operating at about 2-GHz approaches, cellular service providers are quick to point out that the FCC definition of PCS only refers to a new and enhanced family of wireless services and not to wireless phones operating in a particular frequency range. "Personal Communications" has become *the* wireless communications marketing buzzword. However, the most common use of PCS in the telecommunications industry refers to new devices and services that will operate in the spectrum around 900 MHz and 2 GHz recently set aside by the FCC for "narrowband PCS" and "broadband PCS," respectively. Use of the term "PCS" in this report will refer to services and products operating in the 900-MHz and 2-GHz spectrums.

Enhanced Specialized Mobile Radio (ESMR)

ESMR frequencies are both in the 220-MHz and the 800-MHz range, compared with cellular frequencies, which are higher in the same 800- to 900-MHz band. Voice specialized mobile radio (SMR) services originally had been designated for private radio dispatch and fleet management, but the FCC is considering lifting SMR restrictions; this will allow reuse of the spectrum for cellularlike service. Leading the movement for the use of SMR for nationwide digital data communication called ESMR is Nextel Communications Inc. Motorola has a 20 percent stake in Nextel, which it acquired in exchange for SMR licenses. Nextel, in return, is using Motorola equipment to deploy the network. Nextel's strategy is to acquire as many 800-MHz SMR licenses as possible, and in its efforts to do so it has allied with critical partners to gain access to technology and licenses nationwide. Nextel is converting the networks it has acquired from analog to digital TDMA systems. It planned to roll out its digital wireless service throughout California and to the Chicago and New York City areas by the end of 1994 and to the top 100 markets by the end of 1995. Its integrated dispatch/cellular/paging service is already available in the Los Angeles area.

Satellite Communications

Satellite-based services would essentially be global cellular voice and data communications systems using low-earth orbiting (LEO) satellites as the switching and transmission infrastructure. Subscribers typically would use a dual-mode telephone that would interconnect with the standard cellular or PCS network in their home market and communicate via the satellite system when they are traveling outside their home region. Development efforts are reducing the subscriber receivers from the size of a briefcase to the size of a typical cellular handset.

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At least 12 proposals await international approval. The U.S. government has committed to licensing LEO satellite systems by the end of January 1995. Some of the major programs are: Motorola's Iridium with a $3.3 billion start-up cost and plans to launch 66 satellites; Teledisc, backed by Bill Gates and Craig McCaw, with a proposal to launch 840 satellites at an initial deployment cost of $9 billion; Inmarsat's Inmarsat-P project to raise $2.6 billion and launch 12 satellites into intermediate orbit; and Loral's Globalstar program for launching 48 satellites. Inmarsat's recent entry is most controversial because of its status as a quasigovernmental organization. Investors in the various projects come from countries throughout the world. Targeted service dates for the various projects range from 1996 to 2000.

PCS

PCS is a term that refers to a family of new wireless voice, data, and imaging products and services expected to hit the U.S. market beginning in 1996. Through a "Report and Order" issued in September 1993, the FCC allocated radio spectrum for the creation of a new wireless communications industry. Radio spectrum was set aside for three separate uses: unlicensed PCS, narrowband PCS, and broadband PCS. In this same order the FCC also determined the size of the geographic service areas, established eligibility requirements for service providers, outlined broad technical standards and construction requirements, and created guidelines for evaluating the exposure of users to the RF radiation emitted by PCS devices. A process of reviewing and modifying the original order was completed in the following year, and four "Pioneer's Preference" licenses were awarded to companies for major technical contributions to PCS technology. The auctions for wireless spectrum began in July 1994 with a series of multiple-round auctions for nationwide narrowband PCS licenses and continued with the auctions for broadband PCS licenses, which started December 5, 1994 and continued through January 1995.

The success foreseen for PCS is based on three expectations: more varied offerings, lower costs, and better quality than that of existing mobile services. Early PCS services are expected to include several advanced forms of voice and data products. The digital technologies behind PCS will enable the possible incorporation of strong encryption capability also. PCS later is expected to include video and multimedia applications. PCS advocates expect all those services to cost less than present counterparts such as cellular, specialized mobile radio, and radio paging. They also expect PCS technology to eliminate dropped calls, reception of unwanted conversations, and other interruptions that plague current analog cellular users.

Narrowband

Narrowband PCS license winners were awarded frequency blocks of 50 and 12.5 kHz in the 900-MHz spectrum. Early services announced by the license winners take the form of enhanced two-way paging communications services. These services range from allowing a pager subscriber with an alphanumeric pager to acknowledge that a message has been received by transmitting one of several canned responses to enabling the transmission and reception of longer messages through a portable computer or palmtop device equipped with a PCMCIA transceiver.

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Broadband

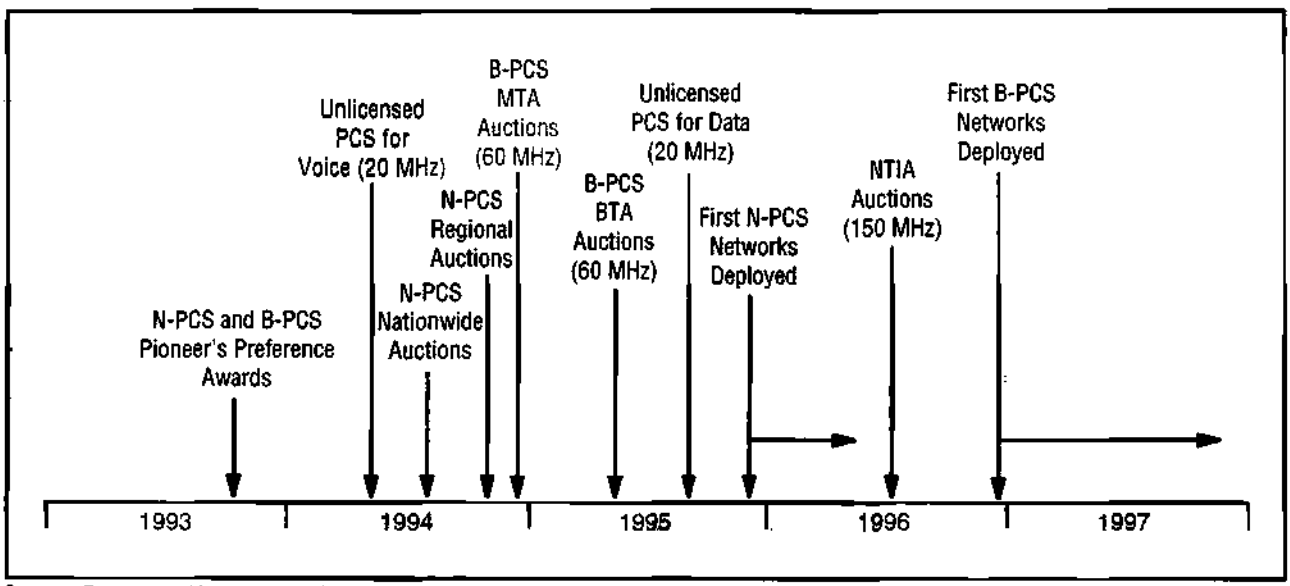
Broadband PCS license winners will be awarded pairs of frequency blocks of 15 MHz and 5 MHz around the 2-GHz spectrum. Voice communications services will lead the way in broadband PCS, followed closely by wireless data communications services. Video and multimedia services are planned as the services progress. Early devices that use broadband PCS will include dual-mode handsets similar to digital cellular handsets, PCMCIA cards used in notebook and subnotebook computers, and communications devices similar to the IBM/BellSouth Simon, Sony MagicLink, and Motorola Envoy. As the development of PCS services proceeds, the types of PCS devices that will be marketed will cover a spectrum ranging from advanced pagers to high-end computing and communications equipment.

Unlicensed

Unlicensed PCS services have been allotted 20 MHz of the 2-GHz spectrum. The FCC is deciding on where to allocate an additional 20 MHz for unlicensed data communications. Unlicensed PCS—strictly speaking, not considered mobile services by the FCC—are for low-power, limited-range devices owned and operated by end users on their own premises; examples are wireless local area networks, wireless PBXs, and palmtop computers. Although the allocations for unlicensed PCS devices are right in the middle of the broadband PCS band, the unlicensed devices may be either narrowband or broadband.

More detailed discussions of narrowband and broadband PCS follow in Chapters 3 and 4. Figure 2-1 provides a time line for the rollout of PCS services.

Figure 2-1
PCS Spectrum Time Line



Source: Dataquest (January 1995) 9500514

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Beyond the United States: PCS Services Worldwide

Although this report focuses on the PCS market in the United States, it is important to note that intense PCS activity is taking place around the globe. Technologies and standards developed in other countries play an important role in the development of PCS in the United States. The European digital cellular standard GSM is the leading digital cellular standard in numbers of subscribers. This standard is moving beyond Europe into other regions, and some are advocating GSM as a de facto global standard. PCS systems based on a derivative of GSM, DCS-1800, are being implemented throughout Europe, beginning with the United Kingdom. The DCS-1800 standard as well as the Digital European Cordless Telephone (DECT) standard form the foundation for two of the seven proposed air interface standards in the United States.

The Personal Handy Phone (PHP) standard in Japan is also playing a major role on the world scene. This standard operates at 1.9 GHz and uses a TDMA architecture. It can be operated both indoors and outdoors at low power. The PHP standard was enthusiastically received by Japanese industry and has standards for voice transmission. Satisfactory tests were conducted for many different companies. However, PHP ran into trouble when engineers revealed that its initial effective range of 150 meters meant that 20,000 to 40,000 base stations would be needed to cover Tokyo alone. Developments since then have extended the coverage of a PHP base station and solved this problem.

Another snag in the PHP standard developed because of the need for the base stations to be connected to Japan's PSTN and use integrated services digital network (ISDN) circuits available only from Nippon Telephone and Telegraph (NTT). NTT denied use of the ISDN circuits to other vendors. The rest of the Japanese industry called on the cable television industry to help. New designs allow PHP systems to achieve full connectivity through the cable television networks. Plans are now moving ahead for implementation of a PHP-based PCS system in Japan. Two major groups have applied for PCS licenses from the Ministry of Posts and Telecommunications (MPT) in Japan and plan to initiative services beginning in mid-1995. Japanese companies are promoting PHP in other Asia/Pacific countries, and it forms the foundation for one of the proposed air interface standards in the United States.

Beyond groups advocating GSM technology as a global standard are other efforts in world standards bodies to produce a unified PCS standard. The International Telecommunication Union's (ITU) 1992 World Administrative Radio Conference (WARC-92) produced two decisions relative to PCS. First, it agreed to maintain its primary allocations for fixed and mobile services at 2 GHz in Region 2 (the Americas, including the United States). Second, it agreed to state that the bands 1,885 to 2,025 MHz and 2,110 to 2,200 MHz are expected to be used worldwide for the prospective Future Public Land Mobile Telecommunications Systems (FPLMTS), a system similar in concept to PCS but available globally. FPLMTS could be available as early as the end of this decade. However, the existence of major standards such as PHP and GSM that would need to be modified to meet a global standard presents a major hurdle to this effort.

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Definitions of Common PCS Terms

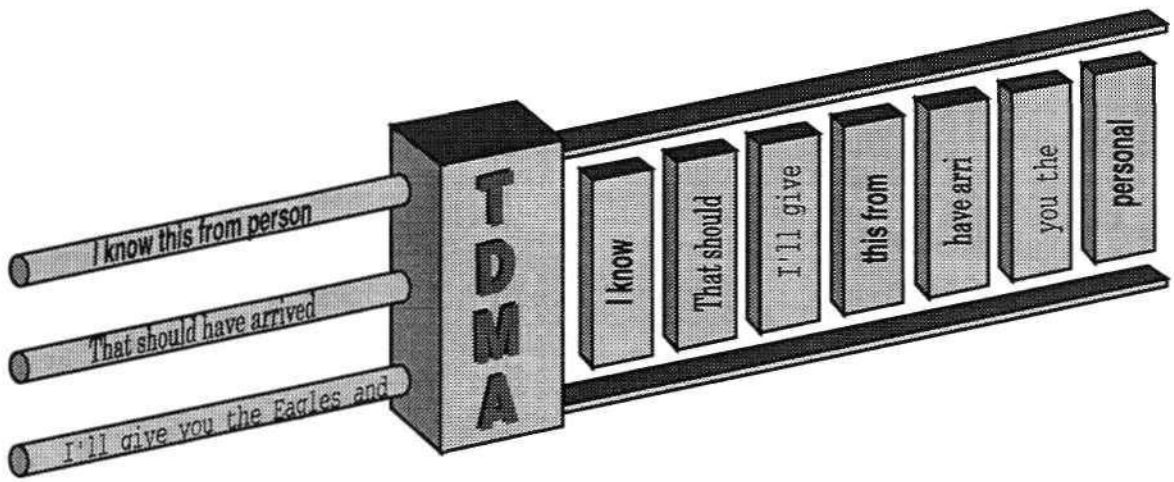
As do most industries, the wireless communications industry has a host of definitions and acronyms that can be difficult to understand. Definitions for a few of the major terms and abbreviations are as follows:

- Basic trading areas (BTAs): Smaller geographic PCS service areas based on Rand McNally Atlas definitions that will be licensed to PCS providers and will determine where the providers can operate. There are 493 BTAs in the United States.
- Code division multiple access (CDMA): A spread spectrum technology standard that assigns a code to all speech bits, sends a scrambled transmission of the encoded speech over the air, and reassembles the speech in its original format. By assigning a unique correlating code to each transmitter, several simultaneous conversations can share the same frequency allocation. CDMA claims to provide 10 to 20 times the call capacity of current analog (see Figure 2-2).
- Common Air Interface (CAI): A set of parameters (such as frequencies, access methodologies, information coding schemes, and the like) that defines the behavior of wireless connections within the PCS network
- Federal Communications Commission (FCC): The federal regulatory agency for telecommunications services providers
- Groupe Speciale Mobile (GSM): A new digital European cellular phone system that originated in Europe and is used in more than 20 countries. This system is based on a TDMA architecture. (Also anglicized as Global Standard for Mobile Communications.)
- Interoperability: The capability of a wireless handset to communicate with the handsets and networks of other wireless manufacturers and licensees
- Joint Technical Committee (JTC): A committee composed of representatives from Committee T1 (a subcommittee of the American National Standards Institute, or ANSI), the Telecommunications Industry Association (TIA), the Personal Communications Industry Association (PCIA), and the Institute of Electrical and Electronics Engineers (IEEE) that has been formed to approve common air interface standards for personal communications
- Major trading areas (MTAs): Geographic PCS service areas based on Rand McNally Atlas definitions that will be licensed to PCS providers and will determine where the providers can operate. There are 51 MTAs in the United States. Each MTA comprises several BTAs.
- Roaming: The operation of a mobile telephone in a service area other than the service area initially assigned to a customer
- Technical Advisory Group (TAG): The seven common air interface standards that will be put out for balloting by PCS industry members have been given labels based on this name. The labels range from TAG-1 to TAG-7.
- Time division multiple access (TDMA): A digital cellular technology standard that allocates a discrete amount of frequency bandwidth to each user in order to permit many simultaneous conversations. Each caller is assigned a specific time slot for transmission. TDMA claims to provide three times the call capacity of current analog (see Figure 2-2).

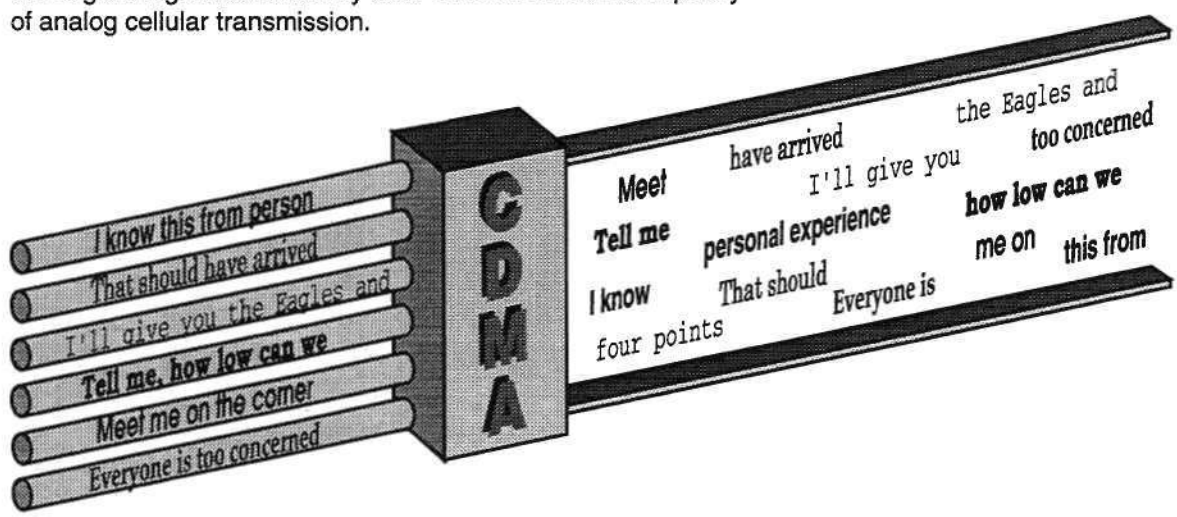
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Figure 2-2
TDMA and CDMA Digital Transmission Technologies

Two emerging forms of digital transmission can save spectrum space in both cellular phones and the PCS of the future. Time division multiple access (TDMA) chops calls into pieces of data that are identified on the receiving end by the time slots to which they are assigned. TDMA enables one wireless channel to handle several calls.



The second technology, code division multiple access (CDMA), spreads its pieces of calls across a wide swath of communications frequencies. The fragments carry a code identifying their phone of origin, and the receiving station uses the code to identify and reconstitute the original signal. CDMA may offer 10 to 20 times the capacity of analog cellular transmission.



Source: Eric Zimits, Volpe, Welty & Co.

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Chapter 3
Narrowband PCS

Perfectly timed to build on the rising swell of subscribers in the paging market, auctions for narrowband PCS licenses began in summer 1994. Service providers hope to make new PCS services available before 1996. In addition to solving the system capacity problems being experienced by current paging service operators, narrowband PCS will enable valuable new services that will expand the market significantly. Although alphanumeric paging services have been growing steadily, the extra capacity demands made by these services has inhibited carriers from promoting these services aggressively. The additional capacity that will be made available through narrowband PCS will solve the problem of tight system capacity.

New services that will be enabled by narrowband PCS technology include: two-way messaging, acknowledgment paging, enhanced voice messaging, facsimile transmission, and e-mail communication. Traditional paging services are on course to reach 35 to 40 million subscribers by the year 2000. Demand for narrowband PCS services is expected to add 10 to 15 million subscribers to that number to create an overall paging and narrowband PCS market of more than 50 million subscribers. This chapter will review the results of the auctions, present information on new paging protocols and technologies that will enable narrowband PCS services, summarize the various trials being conducted, highlight hardware products being developed for this market, and discuss the implications for semiconductors.

The Auctions

Rules governing the auctions for narrowband PCS licenses were established by the FCC in its "Report and Order" released on May 10, 1994. Table 3-1 outlines the licenses that have been or will be auctioned in a series of auctions. The allocated spectrum for narrowband PCS is at 901 to 902 MHz, 930 to 931 MHz, and 940 to 941 MHz, around the existing cellular, SMR, paging, and unlicensed bands. The bidding in the first auction for nationwide narrowband PCS licenses began on July 25, 1994, and ended with six companies winning 11 licenses, as shown in Table 3-2 (Destineer was awarded one of the nationwide licenses in a Pioneer's Preference award, as discussed later in this chapter). There were 69 companies that originally applied to bid in the auction; 29 were finally approved to participate in it.

Table 3-1
The Plan for Narrowband PCS Licenses

Coverage	50/50 kHz (Paired)	50/12.5 kHz (Paired)	50 kHz (Unpaired)	12.5 kHz (Unpaired)	Total	Overall Total
Nationwide	5	3	3	-	11	11
Regional (Five Regions)	2	4	-	-	6	30
MTA (51)	2	3	2	4	11	561
BTA (492)	-	2	-	4	6	2,952
Grand Total	-	-	-	-	-	3,554

Source: Federal Communications Commission

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Table 3-2
Winners of the First Auction: National Licenses

Frequency (kHz)	Company	Winning Bid (U.S. $M)
50/50 Paired	PageNet	80.0
50/50 Paired	PageNet	80.0
50/50 Paired	KDM Messaging	80.0
50/50 Paired	KDM Messaging	80.0
50/50 Paired	Destineer	80.0
50/12.5 Paired	AirTouch Paging	47.0
50/12.5 Paired	BellSouth Wireless	47.5
50/12.5 Paired	Destineer	47.5
50 Unpaired	PageNet	37.0
50 Unpaired	PageMart II	38.0

Source: Federal Communications Commission

The second auction for regional licenses in five U.S. regions ended on November 8, with 9 additional winners out of 28 companies that originally applied to participate auction. Winners in the second auction are listed in Table 3-3. Four of the winners were "designated entities"—small businesses, woman- and minority-owned businesses, and rural telephone companies. Designated entities were eligible to bid, with a 40 percent discount, on frequencies 2 and 6 in each region. Although the total bids in the second auction totaled $489 million, the government will collect $393 million after discounts are applied. About two-thirds of the spectrum allocated for narrowband PCS was sold in the first two auctions. Several smaller licenses in MTAs and BTAs will be sold sometime in 1995 after the broadband PCS auctions are finished.

Pioneer's Preference Award

Destineer, a subsidiary of Mtel, was granted a narrowband PCS Pioneer's Preference license based on its development of a multicarrier modulation technology capable of transmitting a 24-Kbps simulcast signal in a single 50-kHz channel—10 times the rates of the current radio paging transmission. In addition to this license it won two licenses in the auctions, as shown in Table 3-2. Destineer is moving quickly to continue in its role as a pioneer of narrowband services. It plans to use the two additional licenses to enhance system capacity and enable more value-added services that require additional bandwidth, such as advanced voice messaging. Destineer received approval from the FCC on October 6, 1994, to operate a nationwide paging service and hopes to have commercial services running in 300 markets by the second half of 1995.

New Hardware and Services

As companies win licenses in the auction process, they will be pushing to roll out services to begin earning a return on their investment. The FCC has set minimum construction requirements for license winners, outlined in Table 3-4, that will provide a baseline for the infrastructure equipment market. PCS Development Corporation, a winner of six regional PCS licenses that will allow it to develop a nationwide paging service, has estimated that it will cost between $250 million and $500 million to build its

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Table 3-3
Winners of the Second Auction: Regional Licenses

Frequency (kHz)	Company	Winning Bid (U.S. $M)
Region 1		
50/50 Paired	PageMart II	17.5
50/50 Paired	PCS Development[1]	24.8
50/12.5 Paired	MobileMedia PCS	9.5
50/12.5 Paired	Advanced Wireless Messaging	8.9
50/12.5 Paired	AirTouch Paging	8.7
50/12.5 Paired	Lisa-Gaye Shearing[2]	17.1
Region 2		
50/50 Paired	PageMart II	18.4
50/50 Paired	PCS Development	31.3
50/12.5 Paired	MobileMedia PCS	11.8
50/12.5 Paired	Advanced Wireless Messaging	11.5
50/12.5 Paired	Insta-Check Systems[3]	8.0
50/12.5 Paired	Lisa-Gaye Shearing	18.8
Region 3		
50/50 Paired	PageMart II	16.8
50/50 Paired	PCS Development	28.9
50/12.5 Paired	MobileMedia PCS	9.3
50/12.5 Paired	Advanced Wireless Messaging	10.1
50/12.5 Paired	Ameritech Mobile Services	9.5
50/12.5 Paired	Lisa-Gaye Shearing	17.1
Region 4		
50/50 Paired	PageMart II	17.3
50/50 Paired	PCS Development	28.6
50/12.5 Paired	MobileMedia PCS	8.3
50/12.5 Paired	Advanced Wireless Messaging	8.8
50/12.5 Paired	AirTouch Paging	8.3
50/12.5 Paired	Benbow PCS Ventures[4]	17.5
Region 5		
50/50 Paired	PageMart II	22.5
50/50 Paired	PCS Development	38
50/12.5 Paired	MobileMedia PCS	14.9
50/12.5 Paired	Advanced Wireless Messaging	14.3
50/12.5 Paired	AirTouch Paging	14.3
50/12.5 Paired	Benbow PCS Ventures	18.2

[1]PCS Development is a 16-member consortium formed to acquire narrowband PCS licenses. Major shareholders include: A+ Communications, Arch Communications Group, and USA Mobile Communications.
[2]Lisa-Gaye Shearing has teamed with Adelphia Communications Corporation, one of the 10 largest cable TV operators in the United States, to form Page Call Inc., which will be the name of the company developing paging services with the licenses won in the auction.
[3]Insta-Check Systems is a private check-guarantee service provider in Miami.
[4]Benbow PCS Ventures is a company held by June E. Walsh, president of Cal Autofone, a northern California paging operation, and Westlink Licensee, a subsidiary of Westlink Co., which purchased the paging operations of U S WEST in 1994.
Source: Dataquest (January 1995)

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Table 3-4
Narrowband PCS Infrastructure Construction Requirements

	Nationwide	Regional	Major Trading Area	Basic Trading Area
Area to Be Covered in 1,000 km^2				
After 5 Years	750	150	75	1 base station in 1 year
After 10 Years	1,500	300	150	1 base station in 1 year
Percentage of Area's Population Reachable				
After 5 Years	37.5	37.5	37.5	-
After 10 Years	75	75	75	-
Maximum Number of Channels*, Each 50 kHz				
Paired with 12.5 kHz	3	4	3	2
Paired with 50 kHz	5	2	2	-
Unpaired	3	-	2	-

*Only two 12.5-kHz response channels are allowed in any one geographic area. The maximum amount of spectrum will range from 150 to 300 kHz.
Source: Federal Communications Commission

infrastructure. As one of the two major manufacturers of paging infrastructure equipment and the dominant supplier of pagers in the United States, Motorola is leading the way with new technologies and equipment aimed at the narrowband PCS market. Traditional paging products have been limited by the 1,200-bps data rates of the POCSAG signaling standard. Building on the higher data rates of 1,600, 3,200, and 6,400 enabled by the FLEX paging protocol introduced in 1994, Motorola has developed the ReFLEX and InFLEXion protocols that will be at the core of new narrowband PCS products.

New Protocols and System Architectures

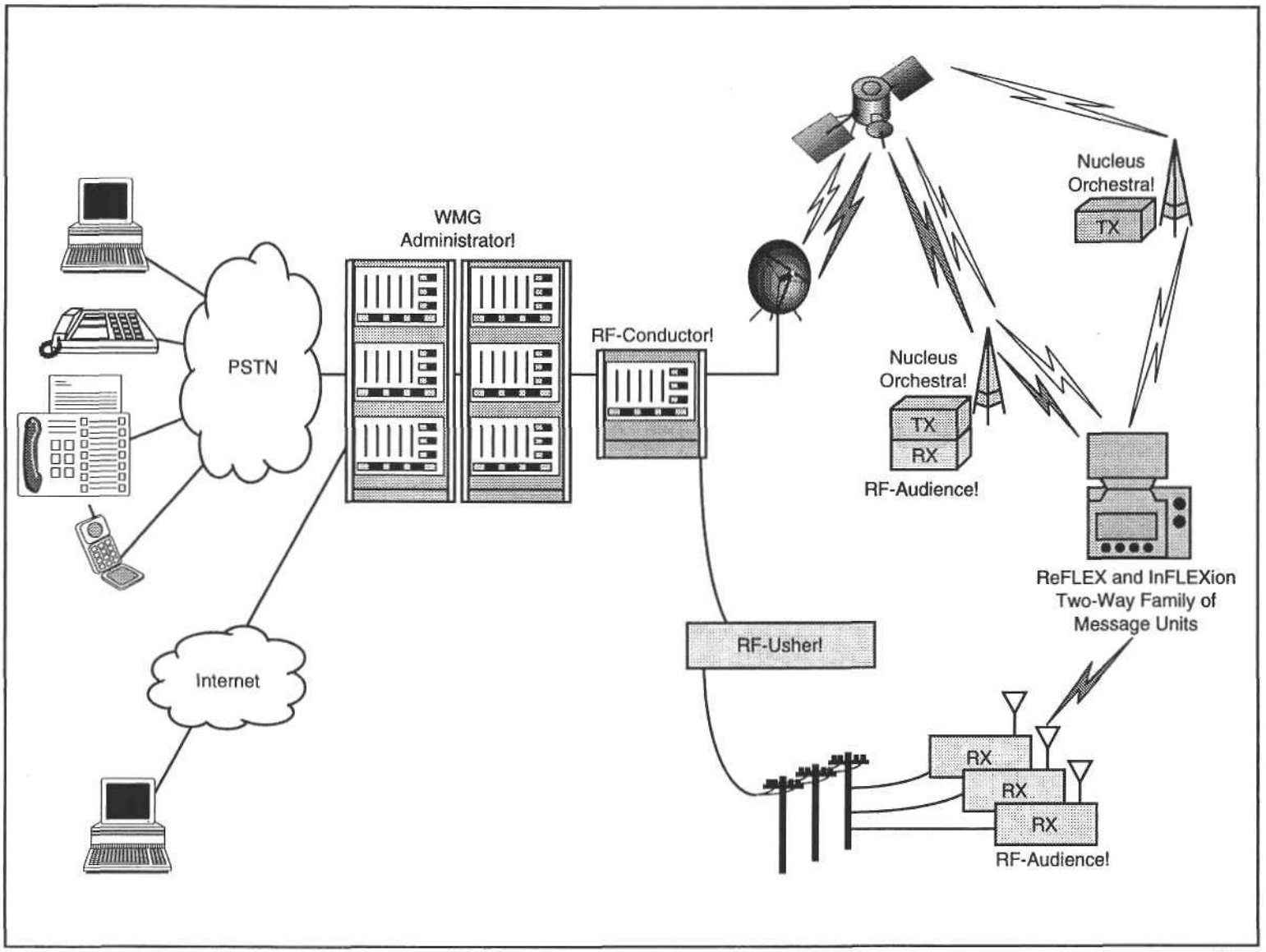
Early agreements that Motorola has entered into with PCS license winners are already beginning to establish ReFLEX and InFLEXion as de facto industry standards for narrowband PCS in the United States. Motorola has been working closely with Pioneer's Preference winner Destineer and has begun to ship products based on these standards to the market. These two signaling protocols build on the development of the FLEX technology. Motorola has licensed GlenAyre Technologies to produce ReFLEX infrastructure equipment and Wireless Access to manufacture paging devices. More details of each of these protocols are provided in the following sections, along with Figure 3-1, which shows a narrowband PCS system based on this technology.

Motorola's New Paging Technology

FLEX. In existing paging systems, pages are gathered by a paging terminal, placed in batches, and then transmitted. This sequence of events can occur at any time and is termed asynchronous transmission. In this type of system, a warm-up sequence is used to wake up all of the pagers. The pagers then look at their assigned address slot to learn whether there is a message. This occurs whenever a batch of pages is transmitted. For long

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Figure 3-1
Motorola's Advanced Messaging Solution



Source: Motorola

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messages, the pager is required to stay awake for extended periods. The pager also must remain awake for some time after the message has concluded because the pager has no indication of when the message intended for it has ended.

FLEX is a Synchronous Multispeed Time Slot protocol. By programming the pager to decode only a particular time slot, the battery life of the pager can be greatly extended over those in existing systems. The time between decoded time slots can be as long as four minutes. After the initial warm-up period, the address code words as well as a vector code word are all located at the beginning of the data block fields. This allows the pager to go to sleep immediately if it does not see its address. If the pager's address does appear, the vector code word tells the pager where its message is located so that the pager can sleep until it is time to receive its message. Embedded in the vector is an indication of how long the message is, thus providing a positive message conclusion. This allows the pager to return to the sleep mode immediately upon reception of its message.

Another difference between FLEX and existing paging protocols is the speed of data on the RF channel. The most common RF data rates are 512, 1,200, and 2,400 bps. With FLEX, paging data is transmitted at 1,600, 3,200, or 6,400 bps. A FLEX pager can operate at any of the FLEX channel rates, eliminating the need to stock pagers for each channel speed used in a system. Other major advantages of FLEX technology include: up to 10ms of fade protection, increased system capacity, support for long message services, and nationwide and global roaming capability.

ReFLEX. The ReFLEX technology takes advantage of a reverse channel capability in PCS. This inbound channel enables message initiations, information requests, and reply and control actions such as registration and acknowledge. The registration and acknowledge capabilities make it possible to achieve geographic reuse, thus increasing the capacity of nationwide and wide-area regional systems. The acknowledge capability also makes it possible to confirm that a unit is able to receive prior to tying up the channel with a long message transmission and enables the confirmation that messages are received correctly. If an error occurs in reception of a message, only those packets that were received in error are retransmitted.

The inbound data rate from a pager is kept low to concentrate the subscriber device's transmitted power in a smaller effective bandwidth. This is done to minimize the number of base receiver sites required to achieve coverage equivalent to that on the outbound channels. Two variations of ReFLEX have been developed, ReFLEX25 and ReFLEX50, to work on 25-kHz and 50-kHz channels, respectively. Information in this protocol can be numeric, alphanumeric, or binary.

InFLEXion. In addition to the features described, InFLEXion uses a voice compression algorithm to further enhance system efficiency and allow more voice messages per channel. The voice compression algorithm can also be used to increase system capacity in simulcast systems that do not have an inbound channel.

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Announced Services and System Trials

Some of the announced plans for services and system trials by winners of the narrowband PCS auctions are:

- Destineer has discussed plans for three types of services: acknowledgment paging, limited two-way text messaging 100 to 150 characters in length, and longer text messaging using a portable computer or palmtop device equipped with a PCMCIA transceiver. Motorola announced at the end of November 1994 that it had shipped its first two-way paging units, called Tango, to Destineer for use in trials that would begin in Dallas the first week in December. Destineer also plans to conduct trials with selected companies in the Dallas metro area as part of a final beta test beginning in spring 1995.
- PageNet has announced plans to deliver a service called VoiceNow. VoiceNow will deliver voice messages of up to four minutes in length to pagerlike devices that will have the functionality of answering machines including: message storing, rewind, fast forward, cueing, and message counting. PageNet plans to offer the basic service, including leasing of the device, for about $20 per month. It has also announced an agreement with Motorola for infrastructure and subscriber equipment. Under the agreement PageNet will have a first right to the domestic market for VoiceNow subscriber units for six months after commercial deployment. The contract is valued at $250 million. PageNet plans to conduct laboratory tests of the system in the first half of 1995 and begin field testing in Dallas, New York City, and San Francisco in the second half of 1995.
- PageMart has not fully described its service plans, but it does have plans to test a data service in one city with IBM and GTE in mid-1995. It has confirmed that it will offer a voice-messaging service similar to PageNet's VoiceNow called VoiceMart, and it has also announced an agreement with Motorola for infrastructure and subscriber equipment. It plans to begin offering new services in late 1995 or early 1996.
- AirTouch Paging envisions consumer uses for PCS services such as acknowledgment paging and limited two-way messaging, beginning in 1996. Plans to conduct joint tests with Motorola in Dallas have also been announced. The two-phased test will evaluate the network equipment and subscriber devices that would be supplied by Motorola, including Tango. Their agreement also gives AirTouch Paging the right to purchase the newest PCS technology from Motorola through January 1, 1997.

The Next Generation of Subscriber Devices

The range of subscriber devices that will be used in early narrowband PCS applications will include:

- Two-way pagers with basic acknowledgment capabilities or limited messaging services
- Two-way "mobile answering machines" with limited voice messaging
- PCMCIA add-in transceivers for use with mobile computing devices such as notebook and palmtop computers or personal communications devices such as MagicLink and Envoy
- Other integrated devices using chipset transceivers that enable broadband or narrowband PCS services.

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Motorola has led the way in developing infrastructure and subscriber equipment for this market and is expected to continue its dominance in this area. Although it has licensed GlenAyre Technologies to produce ReFLEX infrastructure equipment and Wireless Access to manufacture paging devices, other competitors may try to enter the market. NEC is marketing a pager that offers "synthesized" FLEX capability and may choose to try a similar approach to the ReFLEX and InFLEXion technologies.

Motorola's Tango Pager and InFLEXion device

Motorola is the only company with announced subscriber devices for use in the narrowband PCS market. As described, Motorola's Tango is the first two-way pager and has been shipped to Destineer for use in field trials. Tango employs the ReFLEX technology and provides the ability to receive message and data files and respond. It is a four-line alphanumeric pager similar in size to Motorola's Advisor and can store up to 100KB divided among any number of messages. Tango uses a AAA alkaline battery and has a battery life comparable to standard pagers of about 30 days. It is also available with a data port that allows connections, via the RS232 interface, to various computers. Early pricing is expected to be about $300.

There is no announced name for Motorola's voice-messaging device that employs InFLEXion technology. The unit will be capable of four minutes of message storage. This memory is dynamically allocated. There is a maximum length of two minutes per message. This will allow the unit to hold 2 two-minute to 24 10-second messages. It also provides the ability to archive an unlimited amount of messages back on the Wireless Messaging Gateway (WMG) administrator for recall at a later time. The device can be held to the ear for privacy, or messages can be played back at a louder volume for a group. As mentioned, PageNet will be using these devices for its VoiceNow service.

Semiconductor Opportunities

Although Motorola may play the dominant role in subscriber equipment, it does not have an exclusive semiconductor supply arrangement with its semiconductor division. Motorola will source semiconductors from competitive suppliers. The following bullets illustrate the new functions being implemented in narrowband PCS devices. The new requirements of the next generation of paging devices will present opportunities for 20- to 25-MIPS digital signal processors. In dealing with the critical issue of battery life, operating voltages for semiconductors used in pagers have dropped to 1V to 1.5V.

- Current pagers
  - Receiver
  - Decoder
  - Limited memory
  - Display
  - Audio—beeper
  - Battery
- Future PCS devices
  - Transceiver
  - Decode/encode (possibly encrypt)
  - Expanded memory
  - Display and input
  - Audio—limited voice messaging
  - Battery and power management

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Chapter 4
Broadband PCS

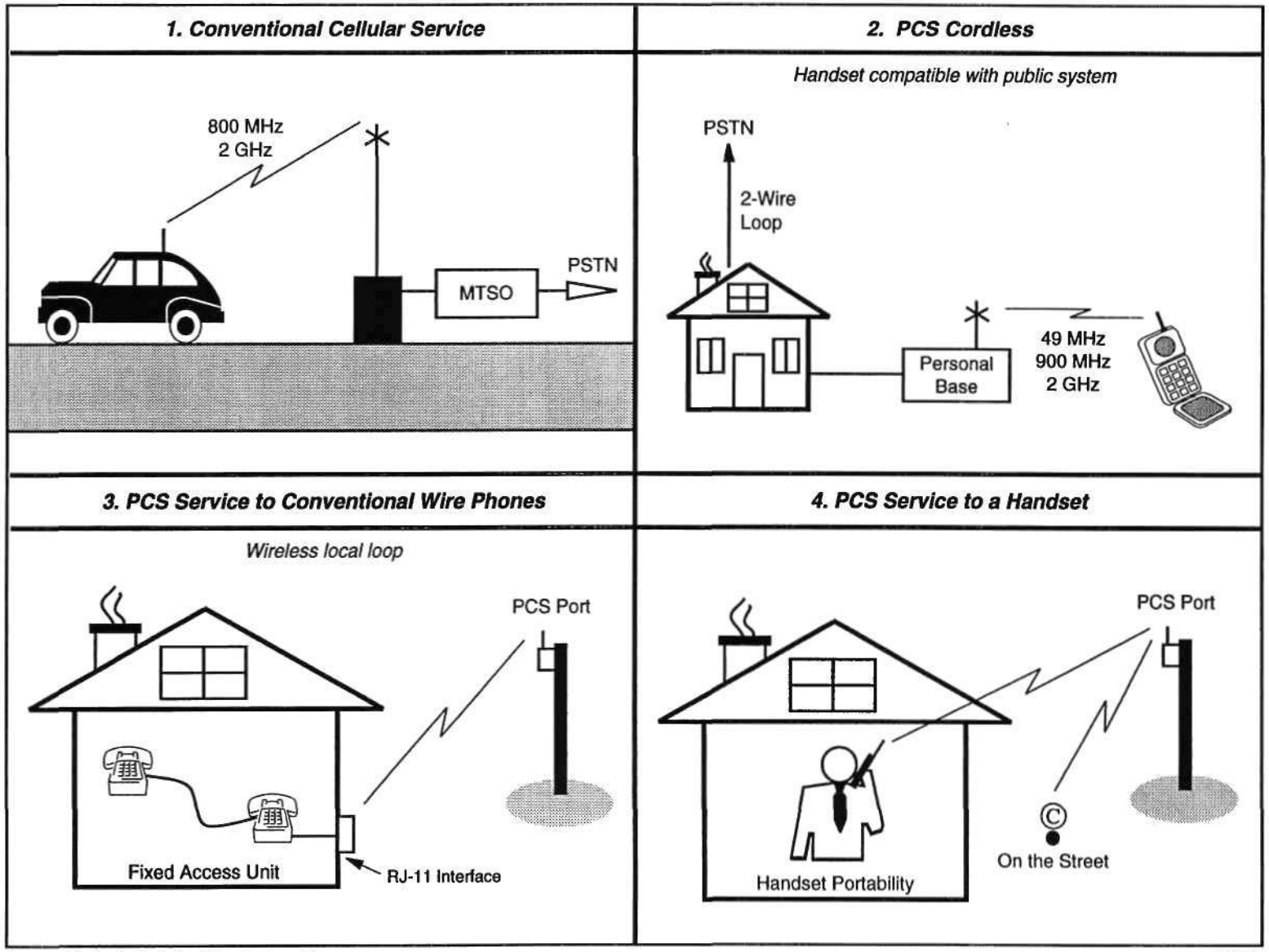
Broadband PCS will play a central role in realizing the "anytime, anywhere" communications environment envisioned for the future. As shown in Figure 4-1, four principal applications already are targeted for implementation of broadband PCS services: "cellularlike" communication in a mobile environment, cordless communication to a base station within a user's own home or business, communication between a home or business and the telephone network through a wireless local loop, and "one person/one number" communications with portable handsets that can be used outside a subscriber's own home or business while traveling at "pedestrian" speeds. Wireless voice communication with limited data services will lead the way in the initial PCS rollout. This will be followed by expanded wireless data communications capabilities and eventually video and multimedia services.

With the booming number of cellular subscribers and exciting predictions about the potential size of the future wireless communications market, the nascent PCS industry has attracted intense interest from potential service and equipment providers. After taking nine years to pass the 10-million-subscriber mark in 1992, the U.S. cellular industry has added another 10 million subscribers in the two years since then. Early predictions for the U.S. PCS market range from 4.5 million to 9.0 million subscribers by 1998, and 20 million to 31 million subscribers by 2003. Pessimistic analysts predict that future PCS services will serve principally as an alternative to current cellular services without significantly expanding the overall market. Optimistic proponents of PCS believe that the combination of new technologies and increased competition will result in sharp price competition and attractive services that will swell the wireless communications market in a dramatic fashion. The participation of seasoned cellular industry veterans in the current PCS spectrum auctions would indicate that they lean to the optimistic view of the PCS market.

The PCS industry faces major internal and external challenges. Although various wireless services were described in Chapter 2, the major competition to the PCS industry will come from the current cellular service providers. Cellular providers are not sitting still waiting for the birth of a new, competitive industry. In addition to rolling out new digital cellular technologies, cellular companies are implementing new services such as one number/one person in their bid to claim the mantle of "PCS" provider. These same cellular companies are also in a position to provide a major boost to the PCS industry. Cellular companies have been allowed limited participation in the PCS spectrum auctions and are seeking to expand their wireless communications coverage. For example, AT&T Wireless is using the auctions as an opportunity to fill in the gaps of its national coverage after its acquisition of McCaw Cellular. Current cellular service providers are preparing to do battle on every front from pricing to services with the new entrants to the wireless communications arena. They will set the standard for the "personal communications services" paradigm.

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Figure 4-1
Potential PCS Services



Source: Motorola Cellular Infrastructure Group

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In addition to external challenges from the cellular industry, winners of the PCS auctions will face several daunting internal hurdles in their efforts to create profitable wireless communications businesses. First, PCS auction winners will incur steep initial costs in paying the final auction bids, relocating current microwave spectrum occupants, and building an infrastructure. Second, because no common air interface standard has been adopted by the PCS industry, they will have to operate in an environment of multiple standards and manage the critical issues of roaming and interoperability.

The following sections in this chapter will describe the broadband PCS auction process and its current status, outline the competing air interface standards, provide an in-depth look at the standards that will likely dominate the market, discuss issues related to the creation of a PCS infrastructure, highlight key technologies in the development of subscriber handsets, and provide details on semiconductor opportunities in broadband PCS handsets.

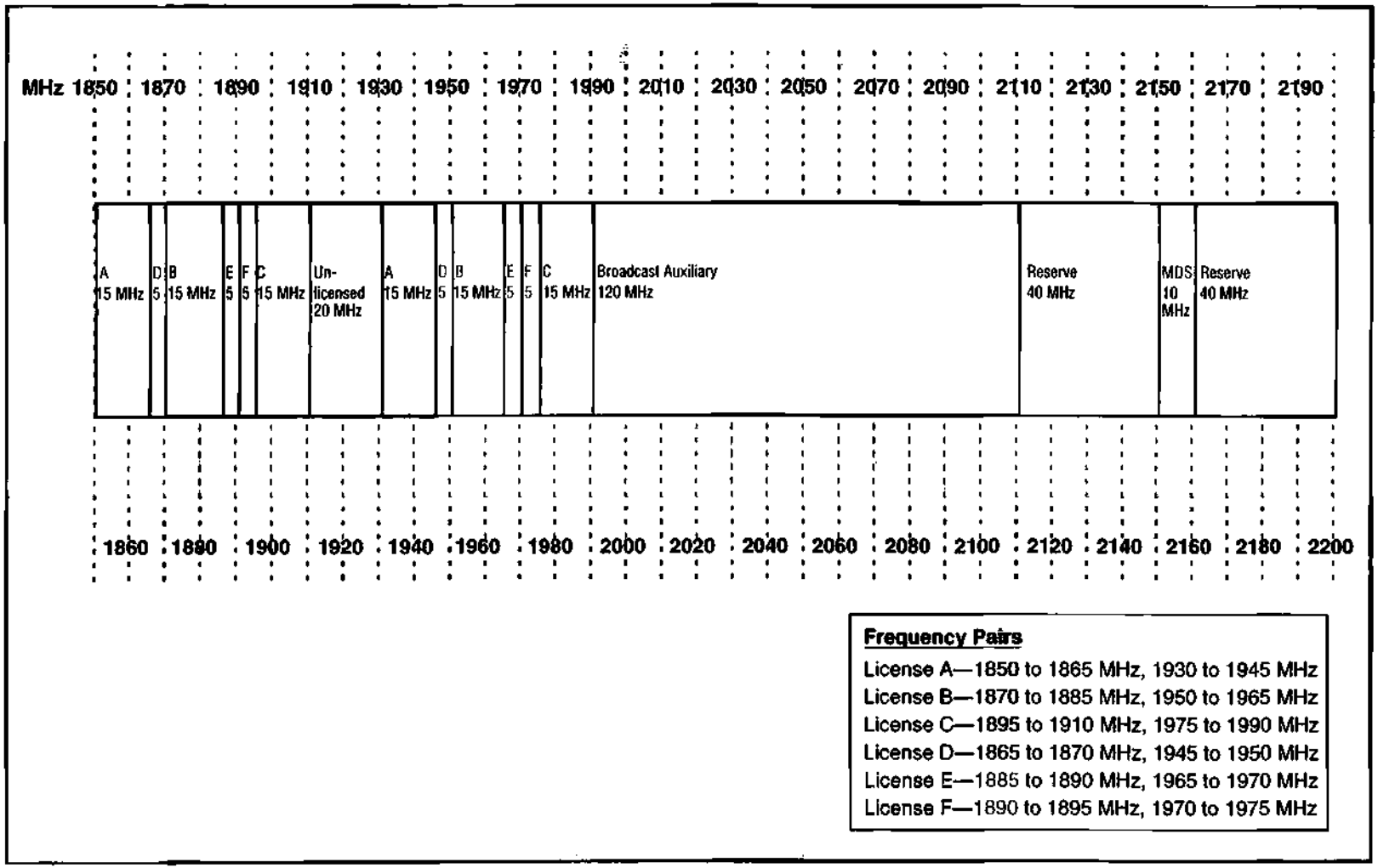
The Auctions

Following the rules established by the FCC, bidding in the first of three multiple-round auctions for broadband PCS licenses began December 5, 1994 and continued through January 1995. Figure 4-2 shows the portions of the frequency spectrum being auctioned for broadband PCS services. The first auction is for two 30-MHz blocks, segments A and B, in each of 51 Rand McNally Atlas-based MTAs. The second auction will cover the other 30-MHz license, segment C, and a 10-MHz license, segment F. The licenses in the second auction will be for the smaller 493 basic trading areas (BTAs). The final auction for segments D and E, 10-MHz licenses, will also be for the smaller BTAs. A summary of this plan (as provided by the FCC) is as follows :

- First auction
  - Began December 5
  - Band A and B
  - Two 30-MHz MTAs
  - 99 available markets
- Second auction
  - Begins 30 days after first auction or April 17, whichever is later.
  - Band C followed by Band F (the FCC is requesting comments on whether to auction Band F licenses with the D and E band licenses)
  - 30-MHz BTA and 10-MHz BTA
  - 986 available markets
  - Designated entities participate
- Third auction
  - Begins after second auction (about August or September 1995)
  - Band D and E
  - Two 10-MHz BTAs
  - 986 available markets

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Figure 4-2
Broadband PCS Spectrum Segmentation



Source: Federal Communications Commission

9500518

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Segments C and F are also known as the Entrepreneur's Block because special rules have been established to benefit women, minorities, and small businesses in bidding for these blocks. In general, bidding on these licenses will be limited to companies with gross revenue less than $125 million in each of the last two years and with total assets less than $500 million. Installment payment plans are available for the winners. Businesses owned and controlled by women or minorities will be eligible for a 15 percent bidding credit when bidding on these blocks. Small businesses with annual revenue less than $40 million are eligible for a 10 percent bidding credit. These credits are cumulative, so a small, minority-owned business would be eligible for a 25 percent bidding credit.

The first auction was preceded by a flurry of acquisition and partnering activity as contenders worked to develop competitive strategies and pool resources. Of the 74 original applicants for the first broadband auctions, 30 made the required payment by the November 18 deadline to participate (Table 4-1). The FCC collected $522 million in payments from these 30 bidders. Many of the original 74 companies filed applications in order to keep their options open while trying to raise capital by the November 18 deadline. Although those that did not make the required payment may not participate in the auction, they can still enter the market by hooking up with auction winners.

Table 4-1
Bidders in the First Broadband PCS Auctions

ALAACR Communications Inc.[1]	GCI Communication Corporation
American Portable Telecommunications	GTE Macro Communications Corporation
Ameritech Wireless Communications Inc.	Micro Lithography Inc.
AT&T Wireless PCS Inc.[2]	Pacific Telesis Mobile Services
BellSouth Personal Communications Inc.	PCS America Limited Partnership
Boston PCS Venture	PCS PRIMECO, L.P.[3]
CCI Data Inc.	PhillieCo, L.P.
Centennial Cellular Corporation	Poka Lambro Telephone Cooperative Inc.
Century Communications Corporation	Powertel PCS Partners, L.P.
Cleveland PCS Venture	Satellite Broadcast Network Inc.
Comcast Telephony Services II Inc.	South Seas Satellite Communications
Communications International Corporation	Southwestern Bell Mobile Systems Inc.
Continental Cablevision Inc.	Western PCS Corporation
Cox Cable Communications Inc.	Windsong Communications Inc.[4]
Data Link One Inc.	WirelessCo, L.P. [5]

[1]ALAACR Communications Inc. is a company formed by Craig McCaw to pursue PCS.
[2]AT&T Wireless PCS Inc. includes AT&T's acquisition of McCaw Cellular.
[3]PCS PRIMECO, L.P. is an alliance formed by Bell Atlantic, NYNEX, U S WEST, and AirTouch Communications to bid on PCS licenses. A separate alliance company called TOMCO has been formed by these companies to develop a national branding and marketing strategy for existing cellular properties and future PCS business.
[4]Windsong Communications dropped out of the bidding when the FCC moved the auctions into Stage 2.
[5]WirelessCo, L.P. is an alliance among Sprint, TCI, Comcast, and Cox.
Source: Dataquest (January 1995)

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Notably absent from the list of bidders is MCI Communications Corporation and Time Warner Inc., which has conducted PCS tests in conjunction with its interactive television system in Orlando, Florida. MCI was apparently frustrated in its attempt to partner with other deep-pocket allies and did not register to bid. MCI has stated that staying out of the bidding "preserves our ability to continue discussions with other wireless companies and enter into selective alliances." Both companies are expected to participate in the market through future alliances.

Pioneer's Preference Awards

Prior to the first auction, American Personal Communications (APC), Cox Enterprises, and Omnipoint Communications were each granted a broadband PCS Pioneer's Preference license for a 30-MHz spectrum block in an MTA. These licenses were granted by the FCC based on significant contributions made by these companies to the development of PCS technology. After a lengthy dispute about payment for the Pioneer's Preference licenses, a section in the General Agreement on Tariffs and Trade (GATT) legislation passed by the U.S. Congress required the three award winners to pay about 85 percent of the average auction value of the top 20 markets. The contributions and licenses for each of these companies is outlined as follows:

- APC developed a frequency-agile sharing technology (FAST) for efficient sharing of the 2-GHz PCS radio spectrum among existing microwave users and new PCS spectrum users. This technology could play a role in enabling PCS services to be deployed while existing microwave users are relocated. The license will cover the Washington, D.C./ Baltimore area.
- Cox showed how to use cable television facilities for backbone communications linking PCS microcells. Its license covers the Los Angeles/ San Diego area.
- Omnipoint produced the first 1,850- to 2,200-MHz handheld telephone. Its technology uses a hybrid of TDMA, CDMA, and Frequency Division Multiple Access (FDMA). Its license will cover most of New York State, New York City, and northern New Jersey.

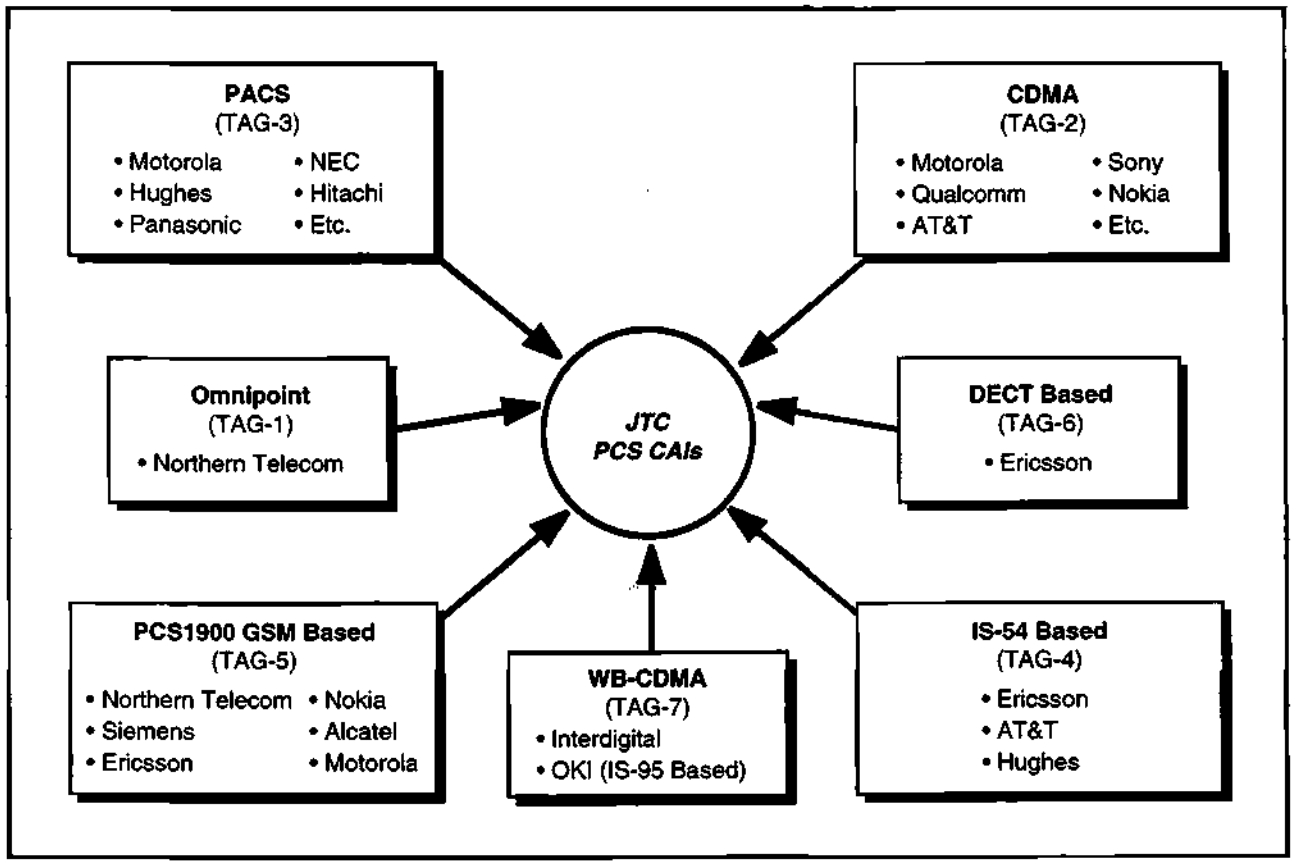
Pioneer's Preference licenses sought by other companies have been denied by the FCC. Companies denied licenses include: Advance Cordless Technologies, Corporate Technologies Partners, Advanced MobileComm Technologies, Digital Spread Spectrum Technologies, Ameritech, Nextel Communications, Personal Communications Network Services of New York, Qualcomm, and Spatial Communications.

The Seven Competing Standards

The Common Air Interface (CAI) standard is at the core of any PCS system. Beginning from a list of 17 air interface proposals in November 1993, the JTC proposed 7 standards for balloting. Figure 4-3 shows the 7 standards and some key supporters of each standard. Four of the standards—TAG-1, TAG-2, TAG-4, and TAG-5—have already been sent to ballot by industry companies for approval, rejection, or additional comment (TAG stands for Technical Advisory Group). The remaining standards should go to ballot sometime in the first quarter of 1995. Even if any or all of these transmission schemes wins approval, a 60-day approval process for ANSI is required.

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Figure 4-3
The Seven Competing PCS Standards



Source: Dataquest (January 1995) 9500519

The JTC believes that these seven standards represent a consensus of "what makes sense" for the industry's vendors and service providers. It is the committee's intent that market forces now decide the standards that will eventually win in terms of which systems are actually deployed. The creation of seven competing standards presents serious challenges to industry players. Instead of a unified standard there is now a potential for fragmented standards that will create challenges for roaming capability and system interoperability. Proponents of each standard are aggressively promoting the benefits of their standards to potential winners of PCS licenses and equipment suppliers.

Brief descriptions of each of the seven competing air interface standards are as follows:

- CDMA (IS-95): This proposal is derived from the CDMA-based IS-95 digital cellular standard developed by Qualcomm. The PCS standard is also known as PN-3384. It is a 1.25-MHz spread spectrum CDMA air interface suitable for high- and low-mobility, licensed-band applications, handling various cell sizes. It supports "soft hand-offs" between cells, uses variable-rate speech coders for capacity, and supports a 13.3-Kbps data rate. Infrastructure manufacturers AT&T, Northern

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Telecom, and Motorola are some of the critical supporters of this standard, along with other manufacturers that have formed the CDMA Development Group (CDG).

- DCS 1900 (GSM): This standard uses an eight-time-slot TDMA air interface suitable for high and low mobility and for large- and small-cell, licensed-band technology. This technology is derived from the European DCS 1800 standard, which is a frequency shifted variant of the GSM cellular interface. This technology has strong backing from suppliers of GSM cellular equipment. Because GSM is the common European standard, most European equipment and semiconductor manufacturers are backing this standard.
- TDMA (IS-54/IS-136): This proposal is a three-time-slot TDMA air interface for high- and low-mobility, licensed-band applications capable of handling various cell sizes. It is extendible to six-time-slot TDMA with half-rate speech coders. It is derived from the IS-54 digital cellular standard. A number of equipment manufacturers already supplying equipment to the digital cellular market for TDMA systems could support this standard.
- Broadband CDMA: This CDMA-based standard is derived from wideband technologies developed by InterDigital and also has the backing of OKI. It is a 5-MHz CDMA air interface for small-cell, licensed-band applications. It supports higher data rates by aggregating traffic channels within a frequency. InterDigital has conducted successful tests demonstrating wireless video transmission over United States Cellular Corporation's cellular networks. Siemens is also providing support for this standard through an alliance with InterDigital.
- PACS: This standard is based on the combined technology of Wireless Access Communications (WACS), developed by BellCore, and the PHP system. It is an eight-time-slot TDMA air interface with a Frequency Division Duplex (FDD) mode for small-cell, licensed-band applications and a Time Division Duplex (TDD) mode for small-cell, unlicensed-band applications. It has significant support from various Japanese manufacturers and Motorola.
- Omnipoint: This technology uses a hybrid of TDMA, CDMA, and FDMA. The technology also allows a subscriber to switch between the large-cell, 2-GHz licensed band and a band for unlicensed, low-power, spread-spectrum consumer devices at 2,400 to 2,485 MHz. (The 2.4-GHz unlicensed band is expected to be the location of future unlicensed voice and data devices.) CDMA is used between cells and TDMA within cells. The proposal is based on Omnipoint Corporation's Pioneer's Preference technology. In September 1994, Omnipoint signed a $100 million agreement with Northern Telecom to install a PCS network in the New York MTA. Northern Telecom will supply a turnkey PCS system based on its distributed PCS networks and Omnipoint's PCS2000 technology. Omnipoint has also joined Phillips Broadband Networks in a strategic alliance to test cable TV-based PCS in Syracuse, New York. Trials of the system will include support of wireline-quality voice, data, and video communications through pocket-size phones.
- DECT: This is a 12-time-slot, TDMA-based standard derived from the DECT standard for small-cell applications. Although Ericsson-GE is a proponent of this standard, marketing activity related to this standard has been minor, compared to the other six standards.

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PCS services and standards that enable wireless communications over a broad area and allow calls to be handed off from one base station to another while traveling at vehicular speeds have usually been termed "high-tier" standards. "Low-tier" standards have been characterized by smaller cell sizes and low-speed call-hand-off capabilities. In the past, some manufacturers have characterized the CDMA (IS-95), DCS 1900 (GSM), TDMA (IS-54), and Broadband CDMA standards as high-tier and the Omnipoint, PACS, and DECT standards as low-tier. The continued evolution of technology behind these standards has blurred this distinction and it is not possible to label a standard as exclusively high-tier or low-tier now. More appropriate use of these terms would rely on specific applications of a particular standard.

Data Standards

The development of wireless data communications standards for PCS has been slow. The delay in developing these standards is primarily because of the larger manufacturers' preference for producing unlicensed data PCS equipment. This attitude could hinder the early success of PCS because a voice-only PCS service would have greater challenges in competing against cellular technology.

The only data communications standard that has been established is Short Messaging Service (SMS). SMS uses the control channels in broadband PCS transmissions to provide brief pagerlike messages and services. Qualcomm has been making progress on creating data standards for CDMA-based systems, but these have not been finalized yet. One point of agreement in the PCS community is the need to have a good interface to the CDPD standard.

Comparing Standards

Support of a particular standard by key equipment suppliers will be crucial for its success. PCS license winners will want to bring their systems up in the quickest and most economical fashion possible. They will be looking at issues such as availability, quality, and cost of equipment as they make their choices on which standard to implement. Equipment suppliers are not anxious to commit to product development unless they have confidence in the future success of particular standard. Multiple tests are being conducted by equipment suppliers and potential service providers in an attempt to obtain data that can be used to compare the different standards through some type of objective process. Everybody is trying to sort through the claims and counterclaims of the proponents of different standards in order to choose the best standard for their particular market.

The Benchmark Debates

Multiple tests of systems based on different standards have been conducted in different areas in the United States. Four standard types of geographies have been defined to provide a common setting for comparing system performance characteristics such as cell capacity and coverage. The four typical geographical areas defined for comparison are dense urban (DU), light urban (LU), suburban (SU), and rural (RU) geographies. Results of most of the tests that have been conducted point to CDMA as being the best standard in terms of cell capacity and coverage. However, supporters of competing standards such as DCS 1900 and Omnipoint are not quick to concede and make their own claims for superiority.

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The JTC is using U S WEST's testbed in Boulder, Colorado, to further examine proposed PCS technologies. PHP completed testing in October 1994. Testing was finished on PCS-1900 at the end of 1994. Wideband CDMA, proposed by OKI and InterDigital Communications, will be tested in early 1995. Discussions are under way for testing CDMA, PACS, and Omnipoint. Testing has not been scheduled for DECT technology. The purpose of this testing has not been to provide competitive evaluations.

In late December 1994, Bell Mobility, on behalf of its Mobility Canada network partners, launched the first public side-by-side test of the CDMA, PCS 1900, and PACS proposals. Faced with the confusion surrounding these standards, Bell Mobility decided to conduct tests that will allow it to more completely evaluate these standards in time for Industry Canada's call for PCS licenses, expected in 1995. The trial will determine the merits of each technology in the areas of voice quality, coverage, in-building penetration, hand-off, power control, microwave coexistence, and to test the PCS guard band. The systems will be tested in a variety of surroundings including indoor, outdoor, mobile, and pedestrian environments.

Supporters of the Leading Standards

Equipment and semiconductor manufacturers offering products that support the various standards are outlined in the following sections.

CDMA (IS-95)

Table 4-2 lists manufacturers that have signed agreements with Qualcomm to support their CDMA standard.

Table 4-2
Announced Signed CDMA Agreements with Manufacturers

Infrastructure	Subscriber Equipment	Test Equipment
AT&T	AT&T	Hewlett-Packard
Motorola	Alps	Tektronix
Northern Telecom	Hyundai	Advantest
Goldstar	Goldstar	Schlumberger
Hyundai	Tatung	Safeco
Samsung	Maxon	IFR
	Sony	Rhode & Schwarz
	Panasonic	
	OKI	
	Motorola	
	Nokia	
	Mitsubishi	
	Samsung	
	NEC	

Source: Qualcomm

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AT&T, Motorola, and Northern Telecom are three critical supporters of the CDMA standard. They recently announced their CDMA product roll-out schedules in hopes of calming the concerns of potential PCS licensees about product availability:

- AT&T's fully integrated, end-to-end CDMA PCS offering will include the company's flagship PCS Minicell for PCS systems, the PCS Module for use with the AUTOPLEX System 1000 Series II Cell Site, a PCS Switching Center based on the 5ESS-2000 digital switch, access managers, intelligent networking and operating support system options, and terminals. Its equipment will be available in the third quarter of 1995 for PCS markets.
- The Motorola Cellular Infrastructure Group's SC system family is its wireless platform for cellular and PCS frequencies and supports CDMA, AMPS, and N-AMPS. Motorola began field trials of 1.8-GHz CDMA using the SC2400 base station in the fourth quarter of 1994. The first office application is slated for the fourth quarter of 1995, with general availability set for the first quarter of 1996.
- Northern Telecom is structuring a business relationship with Qualcomm for joint development, manufacturing, and support of CDMA cellular and PCS networks, with commercial product deliveries scheduled for early 1996. The CDMA infrastructure products will support 13-Kbps voice, short message service, circuit mode data, and G3 facsimile.
- Qualcomm's own CDMA QCS-2000 PCS infrastructure will be available for large market deployment in mid-1995. It will also offer the QCP-1900 PCS portable phone in mid-1995.
- Qualcomm has entered into a joint venture with Sony Electronics to develop and manufacture CDMA cellular and PCS phone equipment. The two companies have begun operation of Qualcomm Personal Electronics. A combined engineering team will jointly design and manufacture CDMA phones and other advanced wireless voice and data products. A factory will be established in San Diego, California. Each company will independently market the products manufactured by the partnership.

DCS 1900 (GSM)

Table 4-3 lists companies that currently supply equipment and semiconductors for GSM products. These same companies also will be likely suppliers of DCS-1900 equipment.

Other items of note include:

- In November 1994, Motorola laid claim to being the first and only company to complete calls using both CDMA and DCS 1900 standards at 1.9 GHz. Motorola plans to have commercially available DCS 1900 products for PCS starting in 1995. Motorola is a highly experienced provider of GSM products, with contracts from more than 30 GSM systems worldwide.

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Table 4-3
GSM Equipment and Semiconductor Suppliers

Infrastructure Suppliers	Handset Manufacturers	Semiconductor Suppliers
Siemens	Motorola	Cirrus (PCSI)
Alcatel	Alcatel	Sony
Philips	Hagenuk	AT&T
Motorola	Dancall	Fujitsu
Ericsson	Orbitel	Analog Devices
Nokia	Panasonic	Motorola
	Matra/AEG	Toshiba
	Nokia	AMS
	Ericsson	Siemens
	Siemens	Philips
	Philips	Hitachi
	NEC	Texas Instruments
	Mitsubishi	VLSI Technology
	Sony	LSI Logic
		SGS-Thomson

Source: Dataquest (January 1995)

- In September 1994, Nokia announced that it is ready to enter the U.S. market with equipment supporting the DCS 1900 standard. Its system, called PCS 1900, is operating in several countries including Germany, the United Kingdom, and Thailand. It noted the attractiveness of a CDMA solution in the long run but also recognized the importance to PCS players of being in the market early.
- Nokia has announced plans to build a wireless phone manufacturing facility in Fort Worth, Texas. This plan will produce cellular and PCS handsets.
- At the Wireless '94 Conference, Nokia Mobile Phones introduced a 1.9-GHz mobile phone originally developed for the European DCS-1800 standard, which the company calls the first true U.S. PCS phone.
- Pioneer's Preference winner APC began tests in 1994 of a PCS system in the Washington, D.C.-Baltimore area using Northern Telecom's PCS 1900 equipment. The tests were designed to test operations and interoperability issues. It also planned to test APC's PathGuard frequency sharing technology, which APC has licensed to Northern Telecom.

TDMA (IS-54/IS-136)

Table 4-4 lists equipment manufacturers currently supplying equipment for the TDMA digital cellular standard and that could leverage their products into PCS products based on TDMA standards. (These manufacturers could also leverage their products to support the TDMA-based DCS-1900 standard.)

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Table 4-4
TDMA (IS-54) Digital Cellular Equipment Suppliers

Infrastructure Manufacturers	Dual-Mode Handset Suppliers
Astronet	Audiovox
AT&T Network Systems	Blaupunkt
Celcore	Ericsson/GE
Ericsson Radio Systems	Hughes
Hughes Network Systems	Motorola
Northern Telecom	NEC
	Nokia
	Technophone
	Mitsubishi
	Novatel

Source: Dataquest (January 1995)

PACS

The PACS standard has significant support, and Motorola has developed products targeted at specific applications. Important items related to the development and support of this standard are as follows:

- As a low-tier air interface, the PACS standard has the support of the PCS Technology Advocacy Group (PTAG), an industry forum of potential PCS providers including Bell Atlantic, Sprint, Time Warner, and U S WEST. PTAG supports CDMA as the high-tier interface.
- Motorola's TeleDensity system has been designed to meet the PCS JTC standards for a PACS system. The technology has been optimized for voice and data telephony service implementation in urban and suburban areas. The flexible nature of the TeleDensity system allows it to be configured to serve specific customer needs with services ranging from fixed telephone services to wireless portability in the home or business to wide area mobility. Motorola chose Reliance Comm/Tec Corporation to supply transmission equipment based on Next Generation Digital Loop Carrier (NGDCL) technology for deployment in conjunction with Motorola's PCS system. The agreement calls for Reliance to deliver initial testbed units to Motorola in early 1995.
- Motorola's wireless local loop product, CableComm, uses the PACS technology. The system was originally designed for pedestrian mobility using PACS, but Motorola has been able to rework the technology to permit high-speed hand-offs between cable radio ports (CRPs).
- PCSI has entered into a deal with DDI Corporation and Kyocera Corporation to develop a chipset for the Japanese PHP. PCSI's five-chip set for PHP consists of a CMOS ADPCM processor, one bipolar and one BiCMOS device for IF functions, and two GaAs devices for RF functions. PCSI has also been working with Matsushita and NEC in the development of the PACS standard. Semiconductors developed for the PHP standard could be leveraged into products supporting the PACS standard.

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And the Big Standards Winners Are...

In spite of the emphasis being placed on determining the technical merits of each standard, the final decision on which standard will be deployed by a particular service provider will be based on a number of factors. A key concept guiding the actions of many players in the market is that there is no one "right technology or standards" answer for all MTAs, BTAs, service providers, or users. Different service providers in different areas will make their final decision on which standard to implement based on a mixture of technical merits, marketing angles, market timing, alliances, sourcing issues, and competition, among others.

Based on the current market status, Dataquest predicts that GSM-based DCS-1900 will take off early in high-tier applications because there will be no deployment delays from late PCS auctions. This standard will ramp up and be dominant for a few years. Other TDMA systems will also be used. This will happen because there will be no need to test and debug TDMA systems because this has already been done in Europe and elsewhere. Beginning in 1996 and building from there, CDMA will become the technology of choice because of its increased capacity virtues and enhanced quality and features. It will go through growing pains via testing and refinement stages. Then, by the end of the decade, CDMA will become the U.S. multiple access standard. PACS systems have garnered strong support from the regional Bell operating companies, and with Motorola backing should provide a strong low-tier solution.

The strategy being followed by Sprint in implementing a digital cellular system provides an example of how CDMA can become the long-run winner in the standards battle. Sprint has announced plans to use CDMA technology in its cellular markets. Sprint has already upgraded its systems to NAMPS as an interim move and does not believe that TDMA will provide much improvement over this in its network. It plans to continue to deploy NAMPS in its large markets and assess its need for digital technology in those markets in the future. It believes that it has the luxury of waiting a little longer to deploy CDMA. The company has announced plans to purchase equipment from Motorola to install CDMA in its Las Vegas market at the end of 1995.

The key benefits of CDMA include the following:

- Lower provider capital costs than GSM-based systems because of higher-capacity capabilities (conservatively 10 times the capacity of analog,) requiring less build-out and better coverage
- Offers provider the choice of simultaneous voice, asynchronous, and packet data, fax, and short messaging
- Closer to wireline voice quality than current TDMA-based technologies

Embedded analog systems will continue to exist indefinitely—first to handle growing traffic and eventually to provide redundancy for digital networks, because the existing analog AMPS infrastructure will be the only backup for the assortment of phones based on incompatible digital formats and frequencies.

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Infrastructure

In discussing the issue of infrastructure development for PCS systems, it is helpful to identify the key systems and common architectural elements of a PCS network. The key elements of any network are as follows:

- Base station (or base terminal station, BTS) – The BTS transmits and receives signals from the subscriber's terminal and provides the interface to the network.
- Base station controller (BSC) – Each BSC controls a number of base stations. Principal tasks realized by the BSC include managing BTS radio channels, performing hand-offs (provided both cells are controlled by the same BSC), controlling the output power of BTS, and adapting the transmission speed between the radio link and the main network. The BSC and BTS are usually supplied by the same manufacturer, and the combination of the two is called the base subsystem (BSS). The total BSS accounts for about 70 percent of the hardware expenditure in a typical network.
- Main switching center (MSC) – This provides switching both to other parts of the cellular network and to other networks such as the PSTN, allowing calls to be connected to ordinary telephones. It also handles call routing, which involves finding the location of the called party, hand-offs between cells controlled by different BSC, and several other key functions. In practice, MSCs use adaptations of the switches used in the PSTN. The MSC cost is usually about 30 percent of the total system hardware cost.

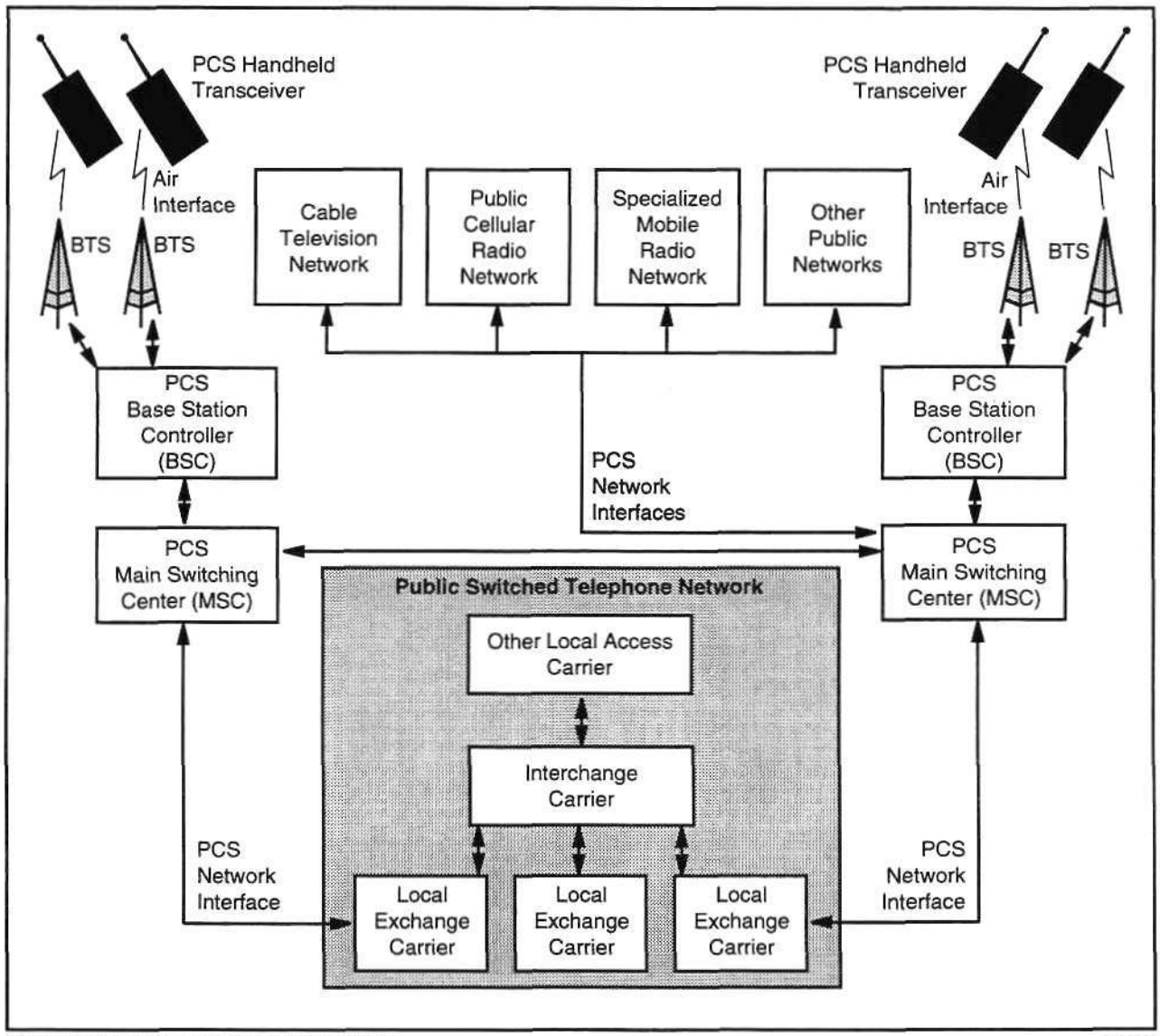
These descriptions of network elements are somewhat idealized, in the sense that there is still disagreement about where certain network functions should be performed. In particular, there is disagreement about how the network intelligence should be distributed among the various network elements. Figure 4-4 shows a typical PCS network topology.

In competition to the local exchange carriers, cable companies have an opportunity to provide the interconnections medium for PCS networks. Numerous tests of cable TV-based PCS networks have been conducted, including Time Warner's Orlando experiment using CDMA-based systems on a multimedia telecommunications hybrid fiber/coax network. Motorola has developed a product called CableComm that uses the huge signal capacity of existing fiber/coax cable systems to run a number of advanced services simultaneously, including: video-on-demand, electronic shopping, data services, and standard and video telephone services. On the PCS side, this system can be configured to provide both fixed and mobile wireless services. As shown in Figure 4-5, cable operators can offer these services by installing base stations called cable radio ports (CRPs) that connect directly to the cable plant. Situated centrally in a neighborhood, the CRP can serve 25 to 150 homes in a true wireless local loop. Motorola has also added the capability to support vehicular speed mobility in this PACS-based system.

Key Variables in the Profit Equation

The key, interrelated variables that potential service providers are evaluating as they choose infrastructure equipment to implement their PCS networks are: availability of equipment, cell capacity, cell coverage, cost,

Figure 4-4
Example of PCS Network Topology

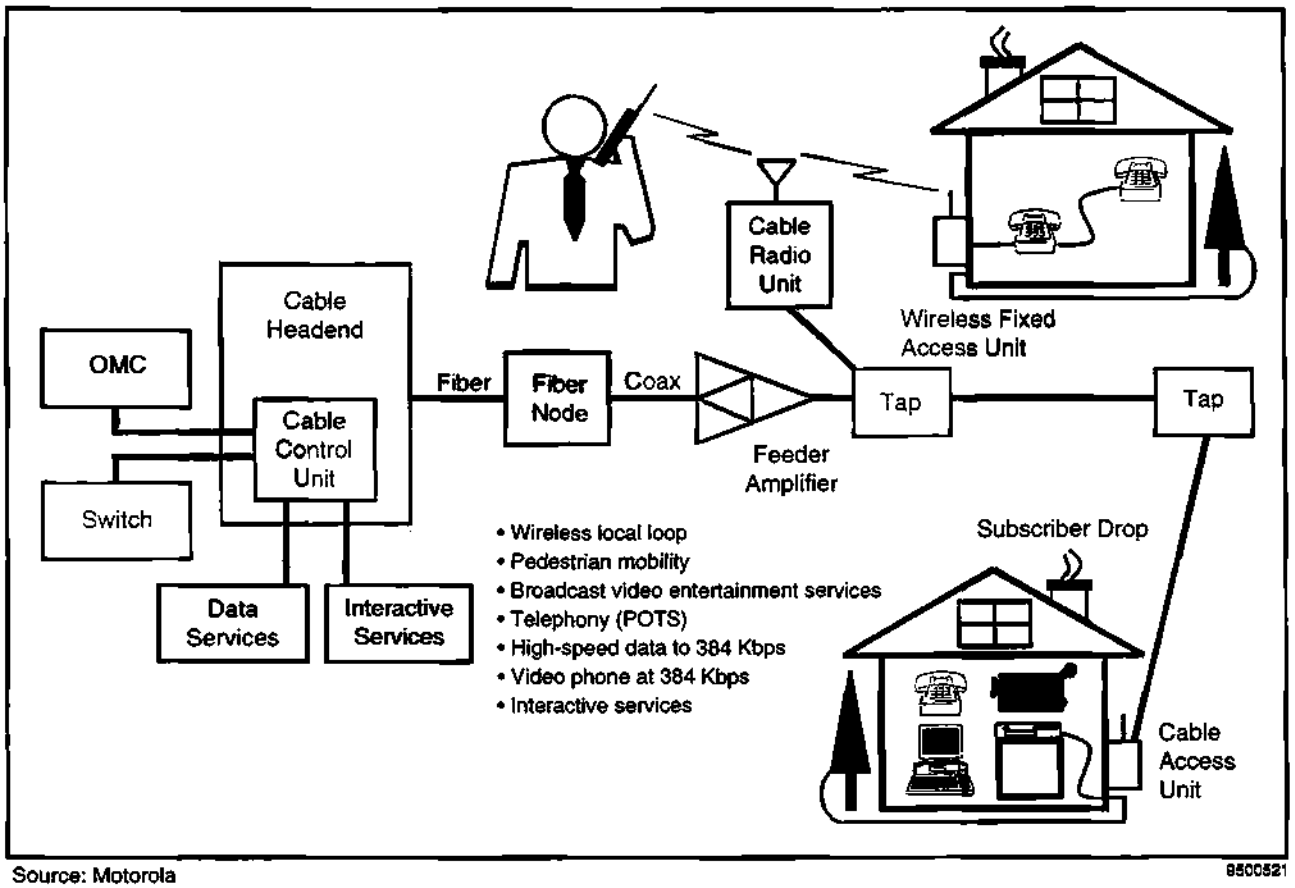


Source: Federal Communications Commission

interoperability, and voice quality. The FCC has ruled that a licensee must build a 2-GHz PCS system fast enough to reach one-third of the population in its service area within 5 years and two-thirds within 10 years of the license grant. Service providers will be working to bring their networks up as quickly as possible in a very competitive PCS market.

The factors of cell site coverage and capacity dictate how many cell sites it takes to cover a particular area. This becomes important when a service provider is trying to determine how quickly and cost-effectively it can bring services to the market. Delays in availability of infrastructure equipment can be made up if the coverage enabled under one standard is better

Figure 4-5
Example of Cable Infrastructure-Based PCS Implementation

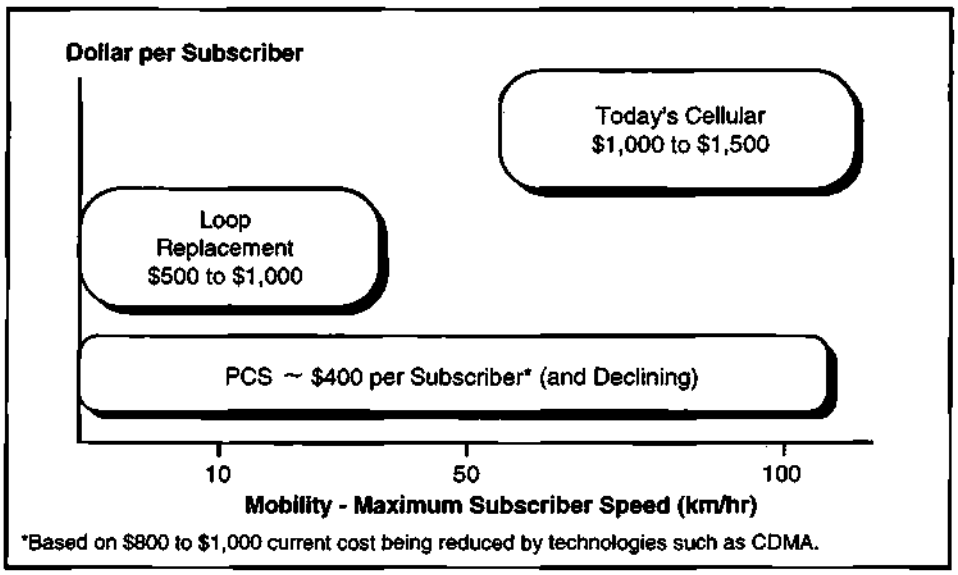


Source: Motorola

than the other. To enable competition with current cellular providers, infrastructure costs must be managed carefully. Figure 4-6 shows the infrastructure cost profile that AT&T believes can be achieved in a PCS network.

The issue of network interoperability with the existing telecommunications infrastructure in North America and among the wireless infrastructures has become a hot topic. The U.S. digital cellular standards use the IS-41 mobile application part (MAP) protocols and ANSI standards for interfacing with the existing local exchange carriers (LECs), interexchange carriers (IXCs), and advanced intelligence network (AIN) services. With its GSM technology, DCS 1900 will have to develop solutions for this issue. Early plans are to use protocol converters/translaters to interface to the existing U.S. infrastructure. MCI has pursued the idea of developing an isolated GSM system and only interconnecting to the telecommunications infrastructure at selected points. These solutions are expected to provide a minimum level of interoperability, but many challenge the long-term adequacy of this approach.

Figure 4-6
Wireless Infrastructure Cost Profile



Source: AT&T Network Wireless Services 9500522

Various logistical issues will impact the speed of deployment of PCS. It is important to remember that the entire U.S. cellular industry deploys only 1,500 sites per year. With an "unlimited budget," the fastest deployment ever made for one client was 150 sites over 12 months. This required 12 to 16 hearings every week before city councils. In addition to the standards activities and FCC actions that have been discussed, other major factors will impact the rollout of PCS infrastructure:

- Obtaining base station sites: PCS will require many more sites necessary than 800-MHz cellular. It is estimated that 100,000 cell sites would have to be erected before the end of the decade to accommodate the growing demand for wireless services. Obtaining zoning approval for these sites could be a challenge.
- Relocating current microwave users: The high demand for microwave equipment could create a temporary market boom in this area.
- Engineering, equipping, and installing a major system: Many analysts expect shortages in skilled workers and equipment to develop during the "PCS bubble."
- Dealing with state certification and regulation
- Resolving legal challenges

Recognizing the significance of the challenges listed, President Thomas Wheeler of the Cellular Telecommunications Industry Association has written a letter to FCC Chairman Reed Hundt asking the FCC to decide:

- Whether "not-in-my-backyard" activists and local governments will impede the progress of building a national pathway of cell sites necessary to provide wireless service
- Whether local telephone companies will continue to control the assignment of telephone numbers, refuse to compensate cellular carriers for calls terminated on a wireless network, and control rates charged to the wireless carriers for access to the landline network
- Whether state regulatory agencies should continue to control new wireless service offerings and access rates

The rush to bring PCS services to market as quickly as possible could motivate some potential competitors to pursue various time-saving strategies. Some companies might choose to pursue riskier investment in PCS and commit major funds to begin infrastructure development before actually winning a license in the auctions. Also, it may be possible to use existing cellular sites. Figure 4-7 shows an agressive time line for the development of PCS infrastructure presented by Motorola.

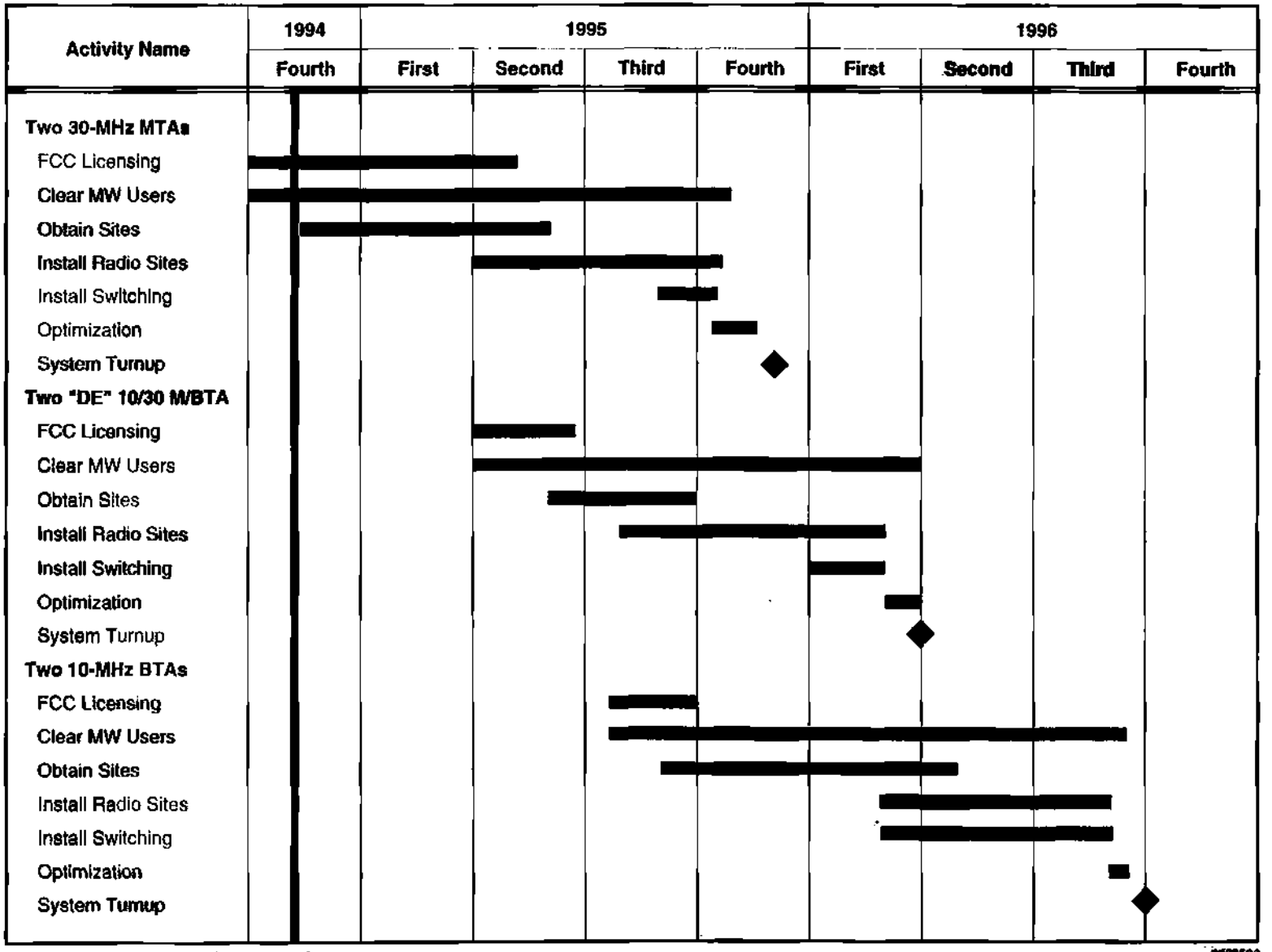
Subscriber Equipment

A spectrum of subscriber equipment will eventually be used by PCS users. Early devices will range from voice-centric terminals similar to cellular handsets and the IBM/BellSouth Simon to data-centric terminals such as the Sony Magic Link, Motorola Envoy, and mobile computers with PCMCIA add-in transceivers.

Early PCS handsets that will come to the market will be similar to "dual-mode" digital cellular handsets with phones supporting a particular PCS standard such as CDMA, DCS 1900, or TDMA and providing analog AMPS capability as a backup. With the development of digital cellular, handsets with "dual-band" capability will be developed. For example, this would allow a phone using CDMA technology to operate over a PCS network at 1.9 GHz or over a digital cellular network at 800 MHz. It will be more difficult to adapt PCS handsets supporting the TDMA-based DCS 1900 standard to dual-band capability. There are no formal proposals for a GSM digital cellular network in the United States, and the U.S. TDMA standard of digital cellular employs an incompatible modulation scheme. The IS-54 standard uses differential quadrature phase shift keying (DQPSK) in its modulation, while GSM-based DCS 1900 uses Gaussian mean shift keying (GMSK).

PCS service providers will be challenged to reduce the cost of using their services in order to promote strong market growth. Figure 4-8 illustrates the correlation between the "total cost of ownership" and the penetration of mobile telephones in selected countries. For a consumer, the total cost of ownership is the sum of the monthly service bill plus the cost of the handset. The cost of the handset may be hidden to the subscriber if it is included in the service agreement, but it will still impact the overall cost to the user. Because the cost, functionality, and quality of subscriber equipment plays a central role in PCS services, there has been a large investment in the key technologies impacting handsets and other subscriber

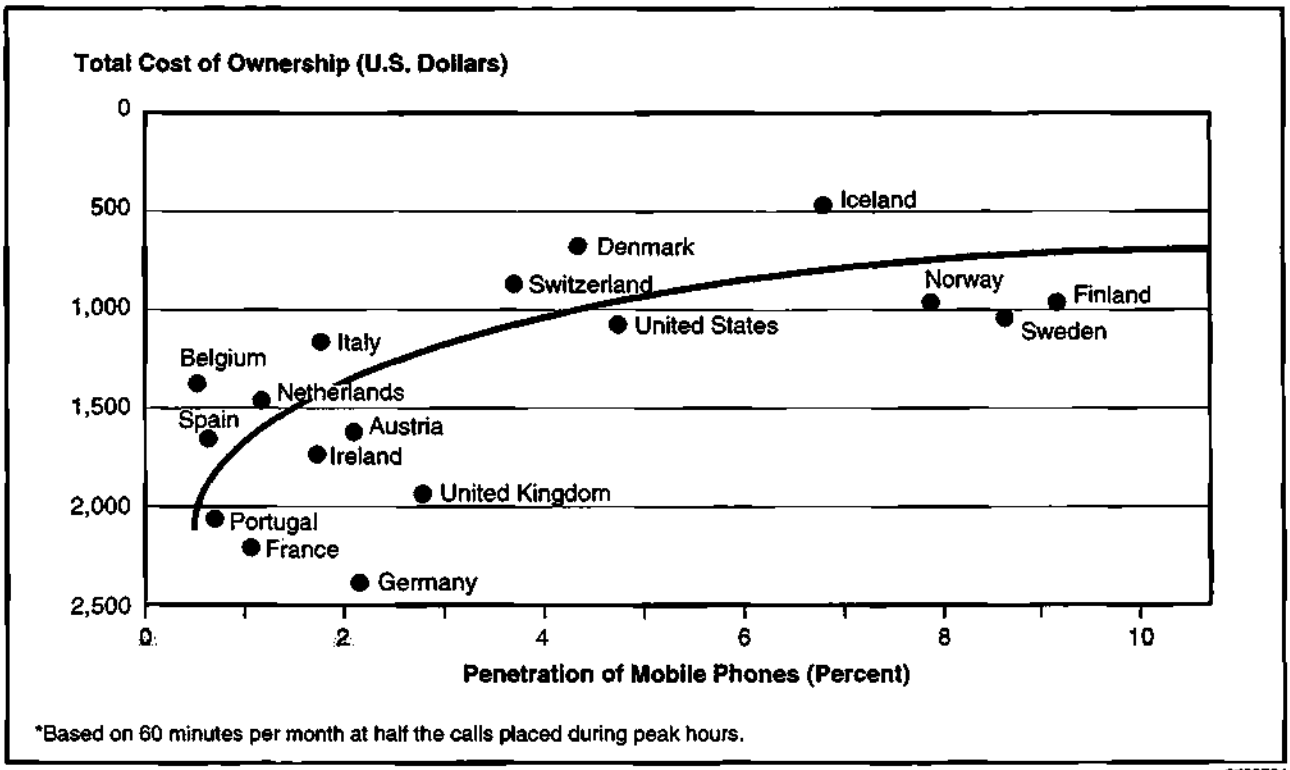
Figure 4-7
Potential Infrastructure Rollout Time Line



Source: Motorola Cellular Infrastructure Group

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Figure 4-8
Correlation of the Total Cost of Ownership and Penetration



Source: Nokia

9500524

terminals. Major areas of emphasis are longer talk-time and standby time through efficient power consumption, enhanced signal transmission capability, and the handset size and weight. Antenna technology is being developed to improve transmission quality, and batteries are a point of focus for extending talk-time. However, semiconductor technology plays a vital role in all three of these critical areas.

Semiconductor Opportunities

The development of handsets and infrastructure equipment for the PCS market presents major opportunities and technological challenges for semiconductor companies. Semiconductors will play a critical role in subscriber equipment as designers work to improve features such as talk-time, voice quality, and size while enabling new data communications features. The confusion over standards presents an added challenge for manufacturers as they try to decide where to invest resources. Some companies are choosing to be cautious in their approach to the market and position themselves to support standards after they emerge as high-volume winners. Other manufacturers are aggressively investing in early development in hopes of gaining early market advantages when service providers begin to deploy networks in 1996. As they push down the integration and power efficiency path, some manufacturers have been able to leverage earlier work on products designed for GSM. Also, much of the investment on semiconductor technology for handsets can be applied to infrastructure markets. As they push toward the ultimate single-chip

solution, manufacturers are focusing their efforts on the baseband and RF/IF sections of the handset.

Baseband

Manufacturers developing baseband products for digital cellular and PCS include AT&T, Texas Instruments, Analog Devices, Motorola, Philips, Siemens, LSI Logic, SGS Thomson, and GEG Plessey. These companies will play a major role in supplying baseband chips for the TDMA- and PACS-based standards. Qualcomm has developed the baseband technology for the CDMA standard and will be the early source for chips supporting this standard. Although early designs are expected to require 60- to 80-MIPS processing power, it is anticipated that they will eventually take advantage of digital signal processors (DSPs) providing 100 to 200 MIPS. Dual-mode handsets do not present a difficult challenge from a semiconductor perspective because the analog baseband processor only represents 5 percent of the silicon in a typical design. As an example of the technology in a PCS handset, Figure 4-9 shows a block diagram for a CDMA handset designed by Qualcomm.

RF/IF

The RF/IF section is the major power consumption culprit in handsets and presents great opportunities for improvements in power efficiency. Although gallium arsenide (GaAs) is now being employed in most RF/IF solutions, advances in silicon will eventually bring BiCMOS solutions to the market. Silicon RF/IF ICs will provide significant advantages, such as lower cost, greater ease of design, reduced heat, and higher integration. Promising developments such as Siemens' 25-GHz RF bipolar transistor are bringing RF silicon solutions closer to reality for PCS.

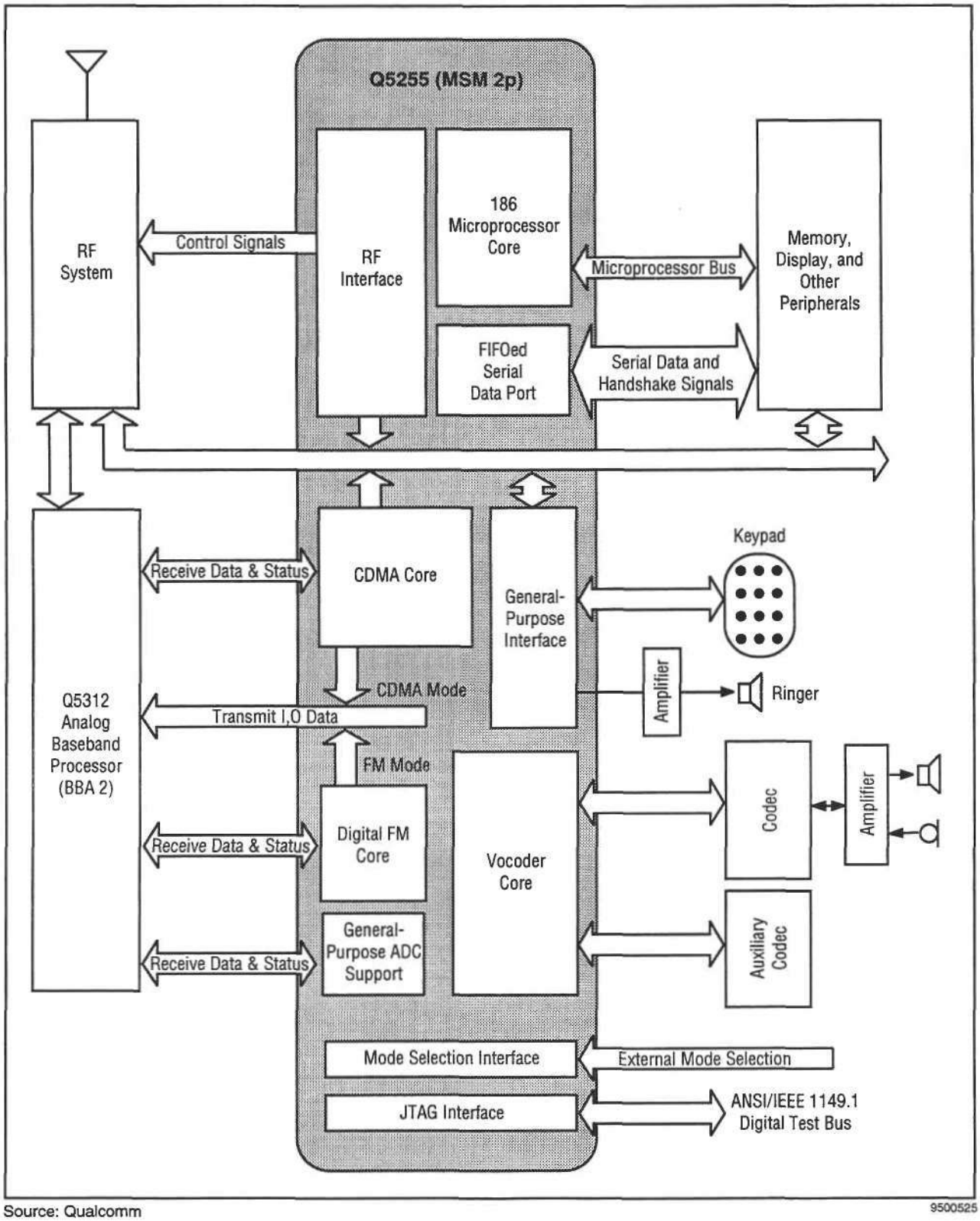
Companies including Rockwell, Siemens, GEC Plessey, Harris Semiconductor, Analog Devices, and Sony will be supplying products for the RF/IF section. However, most manufacturers are being cautious about investing in integrated solutions and are supplying discrete components for PCS handsets. They would prefer to see which standards emerge as the stable, high-volume winners before they develop integrated chipsets because a slight tweak in the DSP can mean a complete redesign of the RF section. In this sense DCS 1900 has an early advantage because GSM is already a high-volume product, and many manufacturers providing chipsets for these handsets will be leveraging their technology into this standard. The CDMA standard has an advantage in the DQPSK modulation scheme it uses. This method provides a 2:1 advantage in spectrum efficiency over the GMSK employed by GSM and DCS 1900.

Leveraging Technology

Companies able to leverage earlier work on digital cellular products could gain an early advantage in the PCS handset market. Nokia has launched a digital cellular phone that serves as an example of leveraging semiconductor components across different standards. At the core of the phone is an ASIC designed by Nokia engineers. The addition of different surface acoustic wave filters and RF components allows the phone to be adapted as a multistandard phone for the U.S. TDMA digital cellular and AMPS systems, for the European GSM and DCS-1800 specifications, and for the Japanese digital phones system. It is also a contender for use with U.S. DCS-1900 networks. Qualcomm has also developed a baseband processor

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Figure 4-9
Example of a CDMA Handset



Source: Qualcomm

for the CDMA standard that can be adapted for digital cellular, PCS, and local loop equipment with minor modifications.

The Integration Challenge

The TDMA- and GSM-based products have been able to get the early jump in making progress down the integration path. Qualcomm also is working aggressively to move down the curve. Qualcomm began with a 5,600-DSP design to implement a digital baseband processor in 1990. It had reduced the chip count to a three-ASIC solution in 1991 and a one-ASIC solution in 0.5-micron technology by the end of 1993. Table 4-5 and Figure 4-10 present projections for future integration of CDMA and TDMA products.

Future Technology Trends

The lower power requirements of PCS handsets are expected to give them an advantage over comparable digital cellular handsets in terms of cost and integration. Although costs for baseband chips will be similar between digital cellular and PCS, the lower-power solutions on the RF/IF side will allow smaller filters and lower currents to be used in designs, which will put them on a more aggressive integration path. Table 4-6 presents a forecast for semiconductor technology. With talk-time and standby time being the top issues in the mind of mobile phone users, lower-power PCS products will have an advantage in this aspect as well.

Table 4-5
TDMA Integration Path

	1992/1993	1995/1996	1998/1999
Baseband	Six or seven ICs plus memory chips	Two ICs plus memory chips	One digital IC
RF/IF	More than 150 discretes	Three ICs plus discretes	One AFE plus transceiver IC
Power	Nonmonolithic PA	Monolithic PA	Monolithic PA plus power control
Batteries	Five cells	Three cells	Two cells

Source: Texas Instruments

Table 4-6
Semiconductor Technology Trends

	1992	1994	1996	1998	2000
Geometries (Microns)	0.8	0.5	0.35	0.25	0.18
Voltage	4.5 to 5	3 to 5.5	2 to 3.6	1.5 to 2.4	1.5 to 2.4
Stand-by Time	18 hours	36 hours	72 hours	144 hours	More than 1 week
Talk Time	1.5 hours	3 hours	6 hours	12 hours	More than 1 day

Source: Texas Instruments

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Figure 4-10
CDMA Integration Path

	First Generation	Second Generation	Third Generation
CPU	16-bit microcontroller	MSM 2.0	MSM 3.0
CDMA Signal Processor	MSM 1.0		
Vocoder	Mask ROM DSP		
A/D and D/A Converters	Baseband Analog ASIC Version 1.0	Baseband Analog ASIC Version 2.0	Baseband Analog ASIC Version 3.0
Baseband Filtering			
TX/RX Mod/DeMod			
TX/RX AGC	Discrete	Tx AGC / Rx AGC	Tx Front-End ASIC / Tx Front-End ASIC
TX/RX Up/Down Convert	Discrete	Tx ASIC / Rx ASIC	
Synthesizer	Hybrid (3)	Dual / BBA-2.0	
Power Amplifier	Standard AMPS	MMIC	MMIC
Operating Voltage (V)	5	3	3
Size	7 x 2.25 x 1-inch	200cc	Less than 170cc
Weight (Oz.)	12.2	8	Less than 6.5

Source: Qualcomm

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Chapter 5
Dataquest Perspective

While recognizing the obstacles that still lie ahead, Dataquest is bullish on the prospects of the PCS market. Even beyond the PCS market, the simple introduction of the element of increased competition will add increased vitality to the overall wireless market. Even though some of the growth in PCS subscribers will come at the cost of current cellular services, the lower service prices that will be generated by competition will result in an expansion of wireless service subscribers in general and a net increase in cellular services in particular.

Through 1995, moving toward the introduction of narrowband and broadband PCS services in 1996, equipment manufacturers will be working to bring infrastructure and subscriber products to market to support the anticipated strong demand for equipment. It can be expected that an inventory of subscriber equipment will develop as service providers work to obtain an adequate supply of handsets to support their initial sales and marketing efforts. This demand will provide increased momentum to the market for wireless semiconductors. With several manufacturers leveraging development from earlier digital cellular products, semiconductor manufacturers will be pushing to meet the market. At the same time, it will be necessary for these manufacturers to remain alert to the trends in standards and regulations. Overall, there is good reason for optimism as PCS opens the door to a wireless communications renaissance.

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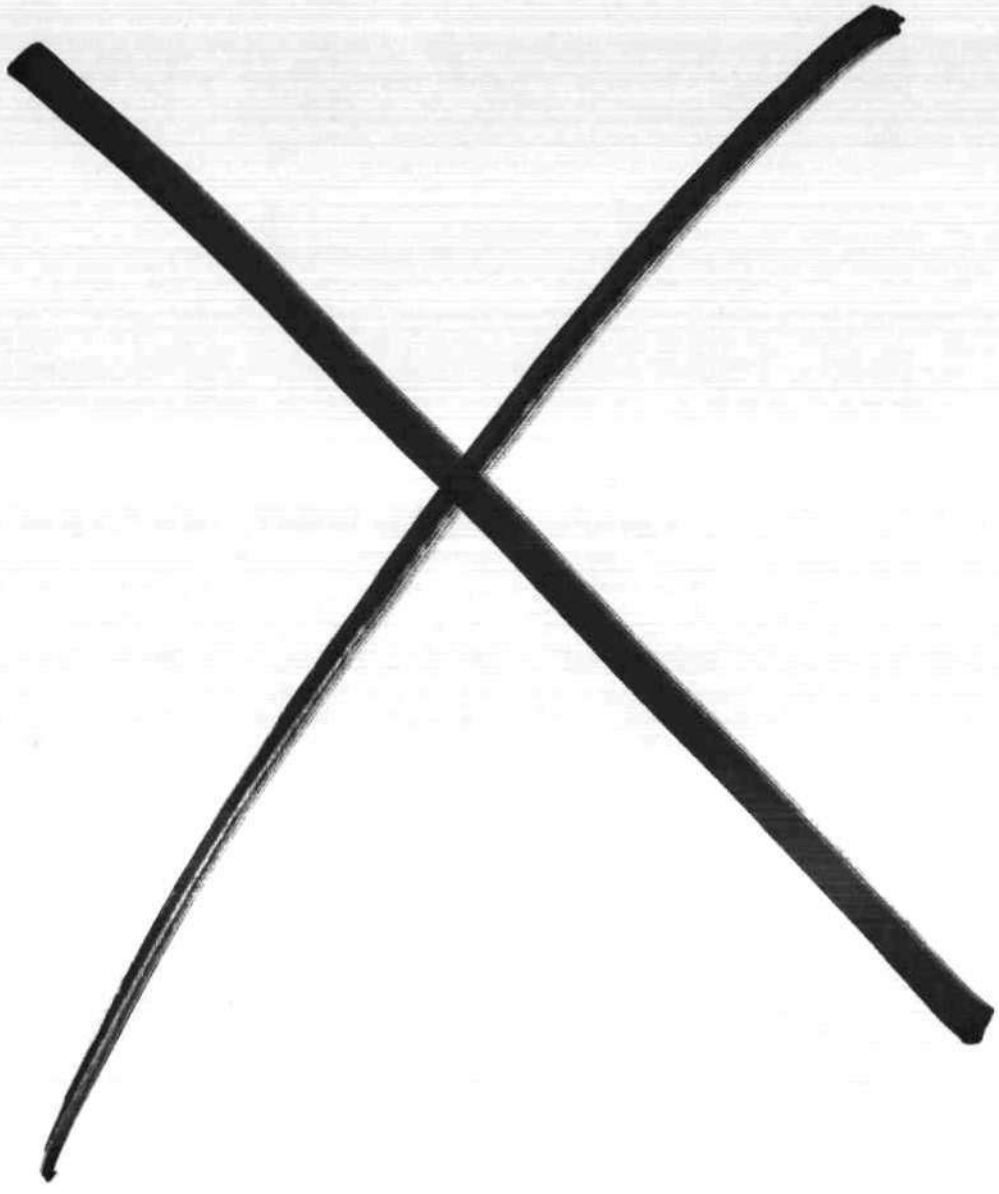
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February 8, 1996

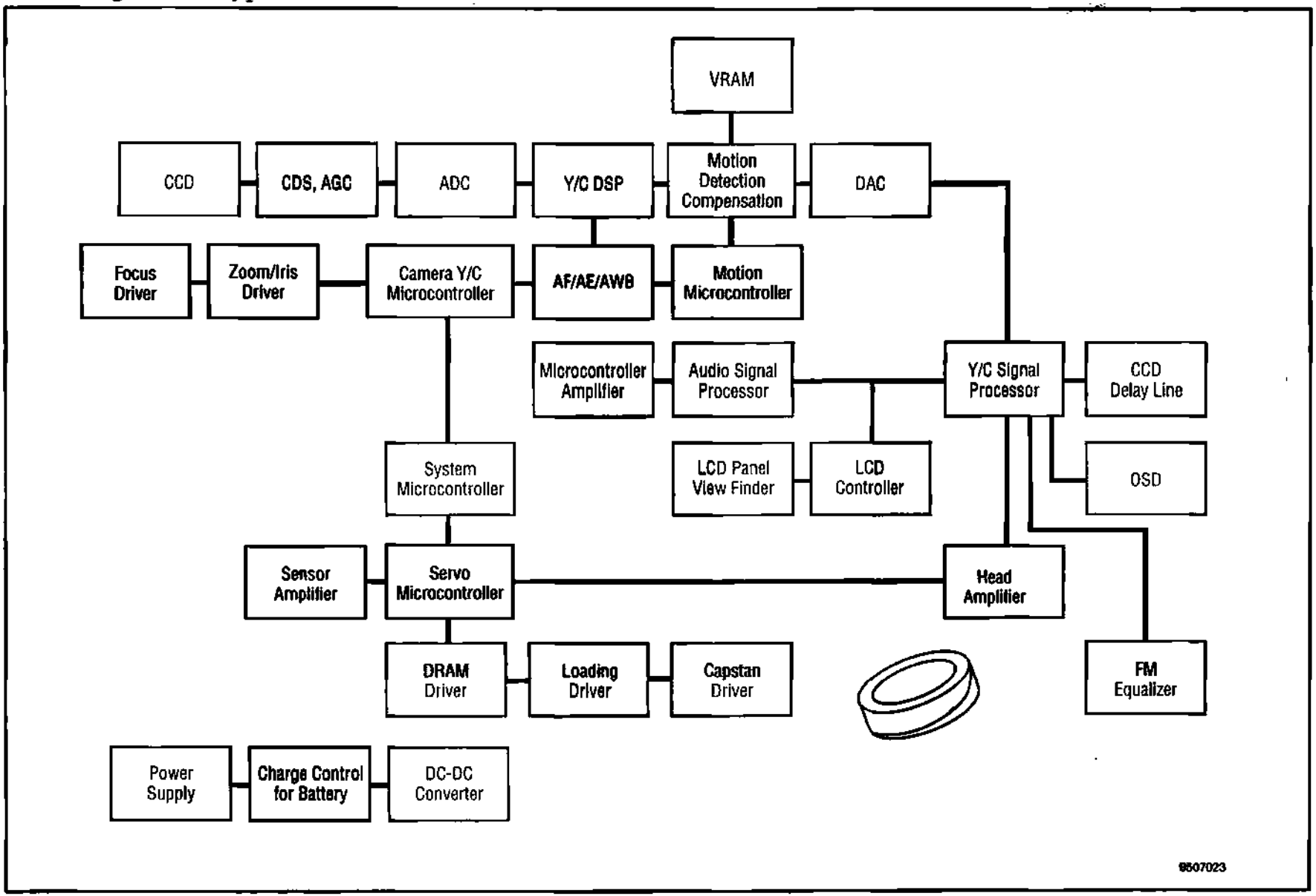
Errata

In Dataquest's Semiconductor Application Markets Worldwide Market Trends document ("Consumer Electronics Semiconductor Application Markets," SAMM-WW-MT-9506), Figure 4-13 was incorrect. Please place the attached correction in your Semiconductor Application Markets Worldwide binder.

Dataquest regrets the inconsistency and apologizes for any inconvenience. For further information, contact Senior Industry Analyst Dale Ford at (408) 468-8311 or at dford@dataquest.com.

December 25, 1962

Figure 4-13
Block Diagram of a Typical Camcorder



Source: Dataquest (December 1995)

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December 12, 1995

Dear Client,

We recently finalized our statistics and forecasts for the "Consumer Semiconductor Applications Market Trends" book that is scheduled to ship to clients of the Worldwide Semiconductor Applications Markets Service in December. In light of the high level of interest in this information, I have decided to fax you the key statistics and forecasts that will be published in this book. The following pages contain the major tables with data for: consumer audio, video, personal interactive, and appliance markets. This document has been completed and submitted to our document production group. The complete document should be shipped to you before the end of December as scheduled.

I would like to acknowledge the feedback I have received requesting that this document be published earlier in the year. You will be happy to know that we have moved up the scheduled delivery of the Consumer Market Trends document to September in 1996.

I look forward to working with you as we continue our research in the area of semiconductors and consumer electronics. Thank you.

Sincerely,

Dale Ford
Senior Industry Analyst
Semiconductor Application Markets

CONSUMER APPLICATION MARKETS

Worldwide Consumer Electronic Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Audio	20,543	22,904	25,556	27,974	31,020	34,537	38,329	42,890	10.9%
Video	43,236	46,009	50,510	53,769	57,675	63,284	68,570	74,410	8.1%
Personal Electronics	17,433	19,286	21,110	21,669	23,203	25,698	28,617	31,489	8.3%
Appliances	46,616	51,564	57,250	59,608	63,486	67,136	72,039	77,391	6.2%
Other Consumer	12,310	13,623	16,262	17,215	18,518	19,598	20,543	22,313	6.5%
Total	142,132	155,379	172,682	182,232	195,899	212,251	230,097	250,494	7.7%

Worldwide Semiconductor Consumption for Consumer Equipment Production, by Device (Millions of Dollars)

Device Type	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Bipolar Digital IC	226	210	216	178	146	118	97	81	-17.9%
MOS Memory	2,413	3,188	4,858	6,310	7,667	8,611	10,190	12,059	19.9%
MOS Microcomponent	2,966	3,976	5,400	6,681	8,016	9,788	11,641	13,845	20.7%
MOS Logic	2,132	2,591	3,427	3,874	4,388	5,020	5,633	6,320	13.0%
Analog IC	5,560	6,837	8,058	9,035	9,782	11,032	12,592	14,373	12.3%
Discrete	3,213	3,670	4,916	5,453	5,886	6,575	7,538	8,642	11.9%
Optoelectronics	1,218	1,446	1,804	2,006	2,133	2,287	2,544	2,830	9.4%
Total	17,727	21,917	28,678	33,537	38,018	43,430	50,235	58,151	15.2%

North American Consumer Electronic Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Audio	716	766	811	864	908	960	1,019	1,078	5.9%
Video	7,622	8,869	9,588	9,973	10,405	11,134	11,692	12,847	6.0%
Personal Electronics	203	210	223	233	241	250	264	276	4.4%
Appliances	13,669	14,942	15,470	15,351	15,917	16,186	17,047	17,502	2.5%
Other Consumer	1,296	1,395	1,461	1,539	1,593	1,655	1,724	1,798	4.2%
Total	23,507	26,182	27,552	27,960	29,063	30,185	31,745	33,502	4.0%

North American Semiconductor Consumption for Consumer Equipment Production, by Device (Millions of Dollars)

Device Type	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Bipolar Digital IC	7	6	6	5	4	3	3	2	-18.6%
MOS Memory	623	875	1,364	1,896	2,473	2,911	3,526	4,271	25.6%
MOS Microcomponent	518	716	945	1,243	1,545	1,879	2,169	2,504	21.5%
MOS Logic	110	141	165	192	218	256	292	333	15.1%
Analog IC	780	938	1,082	1,212	1,330	1,499	1,647	1,810	10.8%
Discrete	257	305	371	415	448	488	530	577	9.2%
Optoelectronics	20	22	24	24	25	25	26	26	1.8%
Total	2,315	3,005	3,956	4,987	6,044	7,062	8,193	9,524	19.2%

Regional Share of Consumer Electronics Equipment Production Revenue (Percentage)

Region	Percentage 1995	2000
North America	16.0%	13.4%
Europe	12.8%	12.3%
Japan	40.7%	33.7%
Asia/Pacific - ROW	30.5%	40.6%
Total	100.0%	100.0%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

United States Household Penetration of Consumer Electronics Products, January 1995

Product	Penetration
Refrigerators	99%
All Television	98%
Home Radios	98%
Color TV	97%
VCR Decks	85%
Microwave Ovens	89%
Clothes Washers	75%
Separate Component Audio System	53%
Rack or Compact Audio Systems	29%
Ranges, Electric	59%
Dishwashers	52%
Dryers, Electric	54%
Color TV with Stereo	47%
Monochrome TV	47%
Ranges, Gas	45%
Color TVs with Stereo	47%
Home CD Players	44%
Video Game Software	44%
Camcorders	20%
Portable CD Player	19%
Home Security Systems	19%
Dryers, Gas	18%
Autosound CD Players	11%
Projection TV	10%
All LCD TV	9%
TV/VCR Combinations	5%
Home Satellite Earth Stations	5%
Laserdisk Players	1%

Source: Dataquest, EIA, Appliance Magazine

Worldwide Audio Equipment Production Forecast (Millions of Dollars)

Revenue	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Audio Equipment	20,543	22,904	25,556	27,974	31,020	34,537	38,329	42,890	10.9%

Regional Share of Audio Equipment Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	3.2%	2.5%
Europe	6.5%	5.6%
Japan	29.1%	17.4%
Asia/Pacific - ROW	61.2%	74.5%
Total	100.0%	100.0%

North American Audio Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Compact disc player	33	41	50	62	76	94	115	136	22.1%
Radio	165	184	194	204	212	221	231	241	4.5%
Personal/Portable Stereo	33	35	36	39	42	45	47	49	6.4%
Stereo component	226	239	252	266	276	288	302	317	4.7%
Musical instrument	242	250	261	274	282	292	302	313	3.7%
Tape recorder	17	17	18	19	20	20	21	22	3.9%
Total	716	766	811	864	908	960	1,019	1,078	5.9%

CONSUMER APPLICATION MARKETS

United States Household Penetration of Consumer Electronics Products, January 1995

Product	Penetration
Refrigerators	99%
All Television	98%
Home Radios	98%
Color TV	97%
VCR Decks	85%
Microwave Ovens	89%
Clothes Washers	75%
Separate Component Audio System	53%
Rack or Compact Audio Systems	29%
Ranges, Electric	59%
Dishwashers	52%
Dryers, Electric	54%
Color TV with Stereo	47%
Monochrome TV	47%
Ranges, Gas	45%
Color TVs with Stereo	47%
Home CD Players	44%
Video Game Software	44%
Camcorders	20%
Portable CD Player	19%
Home Security Systems	19%
Dryers, Gas	18%
Autosound CD Players	11%
Projection TV	10%
All LCD TV	9%
TV/VCR Combinations	5%
Home Satellite Earth Stations	5%
Laserdisk Players	1%

Source: Dataquest, EIA, Appliance Magazine

Worldwide Audio Equipment Production Forecast (Millions of Dollars)

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Audio Equipment	20,543	22,904	25,556	27,974	31,020	34,537	38,329	42,890	10.9%

Regional Share of Audio Equipment Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	3.2%	2.5%
Europe	6.5%	5.6%
Japan	29.1%	17.4%
Asia/Pacific - ROW	61.2%	74.5%
Total	100.0%	100.0%

North American Audio Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Compact disc player	33	41	50	62	76	94	115	136	22.1%
Radio	165	184	194	204	212	221	231	241	4.5%
Personal/Portable Stereo	33	35	36	39	42	45	47	49	6.4%
Stereo component	226	239	252	266	276	288	302	317	4.7%
Musical instrument	242	250	261	274	282	292	302	313	3.7%
Tape recorder	17	17	18	19	20	20	21	22	3.9%
Total	716	766	811	864	908	960	1,019	1,078	5.9%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

Worldwide Personal/Portable Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	114,525	119,062	123,792	128,787	134,099	139,763	145,264	150,984	4.1%
Factory ASP ($)	34	34	33	32	32	32	32	31	-1.2%
Factory Revenue ($M)	3,909	4,007	4,059	4,185	4,333	4,513	4,583	4,656	2.8%
S/C Content ($)	8	8	8	7	7	7	7	7	-2.0%
S/C TAM ($M)	874	917	933	963	998	1,035	1,031	1,028	2.0%

Regional Share of Personal/Portable Stereo Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	0.9%	1.1%
Europe	7.8%	7.5%
Japan	8.2%	4.7%
Asia/Pacific - ROW	83.2%	86.7%
Total	100.0%	100.0%

North American Personal/Portable Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	510	535	565	605	655	710	738	768	6.3%
Factory ASP ($)	65	65	64	64	64	64	64	64	0.0%
Factory Revenue ($M)	33	35	36	39	42	45	47	49	6.3%
S/C Content ($)	12	12	12	12	12	12	12	13	1.6%
S/C TAM ($M)	6	6	7	7	8	8	9	10	8.1%

United States Boombox Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	32.8%	34.4%
RCA	7.5%	7.1%
Magnavox	7.2%	7.0%
Sanyo	5.8%	6.1%
Panasonic	4.8%	4.8%
GE	4.8%	3.8%
GPX	4.7%	3.0%
Emerson	4.0%	2.7%
Sharp	3.9%	5.1%
JVC	3.0%	5.3%
Other	21.5%	20.7%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Boombox Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	33.6%	35.1%
Magnavox	7.9%	7.7%
RCA	7.8%	7.3%
Sanyo	5.8%	5.7%
Panasonic	4.8%	5.2%
GPX	4.4%	2.8%
GE	4.0%	3.6%
Sharp	3.7%	4.4%
Emerson	3.3%	2.5%
JVC	2.9%	5.5%
Other	21.8%	20.2%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States CD Player Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	27.3%	26.5%
Pioneer	10.5%	10.9%
Kenwood	7.9%	8.7%
Technics	7.4%	6.9%
RCA	6.5%	4.1%
JVC	6.1%	5.8%
Magnavox	4.7%	4.1%
Fisher	3.4%	5.1%
Panasonic	3.0%	2.2%
Radio Shack Brands	2.9%	2.9%
Other	20.3%	22.8%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States CD Player Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	25.8%	26.1%
Pioneer	11.6%	11.2%
Technics	8.2%	7.5%
Kenwood	7.0%	6.9%
JVC	6.4%	6.1%
RCA	6.2%	4.4%
Magnavox	4.0%	3.3%
Panasonic	3.7%	2.9%
Fisher	3.4%	5.4%
Radio Shack Brands	2.7%	3.5%
Other	21.0%	22.7%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Personal CD Player Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	44.7%	43.1%
RCA	10.3%	8.6%
Panasonic	8.6%	9.3%
Koss	4.6%	4.0%
Radio Shack Brands	3.8%	3.4%
Magnavox	3.7%	3.6%
Kenwood	3.5%	4.8%
JVC	2.8%	3.6%
Fisher	2.6%	3.7%
Sanyo	2.2%	1.7%
Other	13.2%	14.2%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Personal CD Player Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	45.1%	43.3%
RCA	11.0%	9.4%
Panasonic	10.0%	10.9%
Magnavox	4.2%	4.0%
Koss	4.0%	3.4%
Fisher	2.9%	4.7%
Sanyo	2.8%	2.3%
Radio Shack Brands	2.7%	2.4%
JVC	2.5%	3.1%
Kenwood	2.1%	2.9%
Other	12.7%	13.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Cassette Tape Deck Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	24.8%	27.7%
Pioneer	10.2%	10.1%
JVC	7.3%	7.2%
GE	6.8%	2.3%
Kenwood	6.3%	9.8%
Radio Shack Brands	6.0%	5.2%
Technics	5.0%	5.2%
Teac	3.4%	2.3%
Panasonic	3.3%	1.9%
Onkyo	2.8%	3.6%
Other	24.1%	24.7%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Cassette Tape Deck Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	23.4%	30.6%
Pioneer	11.3%	10.7%
Kenwood	6.3%	7.6%
JVC	5.5%	4.9%
Teac	5.3%	3.5%
GE	5.3%	1.8%
Technics	5.2%	5.2%
Radio Shack Brands	4.7%	3.9%
Panasonic	3.0%	2.0%
Onkyo	2.2%	2.1%
Other	27.8%	27.7%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Personal Tape Player Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	40.1%	46.5%
GE	12.7%	9.0%
Panasonic	7.2%	9.0%
GPX	6.4%	4.5%
Aiwa	4.2%	5.4%
Radio Shack Brands	3.8%	4.1%
Emerson	2.9%	1.9%
Sanyo	2.7%	2.3%
Philco	2.5%	1.8%
Lenoxx Sound	2.1%	1.0%
Other	15.4%	14.5%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Personal Tape Player Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	41.2%	47.8%
GE	12.0%	8.7%
Panasonic	6.5%	7.5%
GPX	5.4%	4.2%
Radio Shack Brands	4.6%	4.9%
Aiwa	4.5%	6.2%
Lenoxx Sound	2.9%	1.4%
Emerson	2.5%	1.7%
Philco	2.3%	1.4%
Sanyo	2.0%	1.7%
Other	16.1%	14.5%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Stereo Rack System Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	22.3%	24.0%
Fisher	8.3%	13.0%
Pioneer	8.1%	13.0%
Sharp	6.9%	4.9%
Soundesign	6.9%	2.8%
Technics	5.1%	9.3%
Aiwa	4.4%	3.6%
Magnavox	4.0%	1.7%
Panasonic	3.5%	2.8%
JVC	3.4%	4.1%
Other	27.1%	20.8%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Stereo Rack System Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	20.7%	23.6%
Pioneer	8.6%	12.8%
Soundesign	7.2%	4.2%
Fisher	7.0%	9.5%
Aiwa	6.9%	5.3%
Sharp	6.3%	4.5%
Technics	6.0%	10.2%
JVC	4.2%	5.3%
Panasonic	3.8%	3.8%
Magnavox	3.4%	1.7%
Other	25.9%	19.1%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Stereo Receiver Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	22.3%	21.2%
Pioneer	17.4%	16.0%
Kenwood	10.5%	9.9%
JVC	8.9%	6.4%
Technics	6.0%	4.9%
Onkyo	5.9%	7.8%
Radio Shack Brands	4.9%	5.1%
Denon	3.7%	5.4%
Yamaha	3.3%	4.4%
Fisher	3.1%	4.1%
Other	14.0%	14.8%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Stereo Receiver Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	24.2%	24.9%
Pioneer	17.0%	14.8%
JVC	10.6%	8.8%
Kenwood	9.4%	8.1%
Technics	7.3%	6.3%
Onkyo	5.6%	7.9%
Yamaha	3.5%	5.3%
Radio Shack Brands	3.0%	3.0%
Fisher	2.5%	2.6%
Denon	2.2%	3.9%
Other	14.7%	14.4%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Stereo Speaker Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Bose	17.9%	28.4%
Radio Shack Brands	10.0%	4.5%
Sony	9.1%	7.4%
Pioneer	8.6%	5.9%
KLH	5.9%	1.9%
Infinity	5.8%	8.1%
JBL	3.9%	5.0%
Yamaha	3.0%	1.6%
Advent	2.9%	2.3%
Technics	2.8%	1.1%
Other	30.1%	33.8%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Stereo Speaker Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Bose	17.6%	27.8%
Sony	9.2%	7.1%
Radio Shack Brands	8.3%	3.5%
KLH	7.4%	2.5%
Pioneer	6.5%	4.2%
Infinity	6.4%	8.6%
JBL	4.8%	5.7%
Yamaha	3.6%	2.1%
Technics	3.0%	1.3%
Advent	2.7%	2.6%
Other	30.5%	34.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

Worldwide Video Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Color TV	23,810	25,271	26,724	28,694	31,299	34,516	37,335	40,000	8.4%
VCR	11,241	11,184	11,567	11,375	11,467	11,891	12,303	12,885	2.2%
Digital Video Disk (DVD)	0	0	0	35	345	963	1,700	2,790	-
Camcorder	4,876	4,935	5,602	6,183	6,813	7,533	8,274	9,087	10.2%
Analog Set-Top Decoder	1,104	1,382	1,312	1,127	887	594	527	486	-18.0%
Digital Cable/Satellite Set-Top Interactiv	1	534	1,572	2,433	2,858	3,690	4,296	4,963	25.9%
Other Video	2,204	2,702	3,734	3,921	4,005	4,099	4,136	4,200	2.4%
Total	43,236	46,009	50,510	53,769	57,675	63,284	68,570	74,410	8.1%

Regional Share of Video Equipment Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	19.0%	17.3%
Europe	12.0%	15.6%
Japan	36.1%	26.8%
Asia/Pacific - ROW	32.9%	40.3%
Total	100.0%	100.0%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

North American Video Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Color TV	6,966	7,508	7,630	7,681	8,242	8,845	9,131	9,770	5.1%
VCR	70	107	74	155	203	265	306	311	33.1%
Camcorder	31	44	62	88	126	180	193	207	27.2%
Analog Cable/Satellite Set-Top Decoder	556	689	570	465	348	235	188	135	-25.0%
Digital Cable/Satellite Set-Top Decoder	0	521	1,252	1,583	1,486	1,610	1,875	2,424	14.1%
Total	7,622	8,869	9,588	9,973	10,405	11,134	11,692	12,847	6.0%

Worldwide Color Television Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	102,610	109,901	117,385	125,775	134,855	145,168	154,094	163,631	6.9%
Factory ASP ($)	232	230	228	228	232	238	242	244	1.4%
Factory Revenue ($M)	23,810	25,271	26,724	28,694	31,299	34,516	37,335	40,000	8.4%
S/C Content ($)	29	30	30	30	30	31	33	34	2.4%
S/C TAM ($M)	3,003	3,312	3,502	3,813	4,091	4,468	5,021	5,487	9.4%

Regional Share of Color Television Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	28.5%	24.4%
Europe	10.1%	9.4%
Japan	24.1%	22.8%
Asia/Pacific - ROW	37.3%	43.4%
Total	100.0%	100.0%

North American Color Television Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Color TV Only									
N.A. Units (K)	25,306	27,310	27,594	28,490	29,535	30,618	32,602	34,713	4.7%
Factory ASP $	318	292	294	287	294	294	294	294	0.0%
Factory Revenue ($M)	8,047	7,975	8,113	8,177	8,683	9,002	9,585	10,206	4.7%
TV/VCR Combo									
N.A. Units (K)	1,792	2,229	2,362	2,640	2,864	3,107	3,371	3,657	9.0%
Factory ASP $	368	350	344	337	333	331	330	330	-0.8%
Factory Revenue ($M)	659	780	819	890	954	1,029	1,112	1,207	8.1%

* Includes direct view stereo & non-stereo TVs. Does not include monochrome TV, color LCD TV, or projection TV

North American Color Television Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	20,656	22,043	22,857	23,009	23,857	24,735	26,467	28,319	4.4%
Factory ASP ($)	337	341	334	334	345	345	345	345	0.7%
Factory Revenue ($M)	6,966	7,508	7,630	7,681	8,242	8,845	9,131	9,770	5.1%
S/C Content ($)	29	29	29	29	30	30	30	30	0.9%
S/C TAM ($M)	597	645	657	663	713	742	794	850	5.3%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

North American Color Television Sales Mix, 1994 (Unit Basis)

Category	Percent
Q1 1994 through Q4 1994	
Under 18 Inches	19.9%
19 to 20 Inches	32.1%
25 to 27 Inches	37.4%
30 to 35 Inches	7.7%
Over 39 Inches	2.9%
Total	100.0%
Q3 1994 through Q2 1995	
Under 18 Inches	18.1%
19 to 20 Inches	31.2%
25 to 27 Inches	38.9%
30 to 35 Inches	8.5%
Over 39 Inches	3.2%
Total	100.0%
Q1 1994 through Q4 1994	
Color TV	86.0%
TV / VCR Combination	7.0%
Projection TV	2.2%
Other TV (LCD & Monochrome)	4.8%
Total	100.0%

** Source for Color Television by Size is: The Scout Report / The Polk Company

United States Color Television Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
RCA	16.1%	17.6%
Magnavox	15.0%	12.7%
Zenith	12.0%	13.0%
Sony	6.6%	9.0%
GE	6.6%	5.0%
Sharp	6.0%	3.7%
Sanyo	5.3%	3.3%
Emerson	5.0%	2.7%
Toshiba	3.1%	5.5%
Panasonic	2.9%	3.6%
Other	21.4%	23.9%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Color Television Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
RCA	16.2%	17.2%
Magnavox	16.1%	14.3%
Zenith	12.3%	12.8%
Sony	7.1%	9.4%
GE	6.3%	4.4%
Sharp	6.0%	3.8%
Sanyo	4.9%	3.0%
Emerson	4.4%	2.4%
Panasonic	3.5%	3.9%
Toshiba	3.3%	5.9%
Other	19.9%	22.9%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

Worldwide VCR Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	55,296	57,209	61,844	63,638	65,313	65,891	66,919	68,662	2.1%
Factory ASP ($)	203	196	187	179	176	180	184	188	0.1%
Factory Revenue ($M)	11,241	11,184	11,567	11,375	11,467	11,891	12,303	12,885	2.2%
S/C Content ($)	42	43	43	42	41	39	39	39	-2.1%
S/C TAM ($M)	2,333	2,470	2,656	2,657	2,667	2,585	2,579	2,654	0.0%

Regional Share of VCR Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	0.6%	2.4%
Europe	9.5%	14.5%
Japan	41.4%	11.0%
Asia/Pacific - ROW	48.4%	72.1%
Total	100.0%	100.0%

North American VCR Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
N.A. Units (K)	14,004	14,788	15,232	15,413	15,713	15,930	16,146	16,365	1.4%
Factory ASP $	229	218	206	195	192	195	197	200	-0.6%
Factory Revenue ($M)	3,207	3,224	3,138	3,005	3,017	3,106	3,181	3,273	0.8%

* Does not include TV/VCR Combos or Camcorders

North American VCR Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	302	469	325	673	871	1,127	1,183	1,243	30.7%
Factory ASP ($)	231	228	228	231	233	235	245	250	1.8%
Factory Revenue ($M)	70	107	74	155	203	265	306	311	33.1%
S/C Content ($)	31	31	31	32	33	33	33	34	1.5%
S/C TAM ($M)	9	15	10	22	28	37	39	42	32.8%

United States VCR Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
RCA	13.9%	14.6%
Magnavox	12.1%	11.4%
Emerson	8.0%	5.5%
Panasonic	7.7%	8.0%
GE	5.8%	5.0%
Zenith	5.3%	6.0%
JVC	5.0%	6.0%
Sony	4.7%	7.0%
Sharp	4.5%	4.1%
Goldstar	3.1%	2.4%
Other	29.9%	30.0%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States VCR Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
RCA	14.2%	14.9%
Magnavox	12.5%	11.8%
Panasonic	8.2%	8.6%
Emerson	8.0%	5.6%
GE	5.3%	4.6%
Zenith	5.0%	5.7%
Sharp	5.0%	4.5%
JVC	5.0%	6.1%
Sony	4.6%	6.7%
Goldstar	2.7%	2.2%
Other	29.5%	29.3%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

Worldwide Camcorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	8,566	9,433	11,396	13,300	15,147	17,224	19,465	21,997	14.1%
Factory ASP ($)	569	523	492	465	450	437	425	413	-3.4%
Factory Revenue ($M)	4,876	4,935	5,602	6,183	6,813	7,533	8,274	9,087	10.2%
S/C Content ($)	145	134	124	115	112	110	109	107	-2.8%
S/C TAM ($M)	1,246	1,260	1,409	1,533	1,698	1,890	2,113	2,363	10.9%

Regional Share of Camcorder Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	1.1%	2.3%
Europe	9.7%	11.5%
Japan	85.3%	77.1%
Asia/Pacific - ROW	3.9%	9.1%
Total	100.0%	100.0%

North American Camcorder Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
N.A. Units (K)	3,381	3,530	3,750	3,905	4,072	4,247	4,433	4,626	4.3%
Factory ASP $	611	600	586	570	550	535	520	515	-2.5%
Factory Revenue ($M)	2,066	2,118	2,198	2,226	2,240	2,272	2,305	2,383	1.6%

North American Camcorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	50	75	113	169	253	380	429	485	33.9%
Factory ASP ($)	611	581	552	524	498	473	449	427	-5.0%
Factory Revenue ($M)	31	44	62	88	126	180	193	207	27.2%
S/C Content ($)	92	87	85	84	84	85	85	86	0.0%
S/C TAM ($M)	5	7	10	14	21	32	36	41	34.0%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

United States Camcorder Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sony	26.4%	28.8%
RCA	16.1%	15.7%
Panasonic	14.7%	16.0%
JVC	8.8%	8.4%
Sharp	10.4%	10.5%
Magnavox	5.4%	4.3%
Hitachi	3.5%	4.1%
GE	4.6%	3.2%
Canon	2.7%	3.0%
LXI	2.0%	1.4%
Other	5.4%	4.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Camcorder Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sony	24.5%	26.8%
RCA	16.6%	16.2%
Panasonic	12.8%	13.4%
JVC	11.7%	11.5%
Sharp	11.1%	11.7%
Magnavox	4.8%	3.6%
Hitachi	4.5%	5.2%
GE	4.1%	2.8%
Canon	2.4%	2.6%
LXI	1.7%	1.2%
Other	5.8%	5.0%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

Worldwide HDTV Receiver Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	12	23	55	120	251	358	445	595	61.0%
Factory ASP ($)	8,000	6,000	4,000	3,500	3,100	2,800	2,600	2,700	-7.6%
Factory Revenue ($M)	96	138	220	420	778	1,002	1,157	1,607	48.8%
S/C Content ($)	700	540	450	400	363	340	315	300	-7.8%
S/C TAM ($M)	8.4	12.4	24.8	48.0	91.1	121.7	140.2	178.5	48.5%

North American HDTV Receiver Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 97-2000
Units (K)	0	0	0	0	1	8	15	35	227.1%
Factory ASP ($)	0	0	0	0	3,100	2,800	2,600	2,700	-4.5%
Factory Revenue ($M)	0	0	0	0	3	22	39	95	212.4%

North American HDTV Receiver Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 97-2000
Units (K)	0	0	0	0	1	8	15	35	227.1%
Factory ASP ($)	0	0	0	0	3,100	2,800	2,600	2,700	-4.5%
Factory Revenue ($M)	0	0	0	0	3	22	39	95	212.4%
S/C Content ($)	0	0	0	0	363	340	315	300	-6.2%
S/C TAM ($M)	0.0	0.0	0.0	0.0	0.4	2.7	4.7	10.5	207.0%

NA = Not Applicable

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

Worldwide Digital Video Disk (DVD) Preliminary Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	0	0	0	60	750	2,500	5,000	9,000	NM
Factory ASP ($)	0	0	0	575	460	385	340	310	NM
Factory Revenue ($M)	0	0	0	35	345	963	1,700	2,790	NM
S/C Content ($)	0	0	0	145	115	97	88	85	NM
S/C TAM ($M)	0	0	0	9	86	243	440	765	NM

NM = Not Meaningful

Worldwide Analog Cable/Satellite Set-Top Box Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	10,719	12,233	11,505	11,388	10,200	7,591	7,030	6,839	-9.9%
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0%
Factory Revenue ($M)	1,104	1,382	1,312	1,127	887	594	527	486	-18.0%
S/C Content ($)	42	46	47	41	38	35	32	30	-8.6%
S/C TAM ($M)	450.2	562.7	540.7	466.9	387.6	265.7	225.0	205.2	-17.6%

North American Analog Cable/Satellite Set-Top Box Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	5,400	6,100	5,000	4,700	4,000	3,000	2,500	1,900	-17.6%
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0%
Factory Revenue ($M)	556	689	570	465	348	235	188	135	-25.0%

North American Analog Cable/Satellite Set-Top Box Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	5,400	6,100	5,000	4,700	4,000	3,000	2,500	1,900	-17.6%
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0%
Factory Revenue ($M)	556	689	570	465	348	235	188	135	-25.0%
S/C Content ($)	42	46	47	41	38	35	32	30	-8.6%
S/C TAM ($M)	226.8	280.6	235.0	192.7	152.0	105.0	80.0	57.0	-24.7%

Worldwide Digital Cable and Satellite Decoder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Cable Converters									
Units (K)	0	7	77	260	907	2,580	5,300	8,000	153.1%
Factory ASP ($)	0	528	499	442	386	323	280	259	-12.3%
Factory Revenue ($M)	0	4	38	115	351	834	1,485	2,069	121.9%
S/C Content ($)	0	236	204	183	177	172	168	160	-4.7%
S/C TAM ($M)	0	2	16	48	160	444	889	1,282	141.1%
Satellite Converters									
Units (K)	1	1,205	3,350	5,656	6,901	9,510	10,490	11,400	27.8%
Factory ASP ($)	900	440	458	410	363	300	268	254	-11.1%
Factory Revenue ($M)	1	530	1,533	2,318	2,508	2,855	2,811	2,894	13.6%
S/C Content ($)	400	223	210	196	187	179	172	165	-4.7%
S/C TAM ($M)	0	269	702	1,107	1,291	1,702	1,803	1,880	21.8%

NA = Not Applicable

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

North American Digital Cable and Satellite Decoder Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Cable Converters									
Units (K)	0	5	47	60	107	250	1,500	3,500	136.8%
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1%
Factory Revenue ($M)	0	2	20	23	37	70	375	840	110.5%
Satellite Converters									
Units (K)	0	1,190	2,850	4,000	4,200	5,500	6,000	6,600	18.3%
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1%
Factory Revenue ($M)	0	519	1,231	1,560	1,449	1,540	1,500	1,584	5.2%

North American Digital Cable and Satellite Decoder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Cable Converters									
Units (K)	0	5	47	60	107	250	1,500	3,500	136.8%
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1%
Factory Revenue ($M)	0	2	20	23	37	70	375	840	110.5%
S/C Content ($)	0	222	207	194	182	171	162	154	-5.7%
S/C TAM ($M)	0	1	10	12	19	43	243	539	123.2%
Satellite Converters									
Units (K)	0	1,190	2,850	4,000	4,200	5,500	6,000	6,600	18.3%
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1%
Factory Revenue ($M)	0	519	1,231	1,560	1,449	1,540	1,500	1,584	5.2%
S/C Content ($)	0	222	207	194	182	171	162	154	-5.7%
S/C TAM ($M)	0	264	590	776	764	941	972	1,016	11.5%

Preliminary Worldwide Digital Cable and Satellite Decoder Revenue Market Share, 1995

Vendor	% Revenue Market Share
Thomson	50.2%
General Instrument	35.9%
Sony	12.0%
Pioneer	1.2%
Apple	0.3%
AT&T	0.2%
Others	0.2%
Total	100.0%

Worldwide Video Game Controller Production Forecast*

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	27,641	15,472	15,859	13,532	11,500	13,572	16,266	18,197	2.8%
Factory ASP ($)	94	102	152	172	211	227	197	187	4.3%
Factory Revenue ($M)	2,605	1,584	2,404	2,323	2,422	3,075	3,196	3,405	7.2%
S/C Content ($)	34	45	87	105	136	150	131	124	7.3%
S/C TAM ($M)	945	698	1,384	1,419	1,560	2,030	2,128	2,253	10.2%

* Including Handhelds

Worldwide Video Game Controller Unit Shipment Forecast, by Type(Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
8-Bit Players	1,110	400	280	182	0	0	0	0	-100.0%
16-Bit Players	18,710	8,860	6,202	4,341	1,954	781	469	328	-44.5%
32 / 64-Bit / Future RISC Players	100	1,237	4,802	6,809	8,886	12,791	15,797	17,869	30.1%
TV CD-ROM Players	1,525	860	120	0	0	0	0	0	-100.0%
Handheld Players	6,196	4,115	4,455	2,200	660	0	0	0	-100.0%
Total	27,641	15,472	15,859	13,532	11,500	13,572	16,266	18,197	2.8%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

Regional Share of Video Game Controller Production Revenue (Percentage)

Region	Percentage 1995	2000
North America	0.4%	0.3%
Europe	0.0%	0.0%
Japan	76.3%	19.7%
Asia/Pacific - ROW	23.3%	80.0%
Total	100.0%	100.0%

North American Video Game Controller Production Forecast*

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	65	65	80	80	80	85	92	101	4.8%
Factory ASP ($)	135	129	123	118	114	109	105	101	-3.8%
Factory Revenue ($M)	9	8	10	9	9	9	13	10	0.8%
S/C Content ($)	42	40	38	37	35	34	33	33	-2.8%
S/C TAM ($M)	3	3	3	3	3	3	4	3	1.9%

* Including Handhelds

Worldwide Video Game Cartridge Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Units (K)	135,884	114,077	104,896	100,879	95,210	106,998	141,713	190,107	12.6%
Factory ASP ($)	26	23	25	27	28	32	33	34	6.7%
Factory Revenue ($M)	3,536	2,676	2,591	2,729	2,704	3,382	4,651	6,480	20.1%
S/C Content ($)	9	9	9	10	10	11	11	11	4.9%
S/C TAM ($M)	1,223	1,003	926	979	980	1,132	1,544	2,134	18.2%

Regional Share of Video Game Cartridge Production Revenue (Percentage)

Region	Percentage 1995	2000
North America	0.0%	0.0%
Europe	0.0%	0.0%
Japan	32.4%	0.8%
Asia/Pacific - ROW	67.6%	99.2%
Total	100.0%	100.0%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

Worldwide Video Game Market Share, 1994

Vendor	% Unit Market Share	% Revenue Market Share
16-Bit Players		
Nintendo	52.5%	52.5%
Sega	46.5%	46.5%
Others	1.0%	1.0%
Total	100.0%	100.0%
32 / 64-Bit Players		
Sega	37.5%	23.5%
Panasonic / 3DO	30.9%	42.3%
Sony	22.5%	27.4%
Atari	3.8%	2.9%
Others	5.3%	4.0%
Total	100.0%	100.0%
Handheld Players		
Nintendo	60.8%	39.8%
Sega	36.5%	56.0%
Atari	0.4%	0.4%
Others	2.4%	3.7%
Total	100.0%	100.0%
TV CD-ROM Players		
Philips CD-I	78.8%	78.8%
Tandy VIS	1.5%	1.5%
Others	19.7%	19.7%
Total	100.0%	100.0%

North American Revenue from Production of Cameras, Watches, and Clocks (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Cameras	24	25	27	28	29	29	30	30	2.4%
Watches	110	115	120	127	131	136	142	148	4.2%
Clocks	60	62	66	69	72	75	78	81	4.3%
Total	194	202	213	224	232	241	251	259	4.0%

Worldwide Appliance Production Forecast (Millions of Dollars)

Revenue	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Appliances	46,616	51,564	57,250	59,608	63,486	67,136	72,039	77,391	6.2%

Regional Share of Appliance Production Revenue (Percentage)

	Percentage	
Region	1995	2000
North America	27.0%	22.6%
Europe	22.3%	18.9%
Japan	33.9%	36.7%
Asia/Pacific - ROW	16.8%	21.8%
Total	100.0%	100.0%

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

North American Appliance Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Range & Oven (Gas & Electric)	1,154	1,239	1,286	1,324	1,372	1,400	1,466	1,515	3.3%
Microwave Oven	574	627	657	688	713	734	764	795	3.9%
Clothes Washer & Dryer	3,518	3,724	3,879	3,842	3,997	4,036	4,233	4,343	2.3%
Dishwasher	1,168	1,284	1,341	1,376	1,434	1,439	1,538	1,595	3.5%
Refrigerator	5,228	5,606	5,792	5,693	5,872	6,018	6,357	6,519	2.4%
Room Air Conditioner	2,027	2,463	2,515	2,428	2,528	2,559	2,689	2,735	1.7%
Total	13,669	14,942	15,470	15,351	15,917	16,186	17,047	15,987	0.7%

North American Appliance Market Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Range & Oven (Gas & Electric)	7,390	7,843	7,636	7,700	7,816	7,972	8,091	8,172	1.4%
Microwave Oven	8,945	9,844	9,697	9,862	10,059	10,260	10,465	10,674	1.9%
Clothes Washer	7,472	7,739	7,484	7,613	7,803	8,014	8,214	8,379	2.3%
Clothes Dryer	5,581	5,873	5,623	5,768	5,941	6,132	6,316	6,473	2.9%
Dishwasher	4,509	5,038	4,847	4,956	5,129	5,334	5,521	5,703	3.3%
Refrigerator	8,920	9,517	9,384	9,486	9,676	9,918	10,116	10,319	1.9%
Freezer	1,767	1,860	1,843	1,867	1,904	1,952	1,991	2,030	2.0%
Room Air Conditioner	3,384	4,532	4,697	4,389	4,301	4,344	4,388	4,432	-1.2%
Total	47,968	52,246	51,211	51,641	52,629	53,925	55,102	56,183	1.9%

United States Microwave Oven Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sharp	22.9%	22.2%
GE	15.5%	20.6%
Panasonic	10.4%	8.9%
Sears / Kenmore	9.9%	9.7%
Tappan	6.3%	5.8%
Whirlpool	4.8%	6.7%
Goldstar	4.8%	3.6%
Magic Chef	4.6%	2.9%
Emerson	4.1%	2.5%
Samsung	3.7%	2.4%
Other	13.0%	14.7%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Microwave Oven Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sharp	23.8%	23.8%
GE	14.0%	17.9%
Sears / Kenmore	9.8%	9.5%
Panasonic	9.5%	8.5%
Tappan	6.0%	5.6%
Whirlpool	5.4%	7.4%
Magic Chef	5.3%	3.6%
Emerson	4.7%	2.6%
Goldstar	4.5%	3.5%
Samsung	3.9%	2.8%
Other	13.1%	14.8%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

Source: Dataquest (December 1995)

CONSUMER APPLICATION MARKETS

United States Refrigerator Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	19.4%	20.2%
GE	18.0%	20.1%
Whirlpool	13.5%	14.0%
Amana	13.3%	14.5%
Hotpoint	6.0%	4.8%
Frigidaire	5.6%	4.9%
Admiral	3.1%	2.6%
KitchenAid	3.0%	3.8%
Maytag	2.8%	3.4%
Magic Chef	2.7%	2.1%
Other	12.6%	9.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Refrigerator Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	19.2%	20.2%
GE	18.9%	20.6%
Whirlpool	12.8%	13.1%
Amana	12.1%	13.6%
Frigidaire	6.3%	5.4%
Hotpoint	5.6%	4.6%
Maytag	3.9%	4.5%
KitchenAid	3.1%	3.7%
Admiral	2.9%	2.7%
Magic Chef	2.5%	2.0%
Other	12.7%	9.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Dishwasher Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	20.6%	19.9%
Maytag	19.5%	21.4%
GE	18.8%	18.3%
Whirlpool	17.1%	16.2%
KitchenAid	8.6%	11.3%
Hotpoint	3.4%	2.5%
Frigidaire	2.9%	2.5%
Magic Chef	1.4%	1.1%
Tappan	1.3%	0.9%
White / Westinghouse	1.1%	0.8%
Other	5.3%	5.1%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Dishwasher Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	21.8%	21.3%
Maytag	19.4%	21.2%
GE	18.0%	18.1%
Whirlpool	15.1%	14.3%
KitchenAid	9.8%	12.3%
Hotpoint	3.4%	2.4%
Frigidaire	2.9%	2.6%
Tappan	1.7%	1.3%
Magic Chef	1.5%	1.3%
White / Westinghouse	1.4%	1.0%
Other	5.0%	4.2%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Clothes Washer Brand Share Leaders, Q1 1994 through Q1 1994

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	26.6%	26.8%
Whirlpool	20.4%	20.2%
Maytag	15.7%	18.4%
GE	11.6%	10.7%
Hotpoint	4.1%	3.4%
Amana	3.9%	3.9%
Frigidaire	2.8%	2.7%
White / Westinghouse	2.7%	2.7%
Roper	2.3%	1.8%
KitchenAid	1.8%	1.9%
Other	8.1%	7.5%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Clothes Washer Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	28.7%	28.7%
Whirlpool	20.1%	20.0%
Maytag	15.7%	18.3%
GE	9.3%	8.6%
Amana	4.3%	4.4%
Hotpoint	3.5%	2.9%
Roper	3.1%	2.4%
White / Westinghouse	2.9%	2.7%
Frigidaire	2.4%	2.3%
KitchenAid	1.9%	2.1%
Other	8.1%	7.6%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Clothes Dryer Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	27.7%	27.6%
Whirlpool	19.0%	19.4%
Maytag	14.5%	17.5%
GE	14.4%	13.2%
Hotpoint	4.0%	3.5%
Amana	3.0%	2.9%
White / Westinghouse	3.1%	2.8%
Roper	2.5%	2.1%
Frigidaire	2.3%	2.1%
Speed Queen	1.8%	1.9%
Other	7.5%	7.0%
Total	99.8%	100.0%

Source: The Scout Report / The Polk Company

United States Clothes Dryer Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	29.0%	28.9%
Whirlpool	19.6%	20.3%
Maytag	13.9%	16.7%
GE	13.2%	12.0%
Hotpoint	3.5%	2.9%
Amana	3.0%	2.9%
Roper	2.6%	2.2%
Frigidaire	2.6%	2.2%
White / Westinghouse	2.6%	2.1%
Speed Queen	1.4%	1.5%
Other	8.6%	8.3%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Room Air Conditioner Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	16.4%	17.2%
Fedders	14.1%	12.0%
Whirlpool	11.4%	11.5%
GE	10.3%	9.8%
Amana	5.9%	6.2%
Carrier	5.8%	6.0%
White / Westinghouse	5.5%	4.9%
Emerson	4.5%	4.8%
Friedrich	4.1%	5.7%
Frigidaire	4.0%	4.6%
Other	18.0%	17.3%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

CONSUMER APPLICATION MARKETS

United States Room Air Conditioner Brand Share Leaders, Q3 1994 through Q2 1995

Brand	% Unit Market Share	% Revenue Market Share
Sears / Kenmore	18.9%	19.1%
Fedders	16.6%	14.9%
Whirlpool	10.7%	10.8%
GE	9.4%	9.1%
Carrier	6.4%	7.5%
Amana	6.1%	6.1%
Frigidaire	5.4%	5.9%
White / Westinghouse	4.7%	3.7%
Emerson	4.6%	4.8%
Friedrich	4.3%	5.9%
Other	12.9%	12.2%
Total	100.0%	100.0%

Source: The Scout Report / The Polk Company

United States Electric Range Market Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share
GE	39%
Electrolux (Frigidaire)	19%
Whirlpool	19%
Maytag (Magic Chef, Hardwick, Jenn Ai	13%
Raytheon (Caloric)	6%
Brown	2%
Peerless Premier	1%
Others	1%
Total	100%

Source: Appliance Magazine

United States Gas Range Brand Share Leaders, Q1 1994 through Q4 1994

Brand	% Unit Market Share
GE (Roper)	25%
Electrolux (Frigidaire)	24%
Maytag (Magic Chef, Hardwick, Jenn Ai	24%
Raytheon (Caloric)	20%
Brown	3%
Peerless Premier	3%
Others	1%
Total	100%

Source: Appliance Magazine

Worldwide Revenue from Production of Other Consumer Equipment (Millions of Dollars)

Revenue	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Other Consumer Equipment	12,310	13,623	16,262	17,215	18,518	19,598	20,543	22,313	6.5%

North American Revenue from Production of Other Consumer Equipment (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 95-2000
Automatic garage door opener	352	411	435	464	485	510	537	562	5.3%
Other	944	983	1,026	1,075	1,107	1,145	1,186	1,226	3.6%
Total	1,296	1,394	1,461	1,539	1,592	1,655	1,723	1,788	4.1%

Top OEMs in Home Security Systems

Honeywell
Black & Decker
Sony
Audiovox
Yale

Source: Dataquest (December 1995)

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Global Market Insight for Information Technology Companies



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Dataquest Catalyst Programs

Cross-Functional Insight for:
- Financial Service Providers
- Government Agencies
- IT Business Strategy and Planning Organizations
- Publishing, Media, and Consulting Firms
- IS and Purchasing Organizations
- IT Supporting Organizations

Emerging Markets

Central and Eastern European Markets
- Printers
- Personal Computers

Information Technology Market Opportunities
- China
- Asia/Pacific
- Latin America

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February 8, 1996

Errata

In Dataquest's Semiconductor Application Markets Worldwide Market Trends document ("Consumer Electronics Semiconductor Application Markets," SAMM-WW-MT-9506), Figure 4-13 was incorrect. Please place the attached correction in your Semiconductor Application Markets Worldwide binder.

Dataquest regrets the inconsistency and apologizes for any inconvenience. For further information, contact Senior Industry Analyst Dale Ford at (408) 468-8311 or at dford@dataquest.com.

SEMICONDUCTOR APPLICATIONS WORLDWIDE 1995

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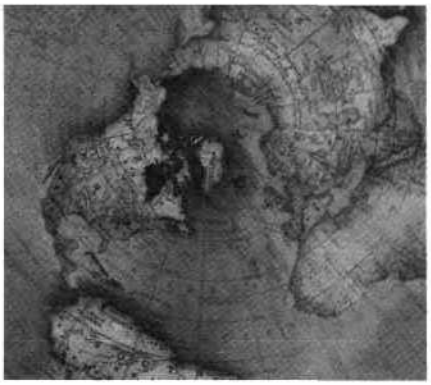
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Market Analysis

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Consumer Electronics Semiconductor Application Markets



Market Trends

Program: Semiconductor Application Markets Worldwide
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Consumer Electronics Semiconductor Application Markets



Market Trends

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Chapter 1
Introduction

This document is the sixth in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, wireline communications, wireless communications, consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analysts: Dale Ford and Mark Gaare

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Chapter 2
Executive Summary

The consumer electronic equipment market represents a significant opportunity for semiconductor applications (see Figure 2-1 and Table 2-1 for our forecast for consumer electronic equipment production). While the worldwide market for consumer electronic equipment is projected to have a compound annual growth rate (CAGR) of 7.7 percent for the next five years, the semiconductor market for consumer electronic products will have a CAGR of more than 15 percent in this same time frame (see Figure 2-2). This difference is driven by the digitization of consumer products from VCRs to dishwashers. New products being introduced—high-definition television (HDTV), digital VCRs, video-CD and digital video disc (DVD) products, MiniDisc (MD) and digital compact cassette (DCC) players, digital cable/satellite set-top boxes, and interactive video games—are boosting the opportunities for semiconductor products.

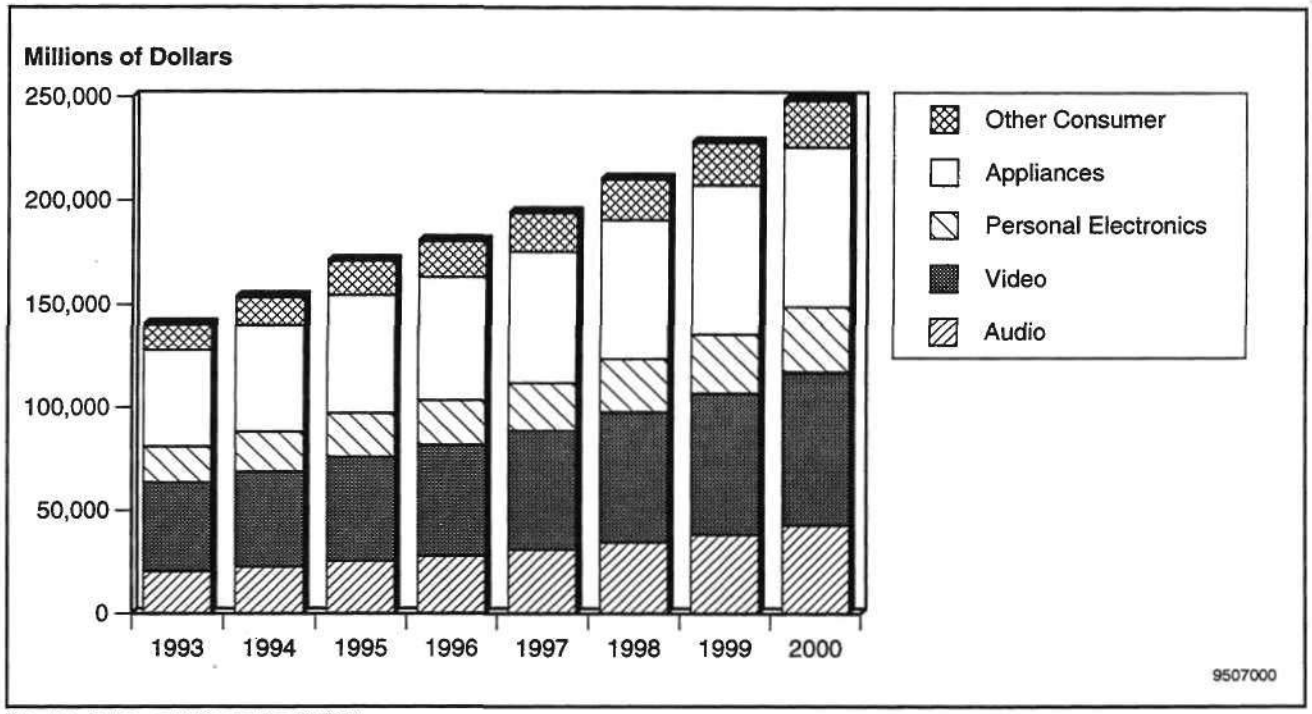
This worldwide trend is accentuated in the North American production arena. Table 2-2 and Figure 2-3 show that consumer electronic equipment production in North America will grow by 3.9 percent CAGR through 1998. However, semiconductor consumption for the consumer equipment production will grow by 19.2 percent CAGR at the same time (see Figure 2-4). The importance of the consumer electronics market is even greater in Japan and the Asia/Pacific region than in North America. Figure 2-5 shows that over 70 percent of consumer electronics production takes place in these regions.

Figure 2-6 shows one measure of the increasing opportunities in the consumer market and provides a forecast of the number of microcontroller ICs used in the home, automobile, and office. The commanding share forecast for the home by the year 2000 is driven by consumer products found in almost every room in the house, as shown in the list in the same figure. Figure 2-7 provides an overview of the penetration of major consumer electronics products into U.S. homes. Although some products, such as televisions, have reached near saturation, other products, such as camcorders, still have room for significant expansion. The market for high-penetration products such as TVs is mainly found in replacements and upgrades. New technology developments targeted at existing products will drive an increase in upgrades of these products.

Several new exciting products will take the stage in consumer electronics markets during the next five years. This report will provide information on many of these new products.

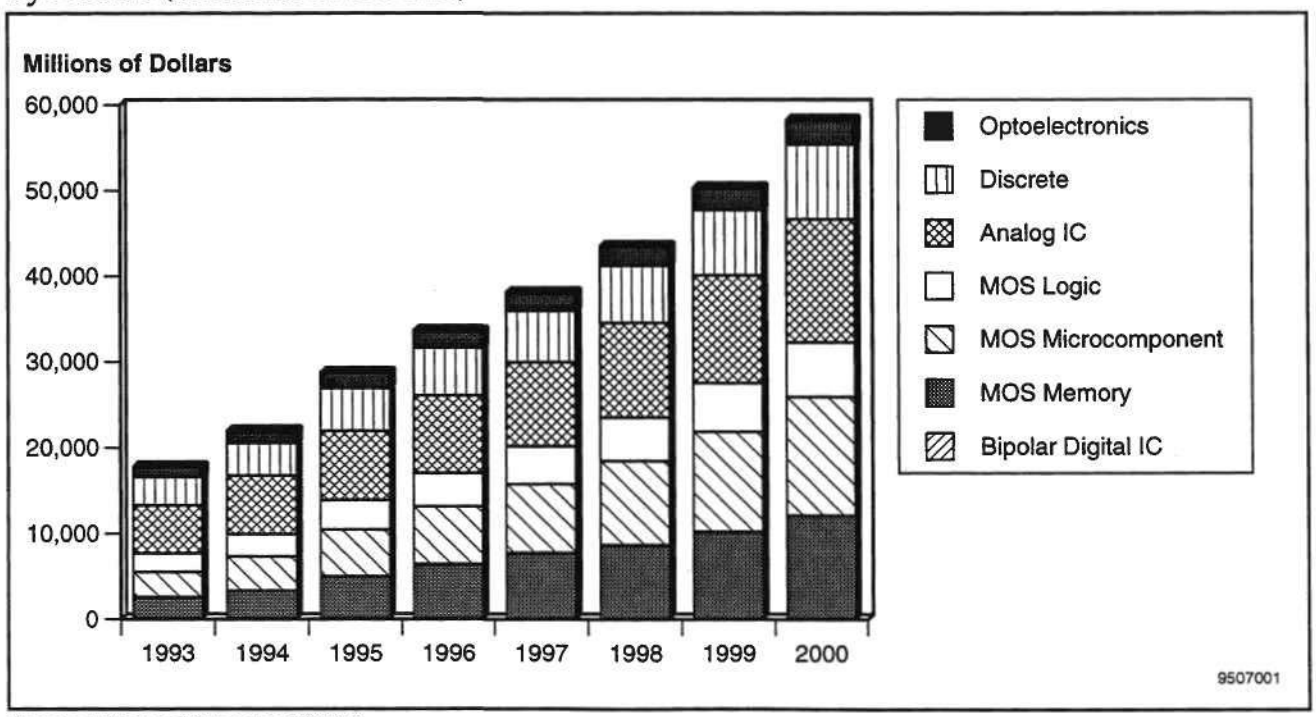
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Figure 2-1
Worldwide Consumer Electronic Equipment Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Figure 2-2
Worldwide Semiconductor Consumption for Consumer Equipment Production, by Device (Millions of Dollars)



Source: Dataquest (December 1995)

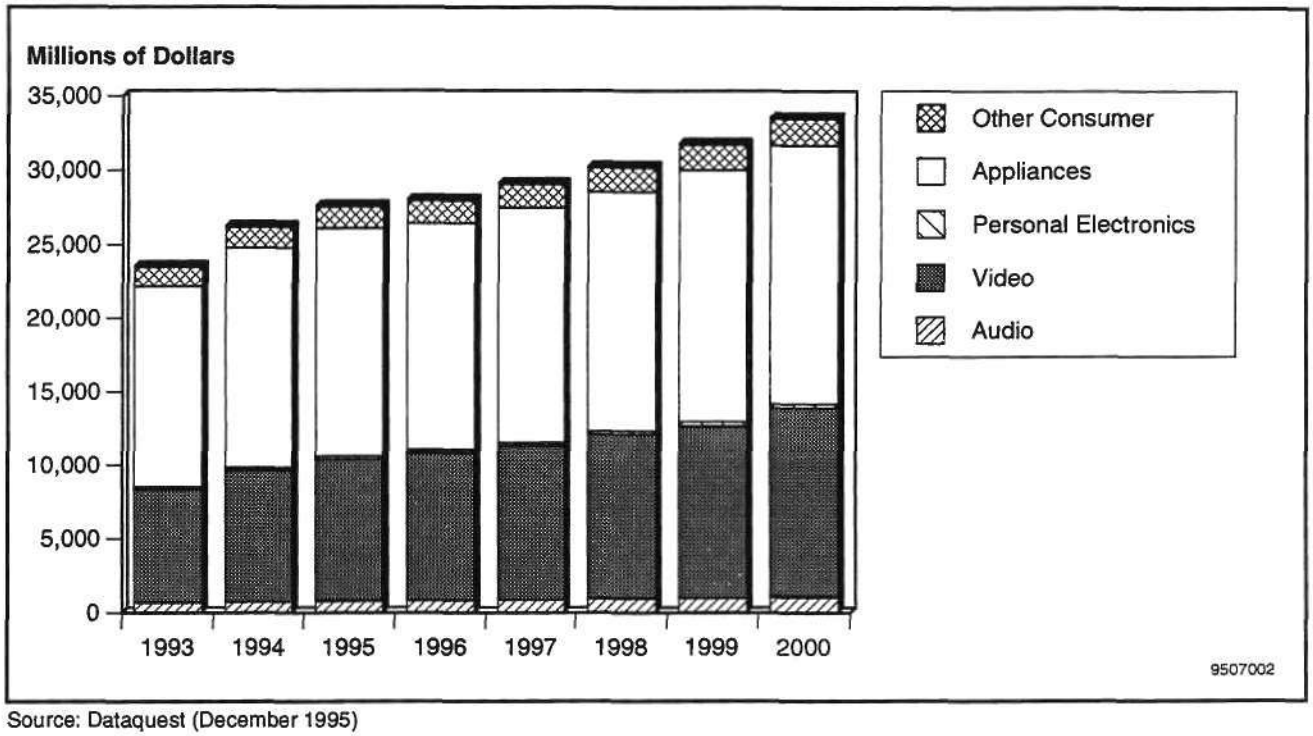
Table 2-1
Worldwide Consumer Electronic Equipment Production Revenue Forecast
(Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Audio	20,543	22,904	25,556	27,974	31,020	34,537	38,329	42,890	10.9
Video	43,236	46,009	50,510	53,769	57,675	63,284	68,570	74,410	8.1
Personal Electronics	17,433	19,286	21,110	21,669	23,203	25,698	28,617	31,489	8.3
Appliances	46,616	51,564	57,250	59,608	63,486	67,136	72,039	77,391	6.2
Other Consumer	12,310	13,623	16,262	17,215	18,518	19,598	20,543	22,313	6.5
Total	142,132	155,379	172,682	182,232	195,899	212,251	230,097	250,494	7.7

Source: Dataquest (December 1995)

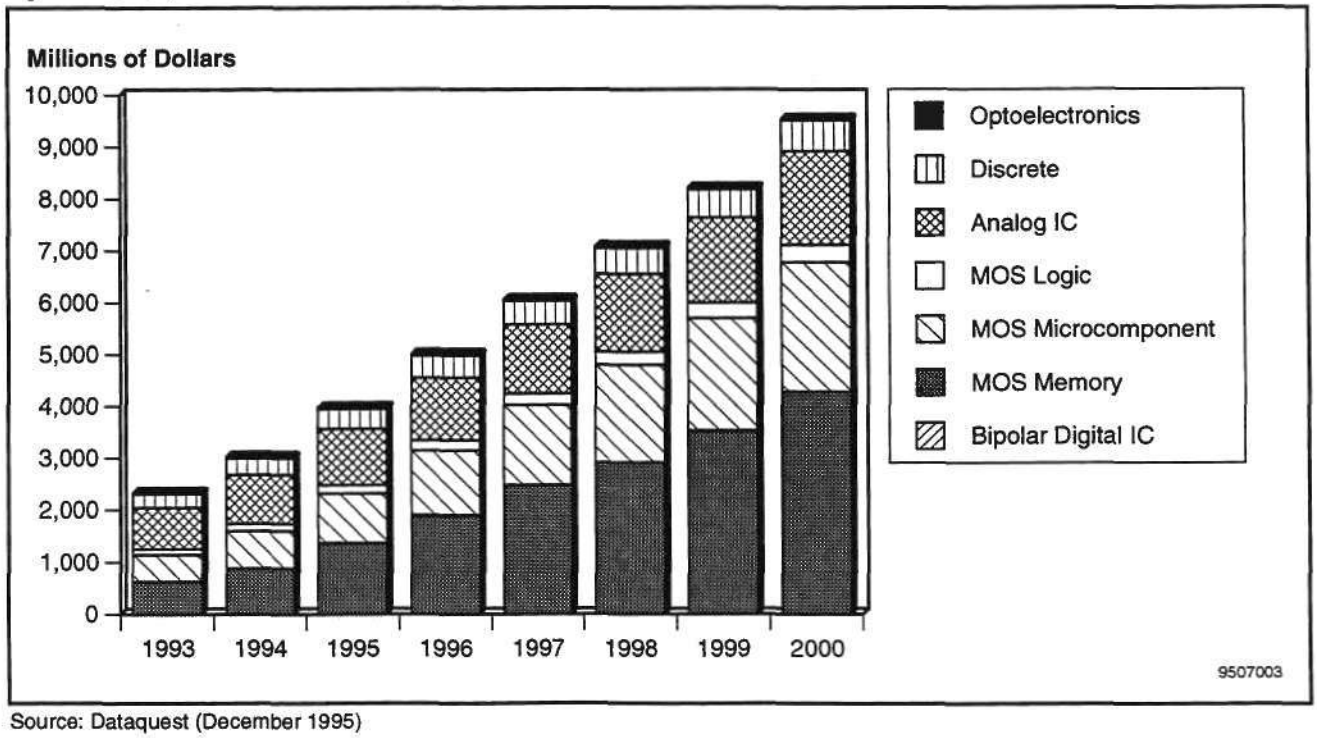
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Figure 2-3
North American Consumer Electronic Equipment Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Figure 2-4
North American Semiconductor Consumption for Consumer Equipment Production, by Device (Millions of Dollars)



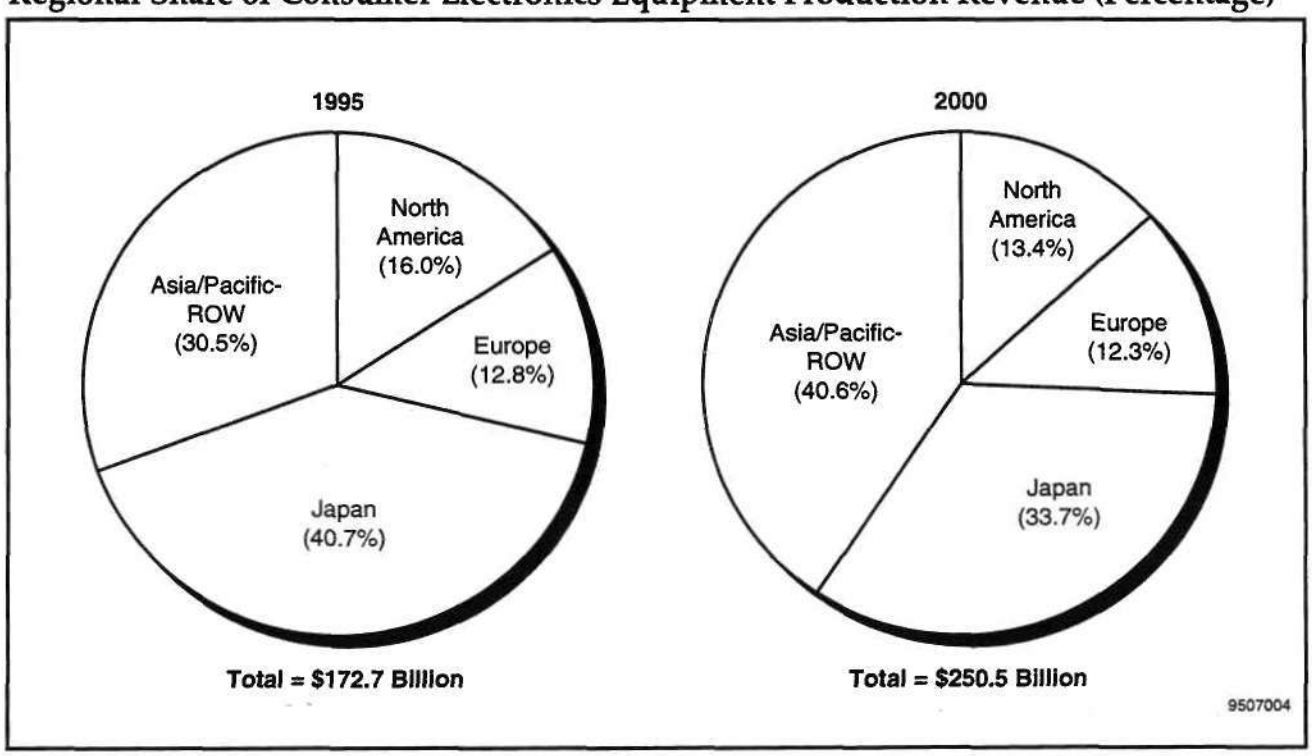
Source: Dataquest (December 1995)

Table 2-2
North American Consumer Electronic Equipment Production Revenue Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Audio	716	766	811	864	908	960	1,019	1,078	5.9
Video	7,622	8,869	9,588	9,973	10,405	11,134	11,692	12,847	6.0
Personal Electronics	203	210	223	233	241	250	264	276	4.4
Appliances	13,669	14,942	15,470	15,351	15,917	16,186	17,047	17,502	2.5
Other Consumer	1,296	1,395	1,461	1,539	1,593	1,655	1,724	1,798	4.2
Total	23,507	26,182	27,552	27,960	29,063	30,185	31,745	33,502	4.0

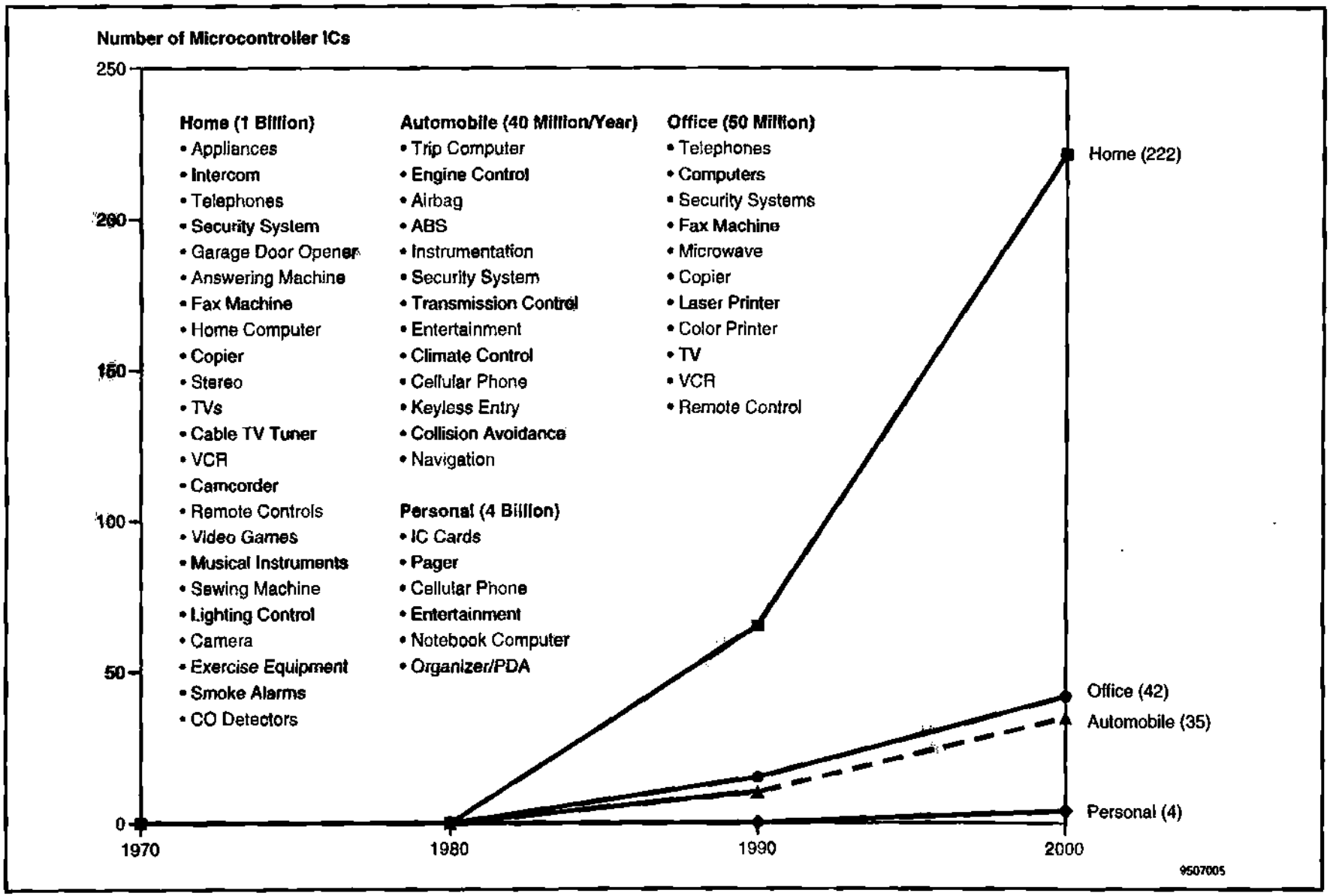
Source: Dataquest (December 1995)

Figure 2-5
Regional Share of Consumer Electronics Equipment Production Revenue (Percentage)



Source: Dataquest (December 1995)

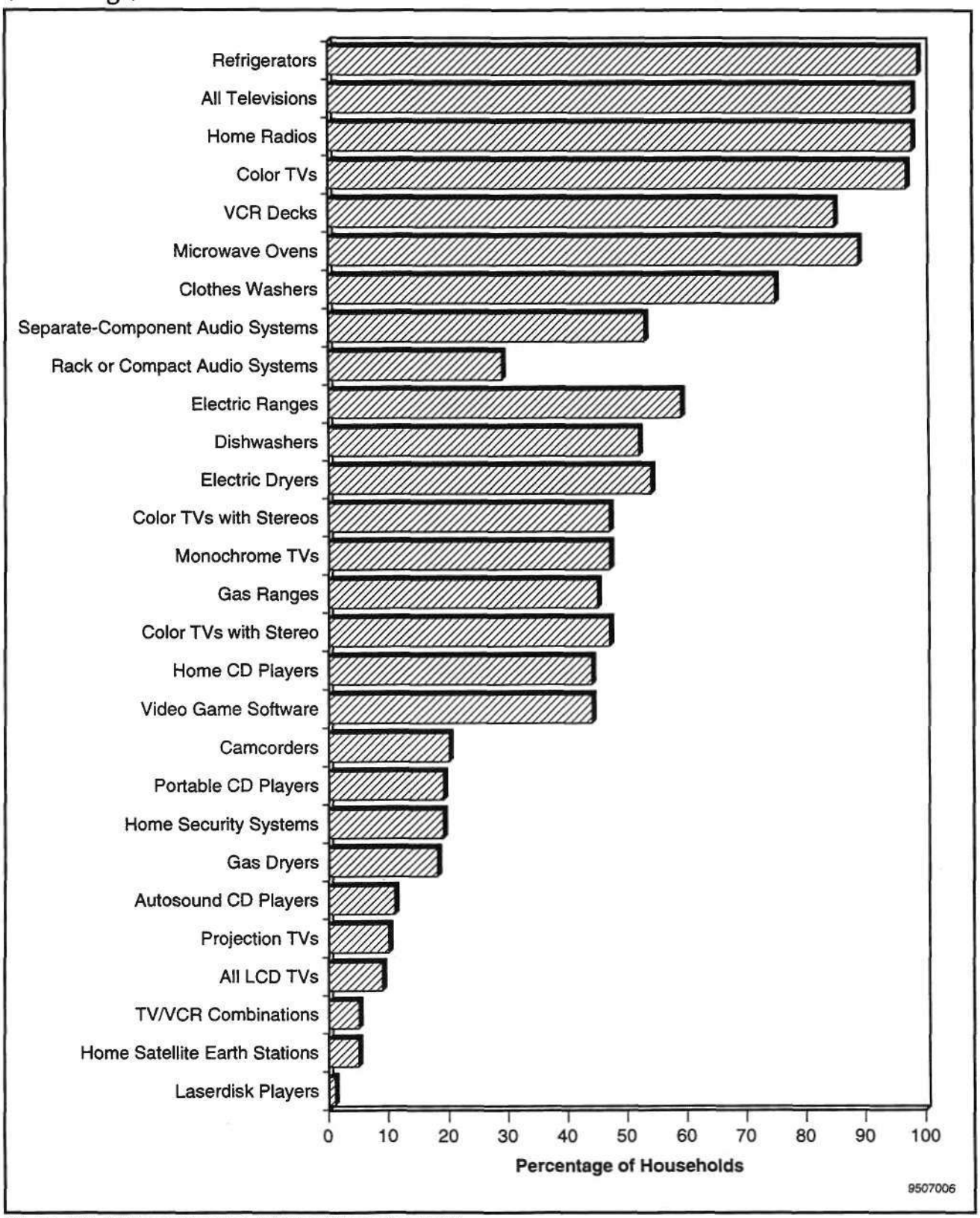
Figure 2-6
Microcontroller Penetration of the Home and Consumer Markets



Source: Motorola (December 1995)

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Figure 2-7
U.S. Household Penetration of Consumer Electronics Products, January 1994 (Percentage)



Source: EIA, Appliance Magazine, Dataquest (December 1995)

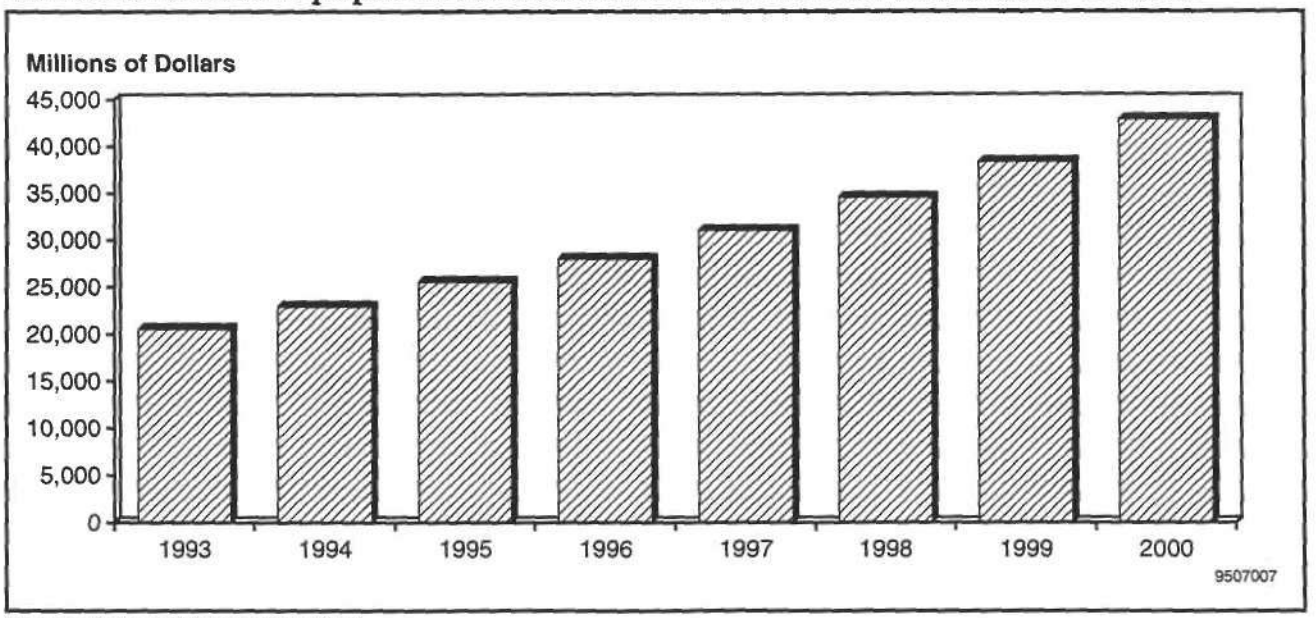
Chapter 3
Audio Equipment

Worldwide audio equipment production is expected to grow at a healthy 10.9 percent CAGR through 2000 (see Figure 3-1). Audio systems sales in the United States will help drive this growth, thanks to growing replacement sales and growing demand for step-up products. An example of this is the changer-equipped CD systems that are replacing single-CD systems. Figure 3-2 illustrates the commanding role the Asia/Pacific region will play in audio products, with more than 60 percent of production taking place there by 2000. Table 3-1 shows North American production of audio products. Major audio electronics manufacturers with U.S. facilities include Emerson Radio, Pioneer Electronics, Sanyo, Tandy, and Toshiba.

Portable products and digital technology are having the most significant impact on the audio electronics market. The Sony Walkman concept first applied to cassette players has continued into products such as personal CD players and personal portable stereos, or boom boxes. New products such as the MD and the DCC represent a combination of digital and portability features. As the various brand share tables in this chapter show, Sony plays a commanding role in every segment of the audio electronic equipment market. The only segment where it does not command a leading share is stereo speakers. Bose is the leader in this category, but even here Sony captured the No. 3 slot in 1994.

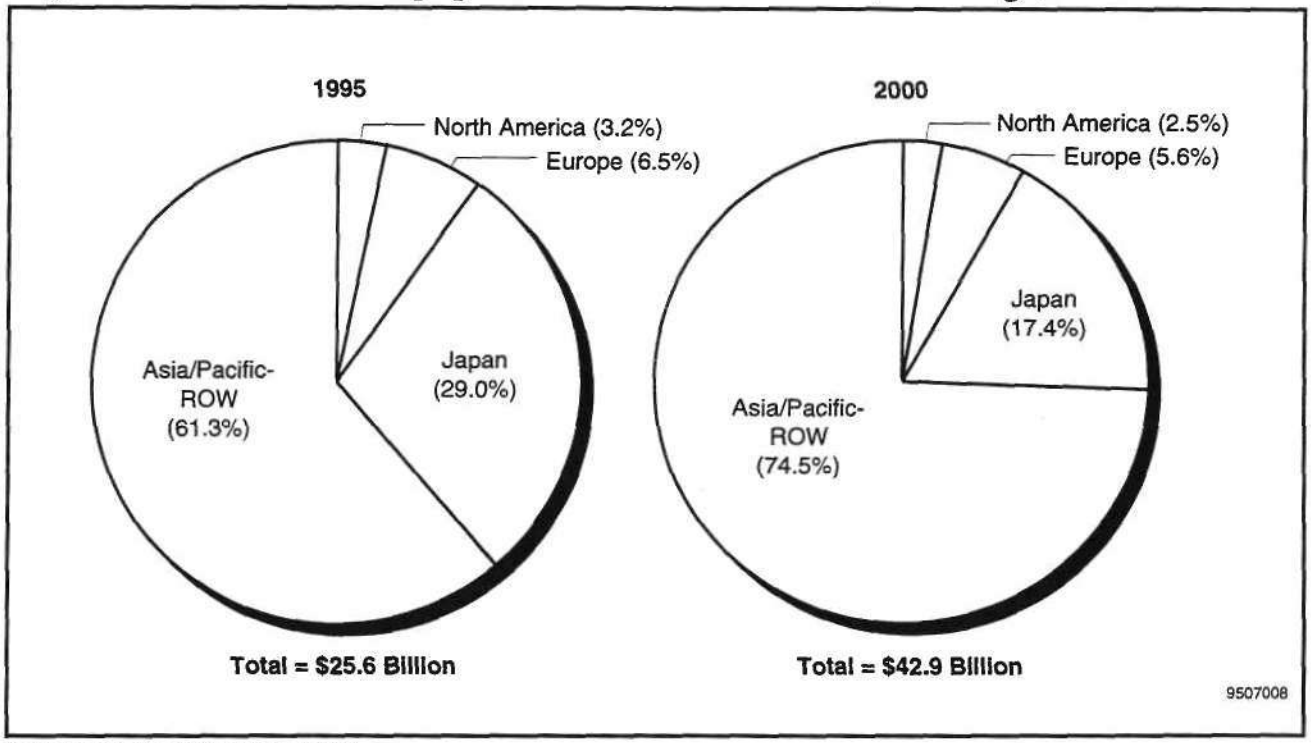
This chapter will present a worldwide production forecast for personal portable stereos and a discussion of the MD and DCC players. Brand share information is also presented for other major audio products.

Figure 3-1
Worldwide Audio Equipment Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Figure 3-2
Regional Share of Audio Equipment Production Revenue (Percentage)



Source: Dataquest (December 1995)

Table 3-1
North American Audio Equipment Production Revenue Forecast (Millions of Dollars)

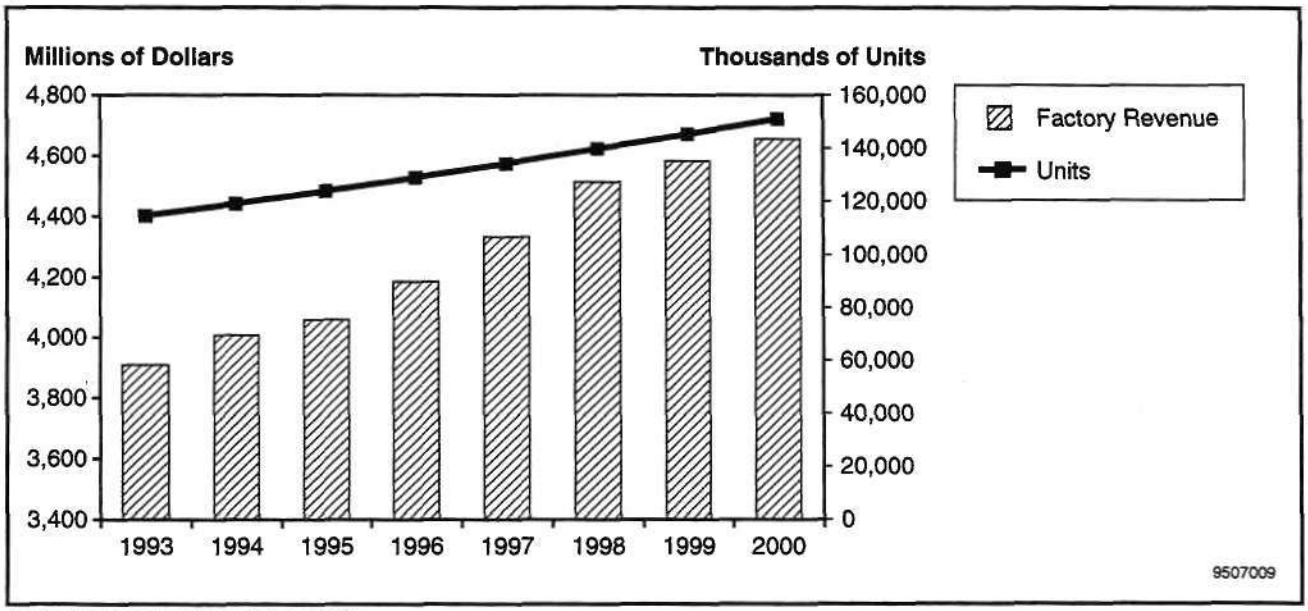
Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Compact Disc Player	33	41	50	62	76	94	115	136	22.1
Radio	165	184	194	204	212	221	231	241	4.5
Personal/Portable Stereo	33	35	36	39	42	45	47	49	6.4
Stereo Component	226	239	252	266	276	288	302	317	4.7
Musical Instrument	242	250	261	274	282	292	302	313	3.7
Tape Recorder	17	17	18	19	20	20	21	22	3.9
Total	716	766	811	864	908	960	1,019	1,078	5.9

Source: Dataquest (December 1995)

Personal/Portable Stereos (Boom Boxes and Headsets)

Figure 3-3 and Table 3-2 show the worldwide production forecast for personal/portable stereos. Although these systems represent a high-volume opportunity, the growth in revenue will remain very low. Figure 3-4 provides a regional breakout of personal/portable stereo production. The dominance of the Asia/Pacific region in production of personal/portable stereos will increase through 2000, reaching 87 percent of worldwide production. Table 3-3 lists the North American production forecast for personal/portable stereos. Sony commanded more than 30 percent of the U.S. market in 1994 for boom boxes (see Tables 3-4 and 3-5).

Figure 3-3
Worldwide Personal/Portable Stereo Production Revenue and Unit Shipment Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

CD Players

Beyond personal CD players, much of the growth in the CD player market is driven by upgrades to the new CD-changer players that accommodate multiple CDs. Tables 3-6 and 3-7 show brand share leaders for CD players in the United States.

Personal CD Players

Tables 3-8 and 3-9 list U.S. brand share leaders in personal CD players.

MiniDisc (MD) Players

Sony's latest plunge into the consumer market is the MD, Sony's replacement for the analog cassette, in terms of recordability, portability, and sonic fidelity. MD is similar to a standard compact disc (CD) player in looks and features but offers much improved portability and the ability to record at slightly less than CD quality. Sony concedes the product is not intended to replace today's CD but to be its portable counterpart. MD uses a compression technique known as Adaptive Transform Acoustic Coding (ATRAC) to fit 74 minutes of near CD-quality music on a 2.5-inch optical disc. ATRAC is designed to remove frequencies the human ear is less sensitive to and therefore least likely to notice missing. Shockproofing is achieved by incorporating a RAM buffer. If the laser does mistrack during play, the music will continue to flow for up to 10 seconds, which is good for mobile applications.

Although the early shipments were swept off shelves quickly, demand for the first-generation devices has quickly dropped. Low demand has limited the entrance of new companies to the market and the introduction of new models by existing players. To date, at least 14 electronics companies have acquired MD manufacturing licenses from Sony, including Sharp,

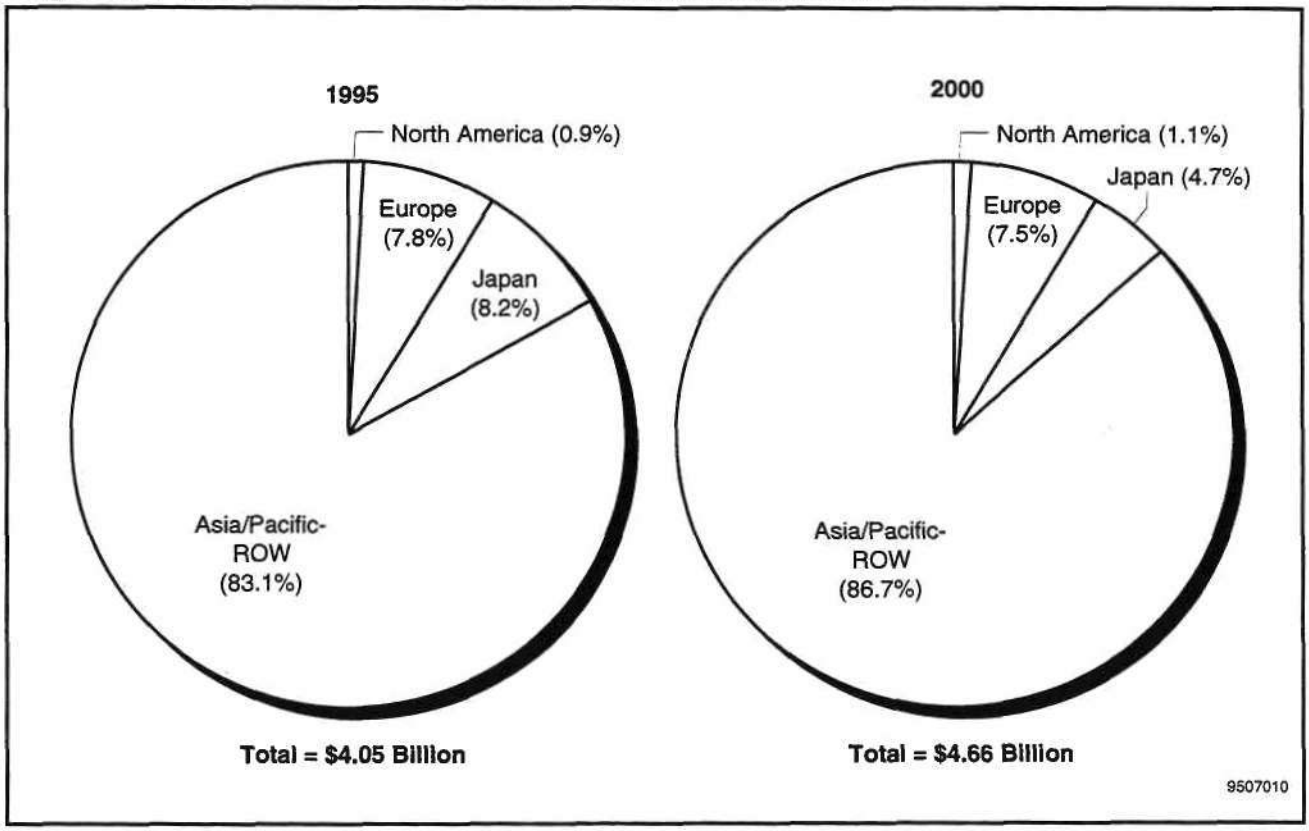
Table 3-2
Worldwide Personal/Portable Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	114,525	119,062	123,792	128,787	134,099	139,763	145,264	150,984	4.1
Factory ASP ($)	34	34	33	32	32	32	32	31	-1.2
Factory Revenue ($M)	3,909	4,007	4,059	4,185	4,333	4,513	4,583	4,656	2.8
Semiconductor Content ($)	8	8	8	7	7	7	7	7	-2.0
Semiconductor TAM ($M)	874	917	933	963	998	1,035	1,031	1,028	2.0

Source: Dataquest (December 1995)

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Figure 3-4
Regional Share of Personal/Portable Stereo Production Forecast



Source: Dataquest (December 1995)

Table 3-3
North American Personal/Portable Stereo Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	510	535	565	605	655	710	738	768	6.3
Factory ASP ($)	65	65	64	64	64	64	64	64	0
Factory Revenue ($M)	33	35	36	39	42	45	47	49	6.3
Semiconductor Content ($)	12	12	12	12	12	12	12	13	1.6
Semiconductor TAM ($M)	6	6	7	7	8	8	9	10	8.1

Source: Dataquest (December 1995)

Kenwood, Sansui, Clarion, Aiwa, RCA, and Sanyo. In September 1995, Matsushita began selling a MiniDisc portable audio player. Matsushita's entry is significant because it was one of the original developers of the rival audio format called digital compact cassettes (DCC). Sony currently dominates the market for MD products with more than 50 percent of the market. However, in September, Sharp estimated that shipments of its MD products to Japan would reach 1.2 million units in 1995, quadrupling its shipments for 1994. Retailers report that play/record portables are outselling their play-only counterparts by at least 3:1.

Table 3-4
U.S. Boom Box Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	32.8	34.4
RCA	7.5	7.1
Magnavox	7.2	7.0
Sanyo	5.8	6.1
Panasonic	4.8	4.8
General Electric	4.8	3.8
GPX	4.7	3.0
Emerson	4.0	2.7
Sharp	3.9	5.1
JVC	3.0	5.3
Others	21.5	20.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-5
U.S. Boom Box Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	33.6	35.1
Magnavox	7.9	7.7
RCA	7.8	7.3
Sanyo	5.8	5.7
Panasonic	4.8	5.2
GPX	4.4	2.8
General Electric	4.0	3.6
Sharp	3.7	4.4
Emerson	3.3	2.5
JVC	2.9	5.5
Others	21.8	20.2
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Cassette Tape Decks

Tables 3-10 and 3-11 list the brand share leaders for cassette tape decks in the United States.

Personal Tape Players

Tables 3-12 and 3-13 list the brand share leaders in the United States.

Table 3-6
U.S. CD Player Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	27.3	26.5
Pioneer	10.5	10.9
Kenwood	7.9	8.7
Technics	7.4	6.9
RCA	6.5	4.1
JVC	6.1	5.8
Magnavox	4.7	4.1
Fisher	3.4	5.1
Panasonic	3.0	2.2
Radio Shack Brands	2.9	2.9
Others	20.3	22.8
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-7
U.S. CD Player Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	25.8	26.1
Pioneer	11.6	11.2
Technics	8.2	7.5
Kenwood	7.0	6.9
JVC	6.4	6.1
RCA	6.2	4.4
Magnavox	4.0	3.3
Panasonic	3.7	2.9
Fisher	3.4	5.4
Radio Shack Brands	2.7	3.5
Others	21.0	22.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-8
U.S. Personal CD Player Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	44.7	43.1
RCA	10.3	8.6
Panasonic	8.6	9.3
Koss	4.6	4.0
Radio Shack Brands	3.8	3.4
Magnavox	3.7	3.6
Kenwood	3.5	4.8
JVC	2.8	3.6
Fisher	2.6	3.7
Sanyo	2.2	1.7
Others	13.2	14.2
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-9
U.S. Personal CD Player Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	45.1	43.3
RCA	11.0	9.4
Panasonic	10.0	10.9
Magnavox	4.2	4.0
Koss	4.0	3.4
Fisher	2.9	4.7
Sanyo	2.8	2.3
Radio Shack Brands	2.7	2.4
JVC	2.5	3.1
Kenwood	2.1	2.9
Others	12.7	13.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-10
U.S. Cassette Tape Deck Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	24.8	27.7
Pioneer	10.2	10.1
JVC	7.3	7.2
General Electric	6.8	2.3
Kenwood	6.3	9.8
Radio Shack Brands	6.0	5.2
Technics	5.0	5.2
Teac	3.4	2.3
Panasonic	3.3	1.9
Onkyo	2.8	3.6
Others	24.1	24.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-11
U.S. Cassette Tape Deck Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	23.4	30.6
Pioneer	11.3	10.7
Kenwood	6.3	7.6
JVC	5.5	4.9
Teac	5.3	3.5
General Electric	5.3	1.8
Technics	5.2	5.2
Radio Shack Brands	4.7	3.9
Panasonic	3.0	2.0
Onkyo	2.2	2.1
Others	27.8	27.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

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Table 3-12
U.S. Personal Tape Player Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	40.1	46.5
General Electric	12.7	9.0
Panasonic	7.2	9.0
GPX	6.4	4.5
Aiwa	4.2	5.4
Radio Shack Brands	3.8	4.1
Emerson	2.9	1.9
Sanyo	2.7	2.3
Philco	2.5	1.8
Lenoxx Sound	2.1	1.0
Others	15.4	14.5
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-13
U.S. Personal Tape Player Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	41.2	47.8
General Electric	12.0	8.7
Panasonic	6.5	7.5
GPX	5.4	4.2
Radio Shack Brands	4.6	4.9
Aiwa	4.5	6.2
Lenoxx Sound	2.9	1.4
Emerson	2.5	1.7
Philco	2.3	1.4
Sanyo	2.0	1.7
Others	16.1	14.5
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Digital Compact Cassette (DCC) Players

DCCs were developed by Philips and Matsushita and are designed to replace the analog cassette as a home recording device. DCC provides backward compatibility, which allows the large installed base of analog cassettes to be played on the new machines. DCC achieves its sound quality by using Precision Adaptive Subband Coding (PASC), a compression scheme that enables near-CD-quality audio to be encoded on tape traveling at the same speed as required by an analog tape transport system. A thin-film head is used for digital recording and playback for both digital and analog. DCC is an innovative product, but it suffers from perceptions in the market that consider tape or "contact-based" mediums to be inferior to "noncontact-based" mediums such as discs. Even though DCC edges out MD in terms of sonic integrity (it sounds better), MD has been more successful. Philips has lowered the price on its DCC products in an attempt to boost sales, which have not met expectations. Only 150,000 units were sold in 1993. In addition to those from Philips, DCC decks are available under the Panasonic, Tandy, and Magnavox brand names.

Stereo Rack Systems

Tables 3-14 and 3-15 list the brand share leaders for stereo rack systems in the United States.

Stereo Receivers

Tables 3-16 and 3-17 list the brand share leaders for stereo receivers in the United States.

Table 3-14
U.S. Stereo Rack System Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	22.3	24.0
Fisher	8.3	13.0
Pioneer	8.1	13.0
Sharp	6.9	4.9
Soundesign	6.9	2.8
Technics	5.1	9.3
Aiwa	4.4	3.6
Magnavox	4.0	1.7
Panasonic	3.5	2.8
JVC	3.4	4.1
Others	27.1	20.8
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-15
U.S. Stereo Rack System Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	20.7	23.6
Pioneer	8.6	12.8
Soundesign	7.2	4.2
Fisher	7.0	9.5
Aiwa	6.9	5.3
Sharp	6.3	4.5
Technics	6.0	10.2
JVC	4.2	5.3
Panasonic	3.8	3.8
Magnavox	3.4	1.7
Others	25.9	19.1
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-16
U.S. Stereo Receiver Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	22.3	21.2
Pioneer	17.4	16.0
Kenwood	10.5	9.9
JVC	8.9	6.4
Technics	6.0	4.9
Onkyo	5.9	7.8
Radio Shack Brands	4.9	5.1
Denon	3.7	5.4
Yamaha	3.3	4.4
Fisher	3.1	4.1
Others	14.0	14.8
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-17
U.S. Stereo Receiver Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	24.2	24.9
Pioneer	17.0	14.8
JVC	10.6	8.8
Kenwood	9.4	8.1
Technics	7.3	6.3
Onkyo	5.6	7.9
Yamaha	3.5	5.3
Radio Shack Brands	3.0	3.0
Fisher	2.5	2.6
Denon	2.2	3.9
Others	14.7	14.4
Total	100.0	100.0

Source: The Scout Report®The Polk Company

Stereo Speakers

Main driving forces behind the growth of the stereo speaker industry are audio-for-video and new designs for speakers-specific applications. The home theater concept, where consumers want speakers to faithfully reproduce movie soundtracks, is a high-end example of this. Speaker designs are taking into account the different demands for movie soundtrack reproduction and music reproduction. Some systems incorporate a switch that allows the user to select the desired music or soundtrack mode. Tables 3-18 and 3-19 list the U.S. brand share leaders in this market.

Table 3-18
U.S. Stereo Speaker Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Bose	17.9	28.4
Radio Shack Brands	10.0	4.5
Sony	9.1	7.4
Pioneer	8.6	5.9
KLH	5.9	1.9
Infinity	5.8	8.1
JBL	3.9	5.0
Yamaha	3.0	1.6
Advent	2.9	2.3
Technics	2.8	1.1
Others	30.1	33.8
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 3-19
U.S. Stereo Speaker Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Bose	17.6	27.8
Sony	9.2	7.1
Radio Shack Brands	8.3	3.5
KLH	7.4	2.5
Pioneer	6.5	4.2
Infinity	6.4	8.6
JBL	4.8	5.7
Yamaha	3.6	2.1
Technics	3.0	1.3
Advent	2.7	2.6
Others	30.5	34.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Chapter 4
Video Equipment

Video equipment is positioned in the consumer market as entertainment equipment, and together with audio equipment has been serving as a market and technology driver for the electronics equipment and semiconductor industries. In particular, it has spurred the development and commercialization of numerous production technologies and systems, which have also promoted the growth of industries that supply necessary components and materials.

Home use of entertainment equipment assures wide market penetration because it is less affected or impeded by social and cultural barriers. Video equipment demand potentially covers the entire world and grows with the economic development in each country. At the same time, establishment of video equipment production bases in the areas offering low-cost labor has helped expand regional economies, which in turn has created the economic base that stimulates video equipment demand.

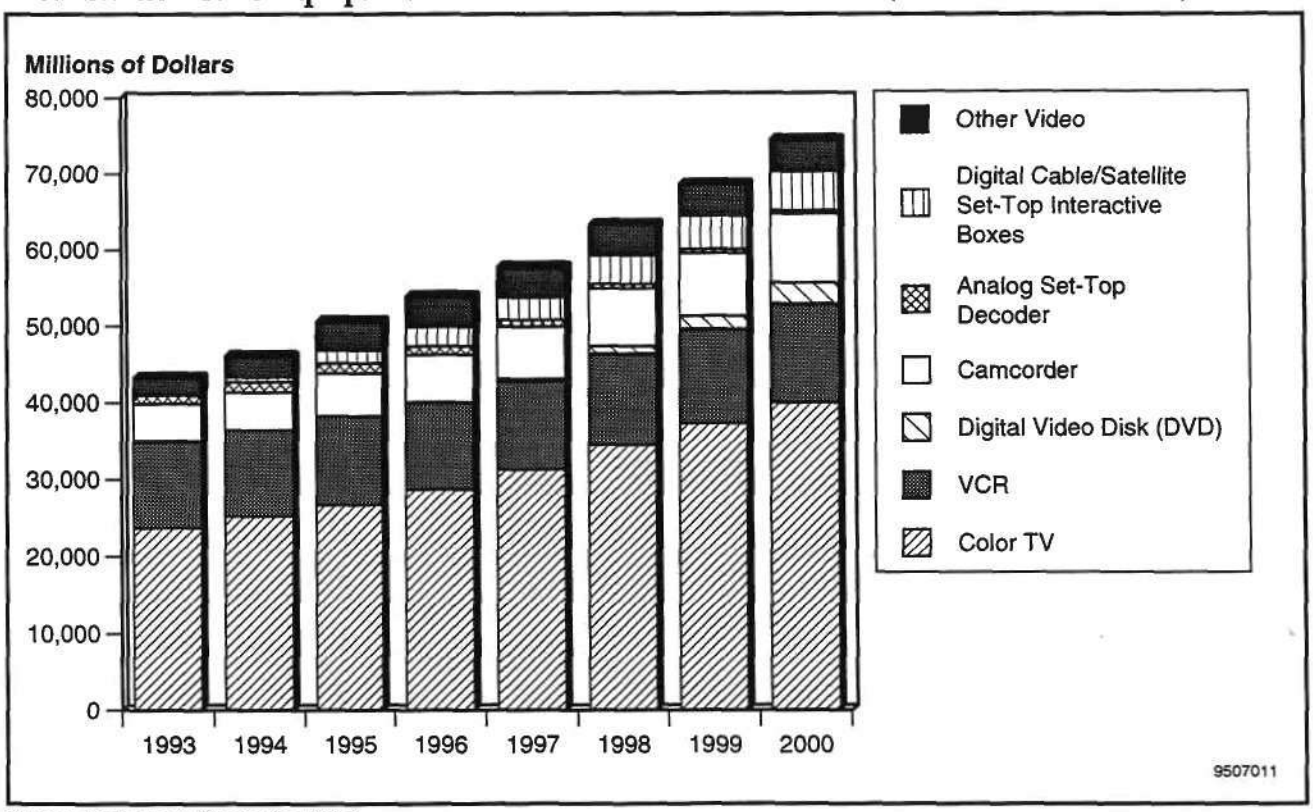
Figure 4-1 and Table 4-1 show the anticipated worldwide growth forecast of video equipment production. The CAGR for the next five years in video equipment is expected to be 8.0 percent. Particularly strong growth is anticipated in digital set-top boxes, with 25 percent CAGR forecast growth. Japan will be displaced as the leading producer of video equipment as production locations shift to the Asia/Pacific region: 40.4 percent of video equipment production will take place in the Asia/Pacific region by 2000 (see Figure 4-2). The forecast for North American video equipment production is given in Figure 4-3 and Table 4-2. Although color televisions represent the dominant slice of revenue production in North America, new technology developments are pushing production rates of VCRs, camcorders, and set-top boxes at much higher levels. The "Other Video" equipment category includes items such as video-CD players, LCD TV, black-and-white TV, and emerging products. Table 4-3 lists major North American video research and design and manufacturing locations.

Major announcements related to video R&D and manufacturing investments in North America include the following:

- JVC selected Tijuana, Mexico, as the location for a new North American color TV manufacturing facility. The new factory will have the capacity to turn out 10,000 20-inch and 27-inch color TVs monthly and will also feed chassis to the color TV assembly facility in Elmwood Park, New Jersey. Output is scheduled to begin in spring 1996.
- Mitsubishi announced plans to build a television R&D center in Orange County, California.
- Philips Consumer Electronics will add complete new production lines at its facility in Ottawa, Ohio, to give it the capacity to turn out 500,000 32-inch tubes and 300,000 35-inch tubes annually. The 32-inch production is expected to begin in summer 1996 and 35-inch production in 1997.

- Sanyo Video Components completed a $25 million expansion with the opening of its second plant in Tijuana, Mexico. The expansion tripled Sanyo's local production capacity for audio-video parts. The new facility can produce 3 million flyback transformers and 2.5 million tuners annually. The first plant, which opened in 1993, produces about 6 million deflection yokes a year.
- Thomson Consumer Electronics has begun expansion of its color TV and picture tube operations in North America. It plans to spend $52 million to expand capacity at its picture tube plant in Marion, Indiana. The company recently boosted production of 25-inch color tubes. The new expansion will increase production of 31-inch and 35-inch tubes by 20 percent and allow for start-up of production of 32-inch tubes. The plant currently produces 4 million of Thomson's total U.S. output of 6.5 million tubes. Thomson will also invest $2 million to double the production capacity of projection TVs at its main color TV manufacturing site in Bloomington, Indiana.
- LG Electronics, formerly known as Goldstar, acquired a 57.5 percent interest in Zenith in 1995. Part of the LG Electronics investment will enable Zenith to make improvements such as upgrading its Melrose, Illinois, and Mexico picture tube plants.

Figure 4-1
Worldwide Video Equipment Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

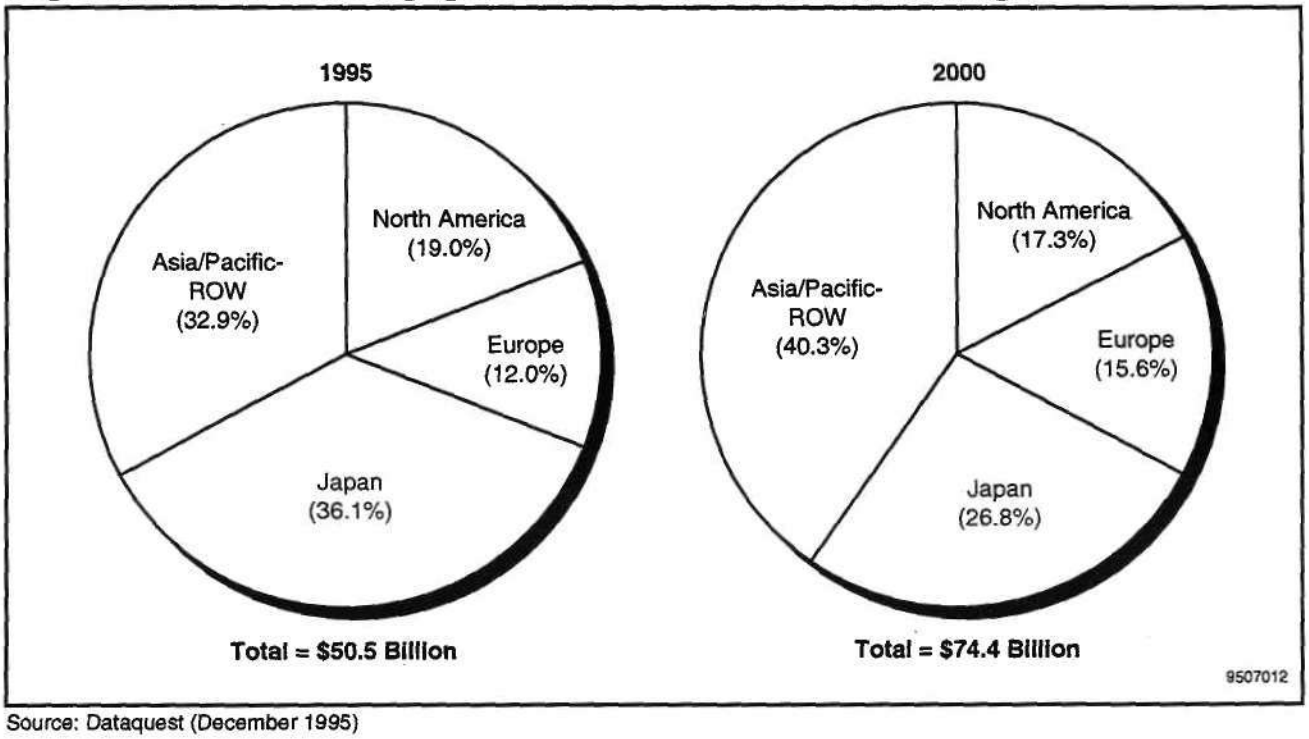
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Table 4-1
Worldwide Video Equipment Production Revenue Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Color TV	23,810	25,271	26,724	28,694	31,299	34,516	37,335	40,000	8.4
VCR	11,241	11,184	11,567	11,375	11,467	11,891	12,303	12,885	2.2
Digital Video Disc (DVD)	0	0	0	35	345	963	1,700	2,790	-
Camcorder	4,876	4,935	5,602	6,183	6,813	7,533	8,274	9,087	10.2
Analog Set-Top Decoder	1,104	1,382	1,312	1,127	887	594	527	486	-18.0
Digital Cable/Satellite Set-Top Interactive Boxes	1	534	1,572	2,433	2,858	3,690	4,296	4,963	25.9
Other Video	2,204	2,702	3,734	3,921	4,005	4,099	4,136	4,200	2.4
Total	43,236	46,009	50,510	53,769	57,675	63,284	68,570	74,410	8.1

Source: Dataquest (December 1995)

Figure 4-2
Regional Share of Video Equipment Production Revenue (Percentage)



Source: Dataquest (December 1995)

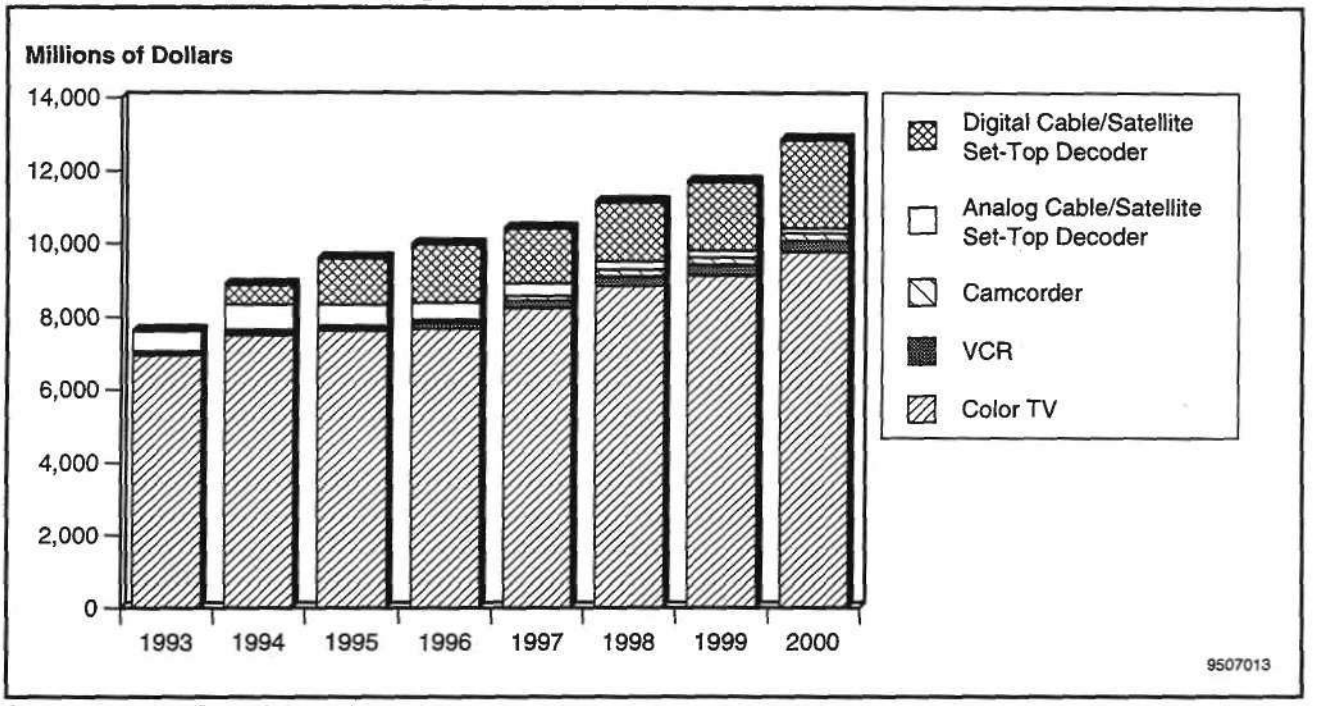
Market Trends

Today, worldwide video equipment demand is stratified by the following distinguishable levels:

- Replacement and additional purchase demand in industrialized countries where the first-time buyer market is nearing a saturation point
- First-time purchase for low end and low cost
- Demand for hybrid products such as TV/VCR combinations
- Demand for next-generation video equipment, including wide-screen TV, HDTV, DVD, and video-CD

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Figure 4-3
North American Video Equipment Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Table 4-2
North American Video Equipment Production Revenue Forecast (Millions of Dollars)

Segment	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Color TV	6,966	7,508	7,630	7,681	8,242	8,845	9,131	9,770	5.1
VCR	70	107	74	155	203	265	306	311	33.1
Camcorder	31	44	62	88	126	180	193	207	27.2
Analog Cable/Satellite Set-Top Decoder	556	689	570	465	348	235	188	135	-25.0
Digital Cable/Satellite Set-Top Decoder	0	521	1,252	1,583	1,486	1,610	1,875	2,424	14.1
Total	7,622	8,869	9,588	9,973	10,405	11,134	11,692	12,847	6.0

Source: Dataquest (December 1995)

As shown in Figure 2-7, color TVs and VCRs are now found in almost all U.S. homes, whereas newer video technologies such as camcorders have more room for growth. The majority of homes in the United States and Canada have more than one TV, and many families have more than one VCR. Most purchases in these categories are for replacement or upgrade of existing products. Lower interest rates and strong new home sales stimulated consumer durable spending beginning in the early part of 1994, which led to robust sales of video equipment in the United States. However, in spite of higher consumer confidence in 1995, video electronics sales growth slowed. The following sections provide more detailed discussion of the high-volume video equipment—color TVs, VCRs, and camcorders. Emerging opportunities in HDTV, video-CD, and DVD also are

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Table 4-3
North American Video R&D and Manufacturing

Company	R&D Center	Manufacturing Sites
Emerson	North Bergen, NJ	North Bergen, NJ
JVC		Elmwood Park, NJ
Matsushita		Franklin Park, IL; Mexico
Mitsubishi	Brazelton, GA	Brazelton, GA
	Santa Ana, CA	Santa Ana, CA
	Orange County, CA	
Philips	Knoxville, TN	Greenville, TN; Ottawa, Ohio; Mexico
Thomson Consumer	Indianapolis, IN	Bloomington, IN; Marion, IN; Mexico
Sanyo		Tijuana, Mexico
Sony	San Jose, CA	San Diego, CA; Mexico
		Mount Pleasant, PA
Zenith	Glenview, IL	Melrose Park, IL; Mexico

Source: Dataquest (September 1994)

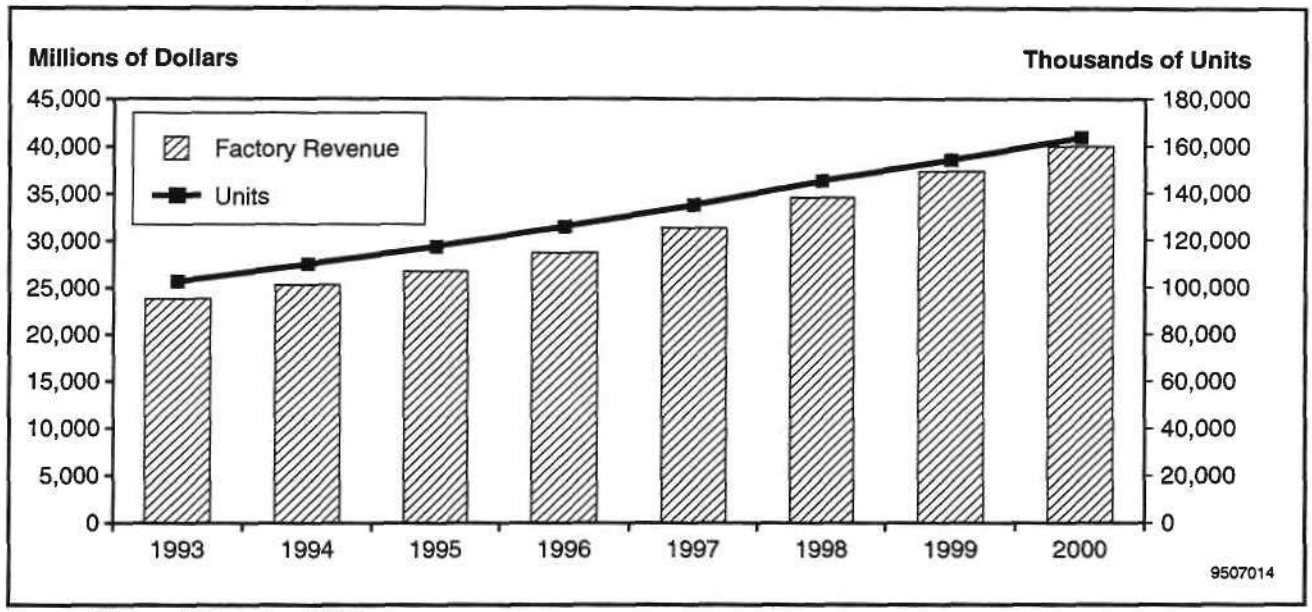
discussed at the end of this chapter. Detailed information on analog and digital set-top boxes is presented in Chapter 5, where interactive products are discussed.

Color Television

Figure 4-4 and Table 4-4 present the worldwide color television production forecast. There will be a significant shift in production from North America and Japan to the Asia/Pacific region during the next five years: 43.4 percent of worldwide production is expected to take place there by 2000. Tables 4-5 and 4-6 show the North American color TV market and production forecast, respectively. Figure 4-5 shows the regional distribution of color TV production. Figure 4-6 shows the sales mix of color TVs sold in the United States. RCA was the leading brand in the United States during 1994 and 1995. Tables 4-7 and 4-8 list leading color television brands. Key market trends and product developments affecting the color television market include the following:

- TV/VCR combinations will continue to grow significantly as several manufacturers introduce new models. These are preferred by families as a unit for children, because they save room and are easy to operate.
- Direct view screens of 20 inches and less are losing favor to screen sizes of 25 inches and more. A continued shift of the sales mix to larger screen sizes is expected. Screen sizes over 30 inches already represented almost 12 percent of the market in 1994.
- Stereo TVs grew to represent 42.5 percent of color TV sales in 1993. Their market share slipped slightly in 1994 to 42.2 percent of the market.
- Plasma displays made a big splash at the fall 1995 COMDEX show. These displays are about 4 inches thick and are expected to find their earliest application in "hang-on-the-wall" TVs. It appears that a market

Figure 4-4
Worldwide Color Television Production Revenue and Unit Shipment Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

that was always "just 10 years away" is finally close to becoming a reality. Fujitsu and Panasonic were exhibiting the most impressive large flat panel designs based on their color plasma technology. Sony also demonstrated its Plasmatron display, which employs plasma-addressed liquid crystal (Palc) technology. Mitsubishi has also announced plans to introduce a flat panel TV-display using plasma technology. Fujitsu looks like it is probably about a year ahead of other plasma panel competitors. Its 42-inch color plasma display featuring 300-candela-per-square-meter brightness, a wide aspect ratio of 16:9, 24-bit color, 852 x 480 resolution, a 160-degree viewing cone, and a 70:1 contrast ratio outclassed virtually everything else in sight and captured constant media attention at the show. Major investments in research and production capacity have been announced by leading Japanese television manufacturers. Market introductions of plasma displays are scheduled to begin in the second quarter of 1996. However, pricing on these displays will create a barrier for early market acceptance. Fujitsu is targeting a price of $5,000 during mass production in 1996. This means that complete consumer systems should be available for less than $10,000.

- New technology developments are paving the way for introduction of three-dimensional televisions (3-D TVs) that allow viewers to see 3-D images without wearing special glasses. Sanyo has already exhibited a 3-D video projection system and announced that it intends to begin shipping systems outside Japan in late 1996. Shipments for use in commercial applications, arcade games, and medical equipment began in 1994. Its 40-inch 3-D LCD system employs twin LCD projectors that cast the images onto a double lenticular lens screen. This screen then separates the signals into right-side and left-side images, resulting in the illusion of 3-D images without the use of special glasses. Also, a company called HinesLab Inc. announced in September 1995 that it had patented a display system that achieves true stereo 3-D images. The

Table 4-4
Worldwide Color Television Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	102,610	109,901	117,385	125,775	134,855	145,168	154,094	163,631	6.9
Factory ASP ($)	232	230	228	228	232	238	242	244	1.4
Factory Revenue ($M)	23,810	25,271	26,724	28,694	31,299	34,516	37,335	40,000	8.4
Semiconductor Content ($)	29	30	30	30	30	31	33	34	2.4
Semiconductor TAM ($M)	3,003	3,312	3,502	3,813	4,091	4,468	5,021	5,487	9.4

Source: Dataquest (December 1995)

Table 4-5
North American Color Television Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Color TV Only									
Units (K)	25,306	27,310	27,594	28,490	29,535	30,618	32,602	34,713	4.7
Factory ASP ($)	318	292	294	287	294	294	294	294	0
Factory Revenue ($M)	8,047	7,975	8,113	8,177	8,683	9,002	9,585	10,206	4.7
TV/VCR Combination									
Units (K)	1,792	2,229	2,382	2,640	2,864	3,107	3,371	3,657	9.0
Factory ASP ($)	368	350	344	337	333	331	330	330	-0.8
Factory Revenue ($M)	659	780	819	890	954	1,029	1,112	1,207	8.1

Note: Includes direct view stereo and nonstereo TV. Does not include monochrome TV, color LCD TV, or projection TV.
Source: Dataquest (December 1995)

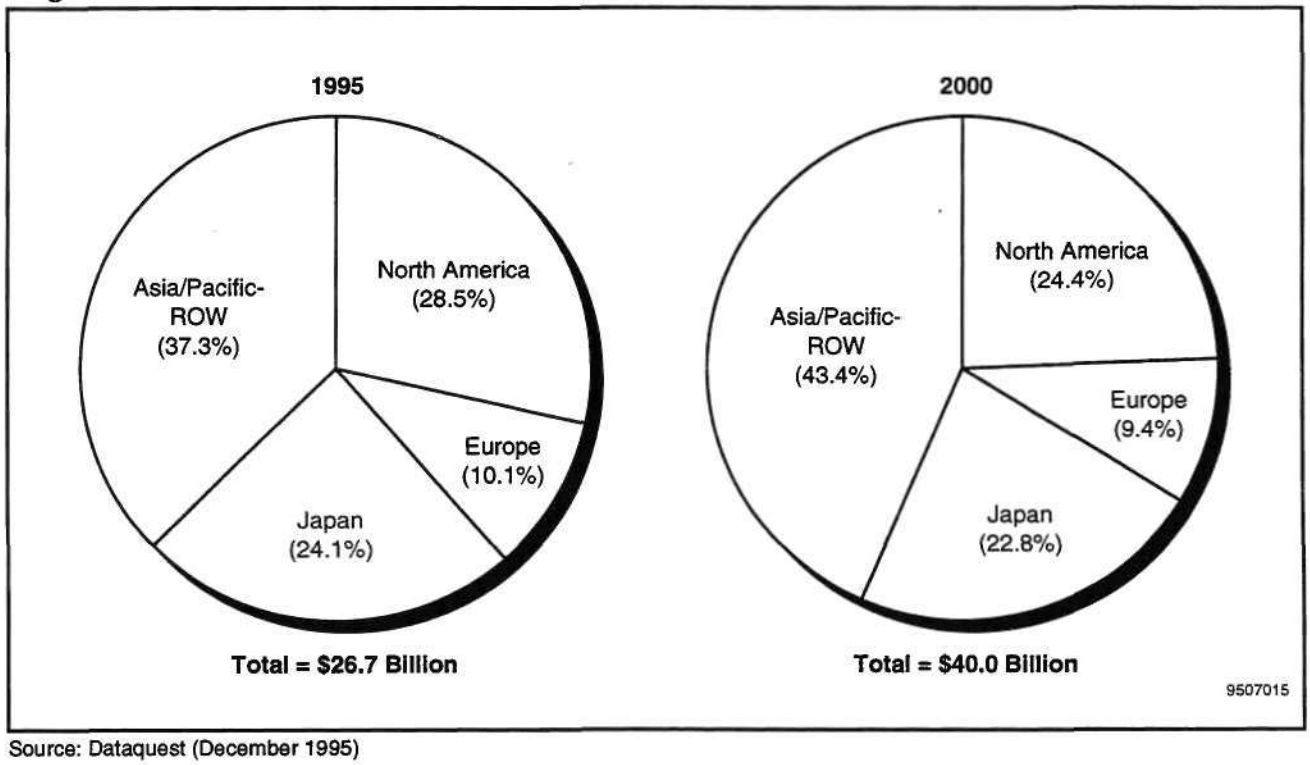
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Table 4-6
North American Color Television Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	20,656	22,043	22,857	23,009	23,857	24,735	26,467	28,319	4.4
Factory ASP ($)	337	341	334	334	345	345	345	345	0.7
Factory Revenue ($M)	6,966	7,508	7,630	7,681	8,242	8,845	9,131	9,770	5.1
Semiconductor Content ($)	29	29	29	29	30	30	30	30	0.1
Semiconductor TAM ($M)	597	645	657	663	713	742	794	850	5.3

Source: Dataquest (December 1995)

Figure 4-5
Regional Share of Color Television Production Revenue

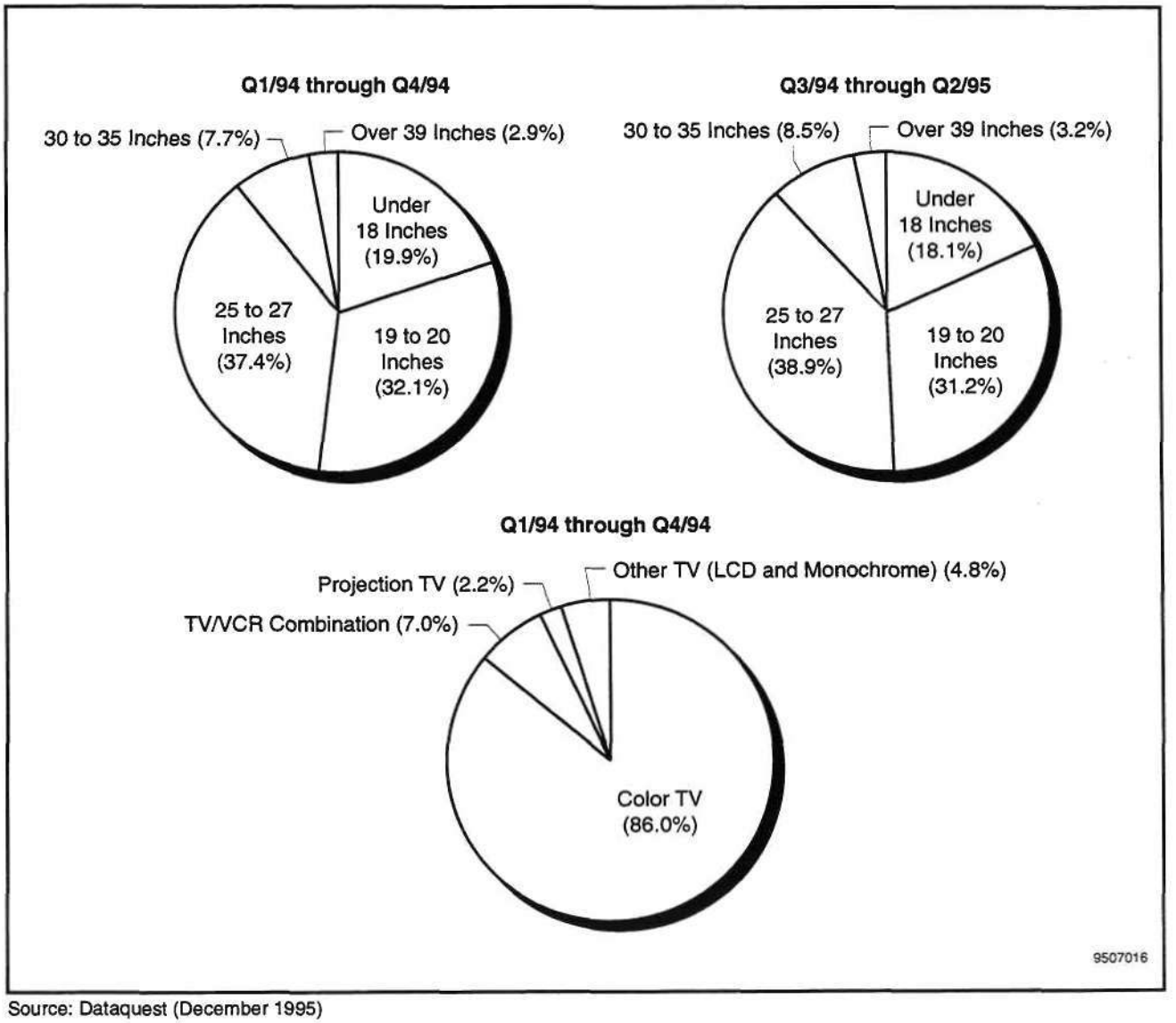


Source: Dataquest (December 1995)

company claims that its system uses conventional optics and is built into a single display panel that affords users a greater degree of freedom, allowing anyone to sit in front of a monitor and experience realistic moving images. Finally, engineers from the University of Alabama have demonstrated a prototype that pumps moving holographic stereogram images through an active matrix LCD. The prototype, called ICVision, is constructed using a 1-inch diagonal active matrix LCD from Kopin Corporation and a diffractive optical element for directing light through a series of slits, which form the left and right halves of the stereo image.

- Digital micromirror display (DMD) technology continues to be advanced by Texas Instruments. Texas Instruments has been working on DMD technology for decades. It has now developed a prototype DMD device that measures 2 centimeters squared and holds 400,000

Figure 4-6
North American Color Television Sales Mix (Unit Basis)



Source: Dataquest (December 1995)

movable aluminum mirrors, each about 16 square microns. By controlling the mirror's movement, the device projects a brighter image than today's LCD-based video projectors. Employing processing techniques the company calls Digital Light Processing (DLP), TI has developed a prototype projection display that was demonstrated at Dataquest's 1995 Semiconductor Conference. Potential partners that could help TI bring this technology to the market include Sony and Thomson Consumer Electronics.

- The "V-Chip" (the V stands for violence) that identifies programs by content and allows consumers to block out objectionable shows was introduced in 1994. Although the major TV networks have voiced opposition to this scheme, President Clinton and both houses of Congress favor legislation that mandates the use of V-chip technology in all new TV sets. The fate of this law hangs on a budget resolution in Washington. Meanwhile, hundreds of Canadian households will participate in a trial implementation of the V-chip. The V-chip could find its way into

Table 4-7
U.S. Color Television Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
RCA	16.1	17.6
Magnavox	15.0	12.7
Zenith	12.0	13.0
Sony	6.6	9.0
General Electric	6.6	5.0
Sharp	6.0	3.7
Sanyo	5.3	3.3
Emerson	5.0	2.7
Toshiba	3.1	5.5
Panasonic	2.9	3.6
Others	21.4	23.9
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 4-8
U.S. Color Television Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
RCA	16.2	17.2
Magnavox	16.1	14.3
Zenith	12.3	12.8
Sony	7.1	9.4
General Electric	6.3	4.4
Sharp	6.0	3.8
Sanyo	4.9	3.0
Emerson	4.4	2.4
Panasonic	3.5	3.9
Toshiba	3.3	5.9
Others	19.9	22.9
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

set-top boxes, VCRs, and TVs. Zilog has already announced that its Z89300 TV control and on-screen display chip family have the recommended TV program rating decoding and control capability. In volume production, this chip will be priced in the $4-to-$6 range.

Functionally, color TVs have reached near maturity, and the focus is being placed on improvement of productivity in the manufacturing process through digitization. Integration of peripherals devices into semiconductor chips allows reduction of components, thus reduction of inspection/adjustment points. Also, an increasing use of microcomputers enables signal processing control by computer bus, leading to standardization of chassis design. Figure 4-7 shows a block diagram of a currently available multifunction, high-performance color TV.

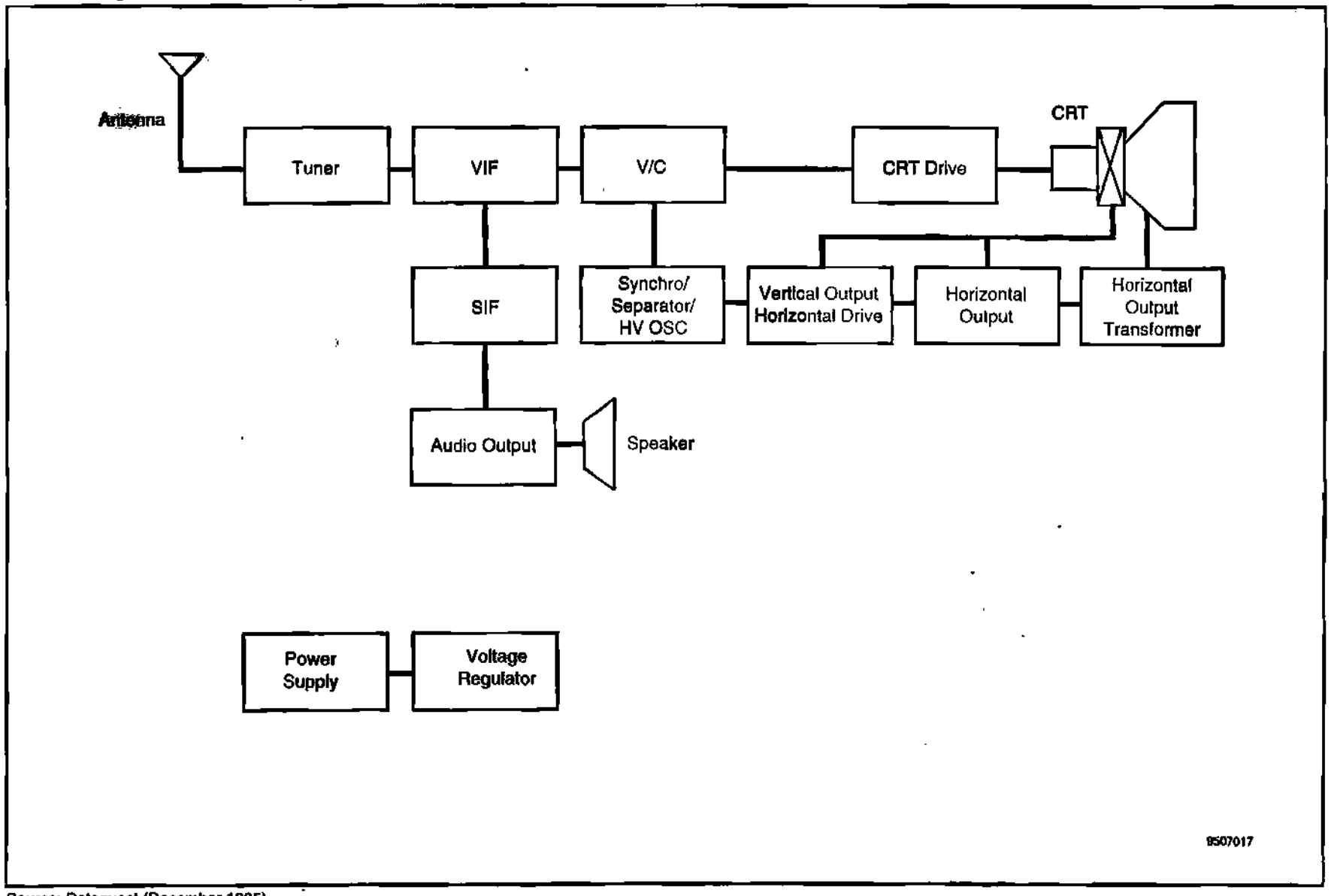
Major technological trends in electronic circuits for video equipment are classified as follows:

- Digital processing of image, voice, and mechanical control signals. Digital processing of video and voice signals for low-end products has been incorporated into ICs except for CRT video and horizontal output circuits, which are configured by discrete devices.
- Since the adoption of the Ghost Cancellation Reference (GCR) by the Federal Communications Commission (FCC) in May 1993, awareness of its technology has increased. Many more stations are including the reference in their transmission. Ghost cancellation technology is also being introduced to the public through a consumer standalone unit. With time, ghost cancellation will become more widely accepted, and the technology will become a commonly integrated feature of the television receiver or VCR.
- Interframe signal processing by using TBC technology and semiconductor memory. Improved-definition TV (IDTV) and EDTV use digital memories to scan 525 lines at a frequency twice that used in the National Television Standards Committee (NTSC) standard. The use of digital memory also allows currently available color TVs to adopt technologies to improve picture quality by eliminating or reducing cross-color and jitter.
- Closed-captioning decoders. Closed-captioning decoders for the hearing impaired are now mandatory on U.S. market TVs.
- Use of the bus system for interactive control of ICs. In particular the I2 bus technology patented by Philips is beginning to be adopted by color TVs.
- Incorporation of new features. Digitization of signal processing has promoted incorporation of new features, such as picture in picture, digital still, and on-screen display.

VCRs

Figure 4-8 and Table 4-9 show the forecast for worldwide VCR production. Because household penetration rates are more than 90 percent, Dataquest expects unit shipments and revenue for the next five years to remain essentially flat. Sales are now sustained by replacement, upgrades, and households adding a VCR. Following the trends for other video equipment, production increasingly will shift to the Asia/Pacific region.

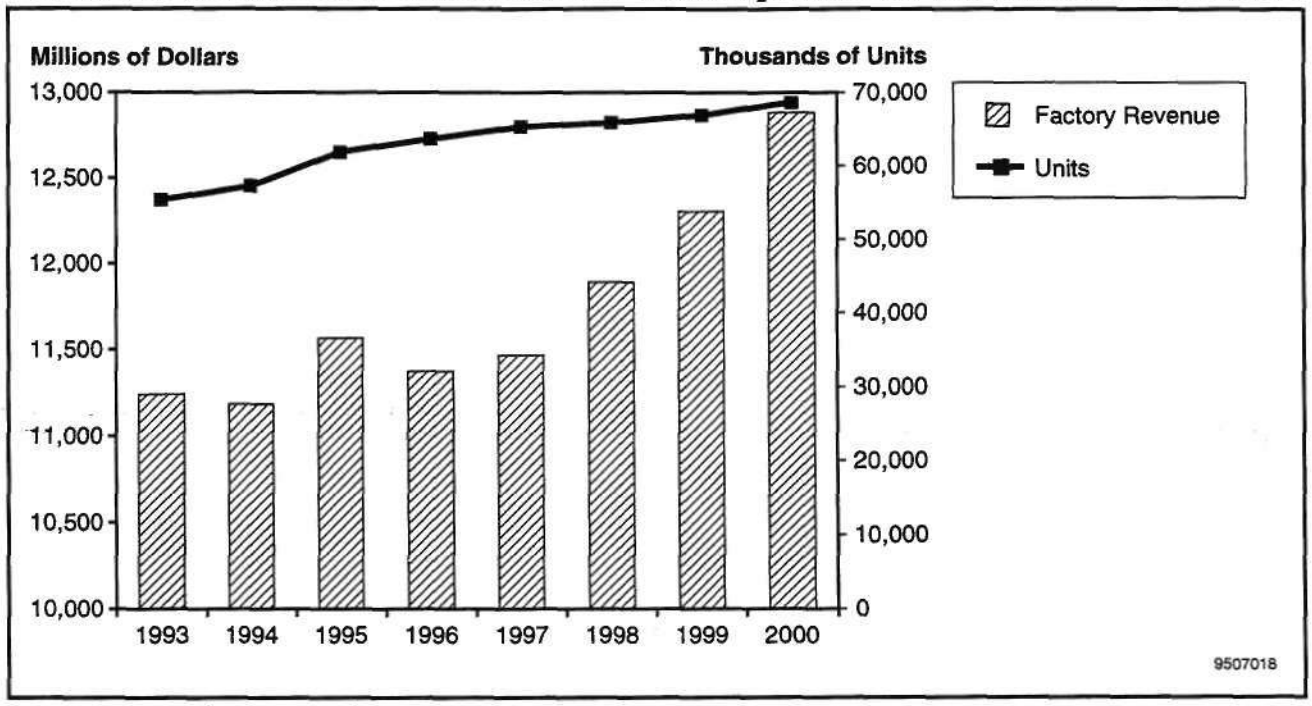
Figure 4-7
Block Diagram of Currently Available Multifunction, High-Performance Color TV



Source: Dataquest (December 1995)

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Figure 4-8
Worldwide VCR Production Revenue and Unit Shipment Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Table 4-9
Worldwide VCR Production Forecast

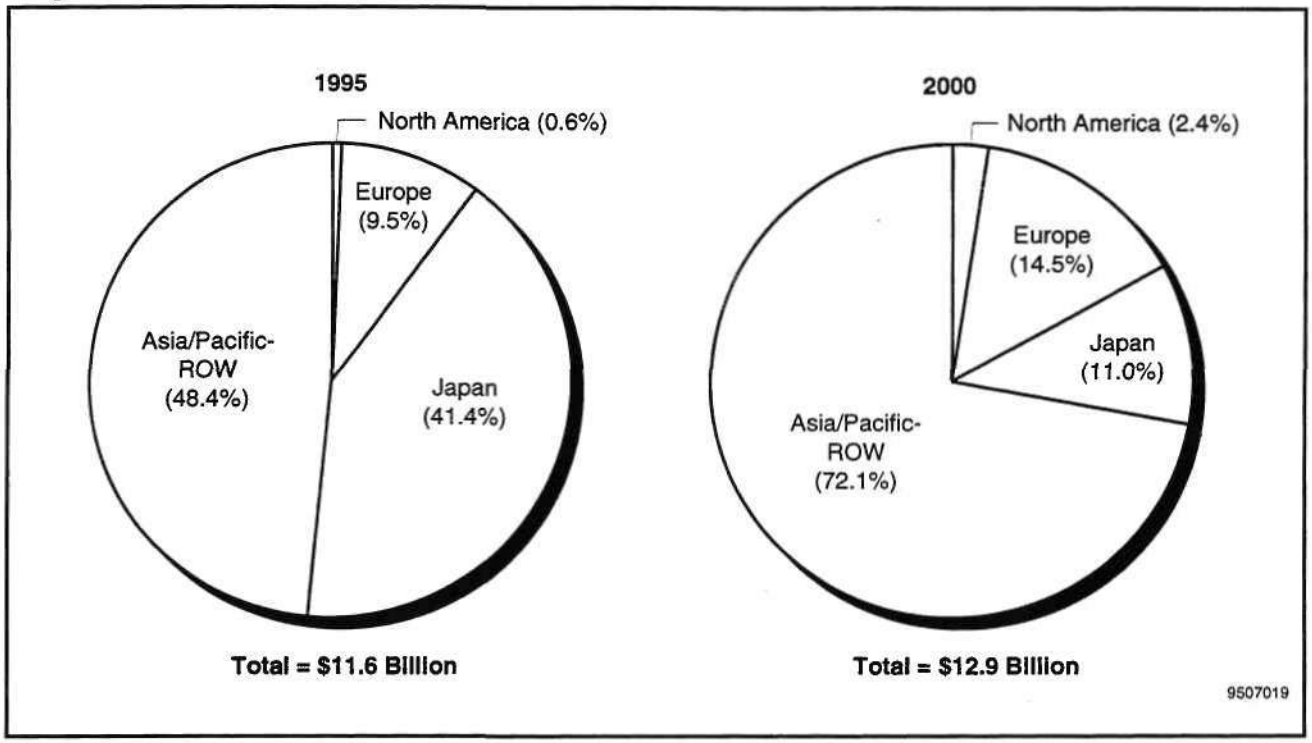
	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	55,296	57,209	61,844	63,638	65,313	65,891	66,919	68,662	2.1
Factory ASP ($)	203	196	187	179	176	180	184	188	0.1
Factory Revenue ($M)	11,241	11,184	11,567	11,375	11,467	11,891	12,303	12,885	2.2
Semiconductor Content ($)	42	43	43	42	41	39	39	39	-2.1
Semiconductor TAM ($M)	2,333	2,470	2,656	2,657	2,667	2,585	2,579	2,654	0

Source: Dataquest (December 1995)

Figure 4-9 shows the distribution of VCR production by region. Tables 4-10 and 4-11 show the North American VCR market and production forecast, respectively. Tables 4-12 and 4-13 list the leading VCR brands. Key trends to note among VCRs are as follows:

- The most popular upgrade feature is stereo audio. The 1996 market for home VCR desks will be heavily stereo-oriented. There will probably be a decline in the sale of mono models in the United States. Other advanced features include special effects with four heads and the S format, which offers more effective scan lines.
- The VCR Plus programming standard for simplified program recording is nearly a standard feature on step-up VCRs.

Figure 4-9
Regional Share of VCR Production Revenue



Source: Dataquest (December 1995)

Table 4-10
North American VCR Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	14,004	14,788	15,232	15,413	15,713	15,930	16,146	16,365	1.4
Factory ASP ($)	229	218	206	195	192	195	197	200	-0.6
Factory Revenue ($M)	3,207	3,224	3,138	3,005	3,017	3,106	3,181	3,273	0.8

Note: Does not include TV/VCR combinations or camcorders
Source: Dataquest (December 1995)

Table 4-11
North American VCR Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	302	469	325	673	871	1,127	1,183	1,243	30.7
Factory ASP ($)	231	228	228	231	233	235	245	250	1.8
Factory Revenue ($M)	70	107	74	155	203	265	306	311	33.1
Semiconductor Content ($)	31	31	31	32	33	33	33	34	1.5
Semiconductor TAM ($M)	9	15	10	22	28	37	39	42	32.8

Source: Dataquest (December 1995)

Table 4-12
U.S. VCR Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
RCA	13.9	14.6
Magnavox	12.1	11.4
Emerson	8.0	5.5
Panasonic	7.7	8.0
General Electric	5.8	5.0
Zenith	5.3	6.0
JVC	5.0	6.0
Sony	4.7	7.0
Sharp	4.5	4.1
Goldstar	3.1	2.4
Others	29.9	30.0
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 4-13
U.S. VCR Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
RCA	14.2	14.9
Magnavox	12.5	11.8
Panasonic	8.2	8.6
Emerson	8.0	5.6
General Electric	5.3	4.6
Zenith	5.0	5.7
Sharp	5.0	4.5
JVC	5.0	6.1
Sony	4.6	6.7
Goldstar	2.7	2.2
Others	29.5	29.3
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

In terms of basic features and functions, VCRs have reached a stage of near perfection. Basic signal processing circuits are increasingly digitized by using analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) and are eventually integrated into semiconductor chips incorporating digital signal processors (DSPs). New developments are expected in restoration of original signals, in addition to accurate replay, as well as the ability to provide output according to diverse consumer demand. Digitization has boosted the number of ICs capable of handling NTSC, PAL, and SECAM formats. Also, the use of on-screen display ICs and filter-equipped ICs is reducing the number of components and adjustment points at the factory. Copy-protection circuitry from Macrovision is becoming more popular as both Philips and Texas Instruments are producing copy-protection chips. Figure 4-10 shows a block diagram of a typical VCR.

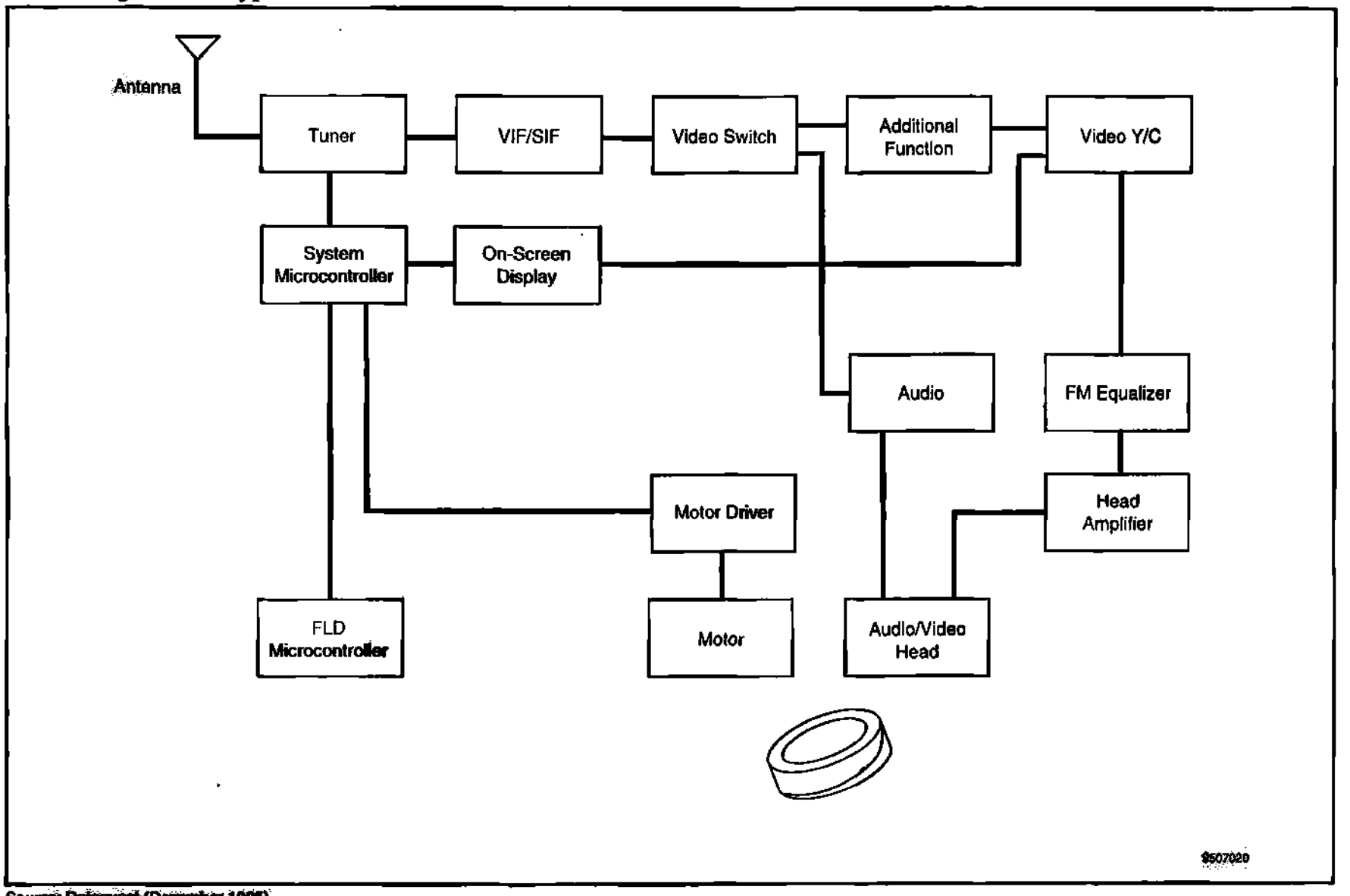
A new standard called Data-VHS (D-VHS) is being developed by VCR manufacturers, led by JVC. The new D-VHS system will be backward-compatible with the VHS format and would also add a bitstream recording capability to allow recording of compressed digital data. The standard would use existing Super VHS media and would be capable of offering 49 hours of recording per cassette. D-VHS will also record analog broadcasts such as NTSC and PAL. This feature would open new applications for VCRs in uses such as data storage and multimedia systems. JVC has consulted with Hitachi, Matsushita, and Philips Electronics in developing this new standard. Also, the following companies have expressed support for the D-VHS format: LG Electronics, Mitsubishi Electric, Samsung Electronics, Sanyo Electric, Sharp, Sony, Thomson Consumer Electronics, and Toshiba. Thomson is looking at D-VHS as an extension of its RCA Digital Satellite System (DSS) equipment line. D-VHS could record the actual digital direct-to-home satellite feeds of DirecTV and U.S. Satellite Broadcasting (USSB) programming.

The inclusion of digital recording capability will add $300 to $400 to the retail price of a VHS VCR. The first D-VHS VCRs are expected to hit the market in mid-1996. The higher price will present a significant barrier to market acceptance. A survey conducted by the EIA explored U.S. consumer interest in a digital VCR. When digital VCR was described to them, 29 percent of the VCR owners said they would be interested in purchasing it and 22 percent were unsure. However, when asked about the price they would be willing to pay, 25 percent of respondents said they would pay $400, 11 percent would pay $600, three percent would pay $800, and five percent would pay $1,000.

Camcorders

Figure 4-11 and Table 4-14 present Dataquest's forecast for worldwide camcorder production. Growth in revenue and shipments will be healthy during the next five years. Tables 4-15 and 4-16 present the North American market and production forecast, respectively. Figure 4-12 shows the production distribution by region. Japan is the primary location for production of camcorders. In spite of some shifting of production to the Asia/Pacific region, Japan will still produce the large majority of camcorders through 2000. Tables 4-17 through 4-18 show the leading camcorder

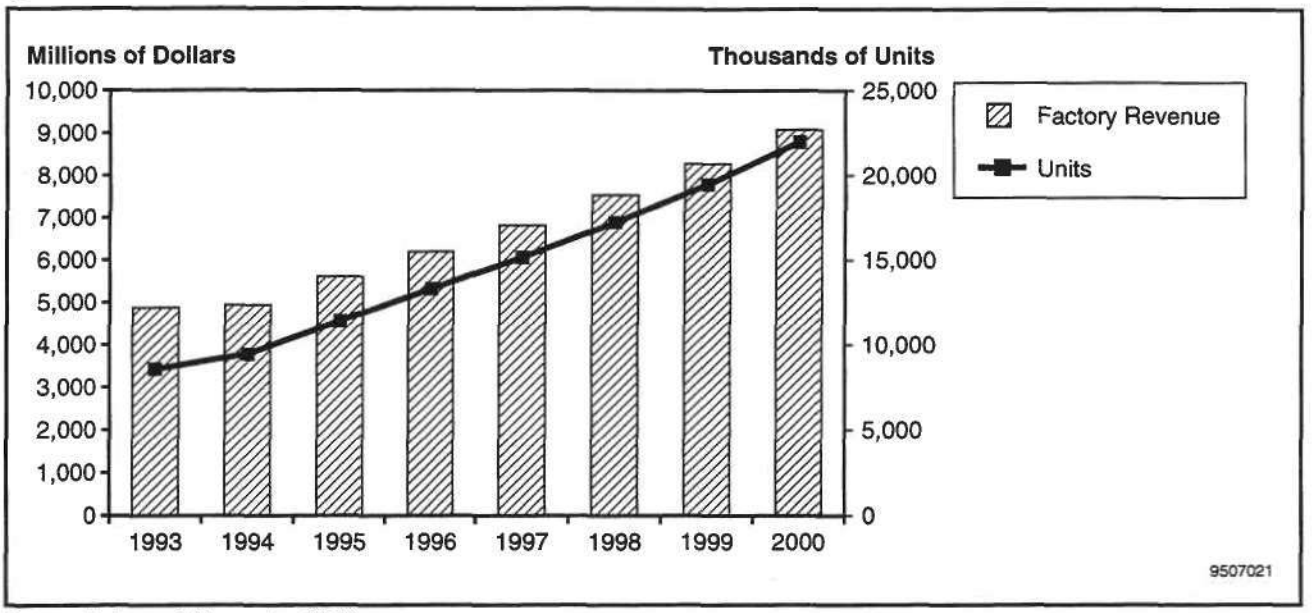
Figure 4-10
Block Diagram of a Typical VCR



Source: Dataquest (December 1995)

SAMM-WW-MT-9506 ©1995 Dataquest December 25, 1995

Figure 4-11
Worldwide Camcorder Production Revenue and Unit Shipment Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

Table 4-14
Worldwide Camcorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	8,566	9,433	11,396	13,300	15,147	17,224	19,465	21,997	14.1
Factory ASP ($)	569	523	492	465	450	437	425	413	-3.4
Factory Revenue ($M)	4,876	4,935	5,602	6,183	6,813	7,533	8,274	9,087	10.2
Semiconductor Content ($)	145	134	124	115	112	110	109	107	-2.8
Semiconductor TAM ($M)	1,246	1,260	1,409	1,533	1,698	1,890	2,113	2,363	10.9

Source: Dataquest (December 1995)

Table 4-15
North American Camcorder Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	3,381	3,530	3,750	3,905	4,072	4,247	4,433	4,626	4.3
Factory ASP ($)	611	600	586	570	550	535	520	515	-2.5
Factory Revenue ($M)	2,066	2,118	2,198	2,226	2,240	2,272	2,305	2,383	1.6

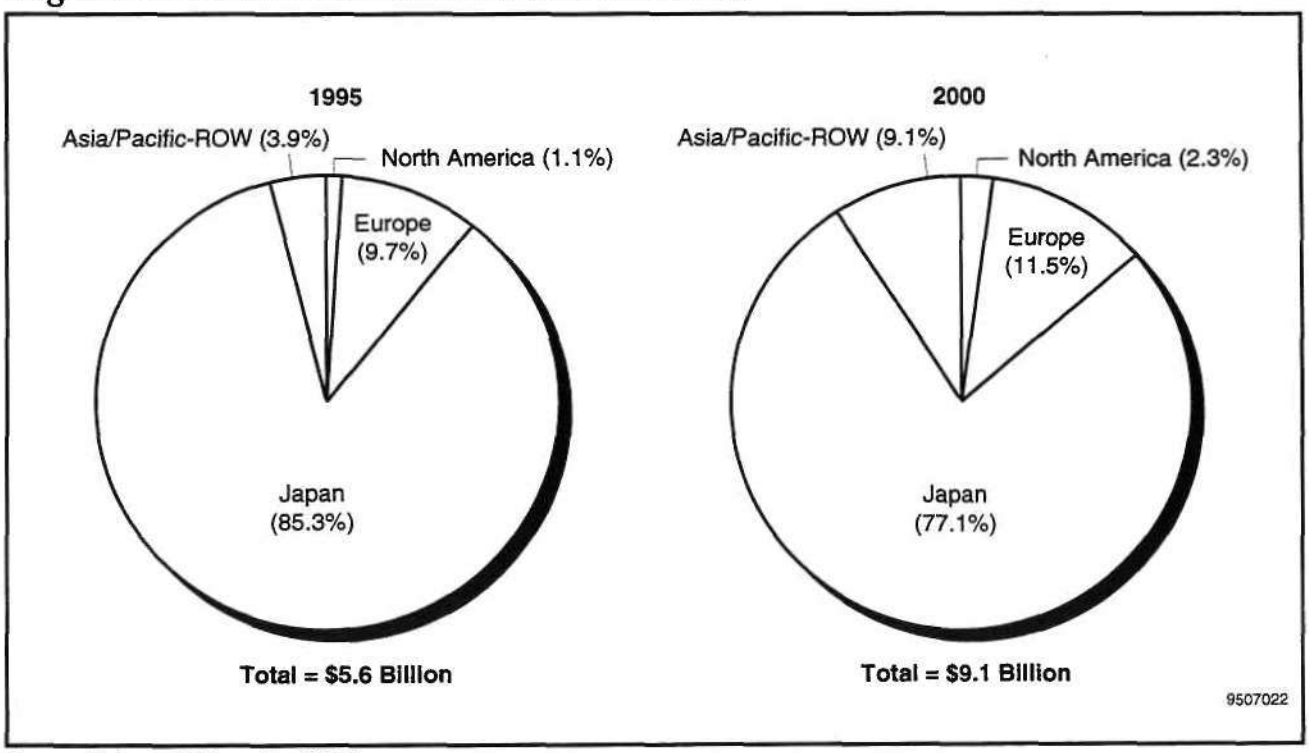
Source: Dataquest (December 1995)

Table 4-16
North American Camcorder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	50	75	113	169	253	380	429	485	33.9
Factory ASP ($)	611	581	552	524	498	473	449	427	-5.0
Factory Revenue ($M)	31	44	62	88	126	180	193	207	27.2
Semiconductor Content ($)	92	87	85	84	84	85	85	86	0.0
Semiconductor TAM ($M)	5	7	10	14	21	32	36	41	34.0

Source: Dataquest (December 1995)

Figure 4-12
Regional Share of Camcorder Production Revenue



Source: Dataquest (December 1995)

brands in the United States. Key trends to note among camcorders are as follows:

- More than 20 percent of U.S. homes have camcorders, although it is primarily homes with children that are buying camcorders.
- The strong movement to compact versions is helping fuel new sales. S versions are beginning to win over resolution-conscious moviemakers.
- Viewfinders that rely on LCDs rather than on traditional optical techniques are contributing to the impressive market surge for camcorders. The percentage of camcorders equipped with LCD monitors is more than doubling annually in Japan and abroad, according to statistics from Sharp, a leader in LCD technology implementation in camcorders.

Table 4-17
U.S. Camcorder Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sony	26.4	28.8
RCA	16.1	15.7
Panasonic	14.7	16.0
JVC	8.8	8.4
Sharp	10.4	10.5
Magnavox	5.4	4.3
Hitachi	3.5	4.1
General Electric	4.6	3.2
Canon	2.7	3.0
LXI	2.0	1.4
Others	5.4	4.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 4-18
U.S. Camcorder Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995

Brand	Unit Market Share	Revenue Market Share
Sony	24.5	26.8
RCA	16.6	16.2
Panasonic	12.8	13.4
JVC	11.7	11.5
Sharp	11.1	11.7
Magnavox	4.8	3.6
Hitachi	4.5	5.2
General Electric	4.1	2.8
Canon	2.4	2.6
LXI	1.7	1.2
Others	5.8	5.0
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

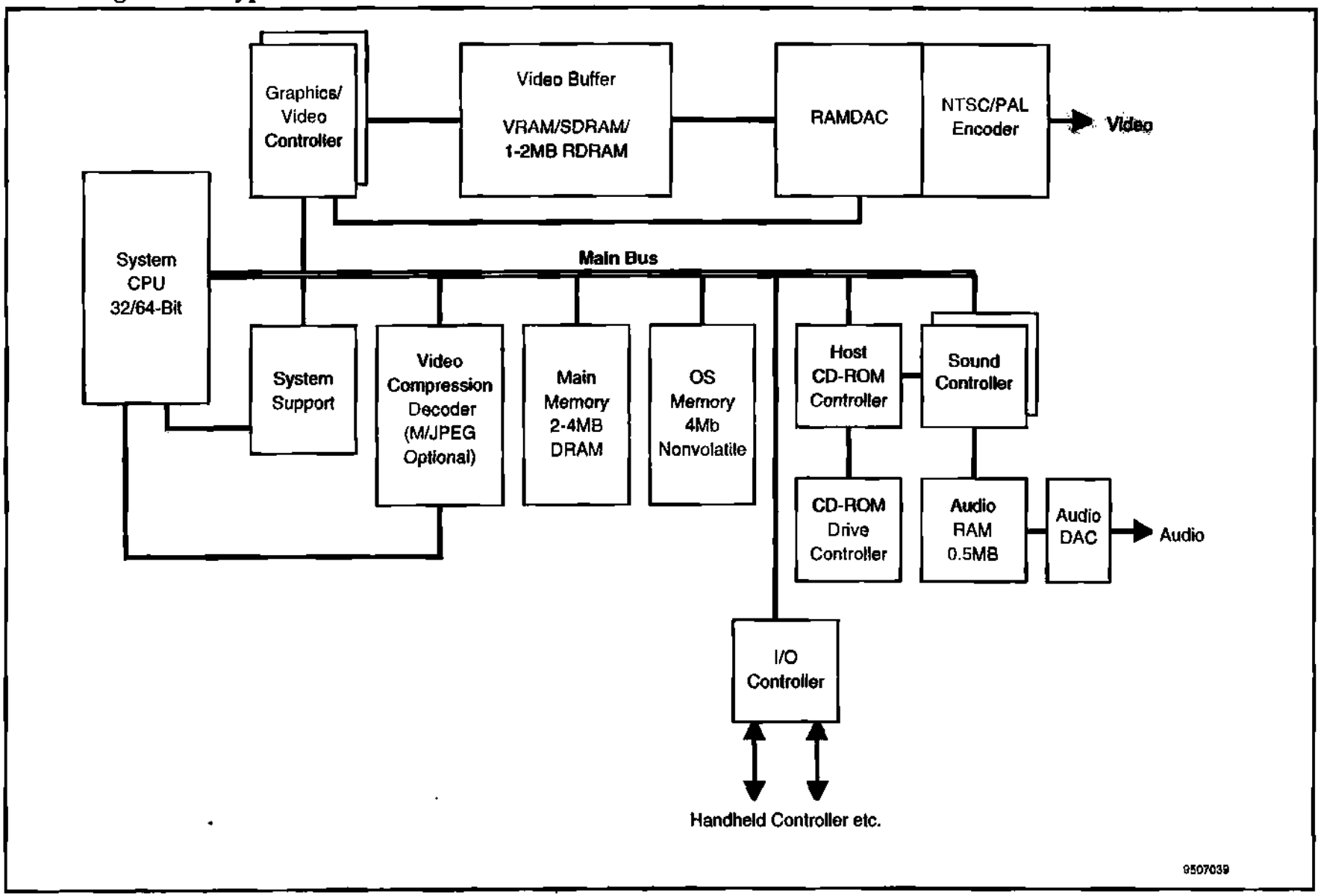
- The VHS-C format appears to be capturing a greater share of the U.S. market at the expense of the full-size VHS camcorders. According to the Photo Marketing Association, in 1991, the full-size VHS standard represented 42 percent of the U.S. camcorder market, with 8mm accounting for 37 percent and VHS-C for 22 percent. By 1994, the mix had shifted to: VHS, 26 percent; VHS-C, 38 percent; and 8mm, 36 percent. By the end of 1995, it appeared that VHS-C and 8mm were neck and neck at 41 percent, and VHS was declining to 18 percent of the market.

Figure 4-13 shows a block diagram of a typical camcorder. Some technology features and trends with implications for semiconductor opportunities are:

- CCD makers are increasing their share in the camcorder market. CCDs are becoming smaller and are accommodating more picture elements.
- CCD output signals, which have been conventionally analog processed, are converted to digital signals through a 10-bit DAC, and after Y/C signal processing by the DSP are sent to the processing stage such as blur correction and electronic zooming. Auto focus/auto iris/auto white balance (AF/AE/AWB) detection has been integrated into digital circuits on a single chip. Peripherals circuits related to blur correction consist of fuzzy logic circuits for motion detectors, blur-correction control, and memory control, which are incorporated into standard cells (DSP).
- Mechanism control is handled by an 8-bit microcomputer (servo microcomputer). With the increasing emphasis on portability, development efforts are being shifted from low power consumption to lower operation voltage to 3.3V (3V). Further demand for high-performance camcorders will encourage digital processing, incorporation of a battery charge circuit into a single chip, and development of a single/hybrid chip.
- In the video equipment market, advanced technology developed for industrial use (broadcast equipment) is finding its way to consumer applications that demand much lower levels of picture quality. Various technologies unique to consumer products, such as blur correction, have been commercialized. At the same time, because color TVs, VCRs, and camcorders share common features, new technology developed for any of them is diffused to others.
- Vibration or shake compensation has become a key feature in camcorders, equal in importance to compact, lightweight design and strong-magnification zooms. There are two approaches to shake compensation, one electronic and the other optical. Recently, almost all but the low-end camcorders have adopted some version of electronic shake compensation.
- With the adoption of digital camera circuits, many camcorders feature digital zooms allowing greater magnification. For example, combining a 12X optical zoom lens with a 2X digital zoom function makes it possible to record images at 24X magnification.

The first digital camcorders were introduced in 1995. These camcorders are based on the Digital Video (DV) format specification for home-use digital camcorders that was agreed to by 55 manufacturers as part of the HD Digital VCR Conference. Matsushita and Sony were the first manufacturers to offer digital camcorders, followed by JVC and Sharp. Hitachi is expected to introduce its digital camcorder at the winter Consumer Electronics Show. The Hitachi camcorder will record on a floppy disk that can be inserted into a PC instead a tape. As with most of the new digital video products, the steep pricing of these new camcorders will limit the potential market to semiprofessionals and the top 1 percent to 2 percent of the consumer camcorder market. Pricing on these early models ranges from $2,200 to $4,700.

Figure 4-13
Block Diagram of a Typical Camcorder



Source: Dataquest (December 1995)

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To record image signals, camcorders using the DV format adopt the digital component system, recording luminance and chrominance (Y and C) signals separately. This format provides a resolution of 500 horizontal lines. Instead of the standard 0.3-MHz color signal bandwidth, the DV format works with a 1.4-MHz bandwidth. The format also calls for a built-in time base correction (TBC) function to diminish jitter. Audio recording involves the use of pulse code modulation (PCM) stereo. There are two possible audio modes. For audio quality equal to that of compact discs and digital audio tapes (DAT), a 16-bit sound system using two channels and 48-KHz sampling frequencies can be used. The specification also defines a 12-bit audio system with four channels and 32-KHz sampling frequencies. The interface format for connecting to personal computers is still being finalized, but it appears that it will be based on the IEEE-1394 standard.

As mentioned previously, Matsushita was one of the first manufacturers to bring a digital camcorder to market. This first model integrated 2.5 million transistors into five main video chips on a 0.5-micron process. Two of the chips, error correction and digital modulation devices, are produced by LSI Logic. A pulse code modulation (PCM) device is made by Mitsubishi Electric. Mitsubishi can use the PCM chip for its camcorder with Matsushita's agreement.

HDTV

HDTV is high-definition television, or advanced television—a quantum leap in video quality. Everyone wants better TV. Consumers want clearer pictures with higher resolution, and broadcasters would love to give it to them. But is HDTV worth the price, especially in light of new technologies, both analog and digital, designed to squeeze more performance out of existing television systems?

The Challenges of U.S. HDTV

- Political: The FCC must approve the system and then allocate space in the frequency spectrum to transmit the signals.
- Broadcasters: Head-end gear for HDTV is currently very expensive compared with NTSC gear.
- Receivers: HDTV sets intended for consumers require very expensive components and may never achieve enough volume to reduce costs significantly.

Political

A lot is known about the arduous journey of HDTV through the U.S. political process. There are even five lobbying organizations that promote HDTV in Washington, D.C. HDTV will eventually be approved by the FCC, but the FCC is now also supporting standard-definition (digital) television (SDTV). Congress is putting pressure on the FCC to raise funds through spectrum auctions to reduce the national debt. If the FCC decides to auction HDTV spectrum, it would be a disincentive to broadcasters. Following are descriptions of the two key U.S. government bodies involved with HDTV:

- Federal Communications Commission: New spectrum is being allocated for digital broadcast TV. If these digital TV spectrum licenses are auctioned, they could be worth as much as $70 billion. If digital

broadcast TV succeeds, the FCC would like to regain the spectrum currently used for analog TV channels and auction it for up to $23 billion. Congress recently voted to raise $14 billion by 2002 from spectrum auctions. Currently, 400 MHz of spectrum is allocated for broadcast TV; however, only about 120 MHz is used even in the biggest cities. The FCC chairman is Reed Hundt. Mark Corbitt is director of technical policy at the Office of Plans and Policy.

- Advisory Committee on Advanced Television Services (ACATS): A 50-member committee was established by the FCC in September 1987 to evaluate and recommend an HDTV standard for the United States. Former FCC Chairman Richard E. Wiley has been the chairman of ACATS since its inception. David Kettler is executive director of science and technology for BellSouth and cochairman of ACATS Systems Analysis Working Party. CBS executive Joseph Flaherty is cochairman of the ACATS Technical Subgroup. Robert Hopkins is chairman of the ACATS Expert Group on Scanning Formats and Compression. Jules Cohen is chairman of the ACATS Field-Testing Task Force.

Broadcasters

Faced with the high cost of HDTV equipment and the possibility of spectrum auctions, broadcasters are likely to place their investments elsewhere. Terrestrial broadcasters can always invest in more translators and more power for their transmitters. In October 1995, *TV Broadcast* magazine conducted a survey of TV station general managers. Of those surveyed, 88 percent of broadcasters expect to switch from tape to digital storage by 2000. Substantial costs will be incurred in the next five years to accomplish this. Also, 28 percent of broadcast general managers wish advanced television would just go away.

Receivers

The challenge that nobody wants to talk about is the cost of an HDTV receiver. The equation is really very simple. If consumers can't afford a special receiver, then broadcasters can't sell air time to advertisers because there will be no audience. Therefore, there is no return on the broadcasters' investment in expensive HDTV gear. Members of the Grand Alliance, the U.S. consortium of HDTV hopefuls, admitted in November 1995 that HDTV will not be available in the United States until 1998 at the earliest. Grand Alliance members remain confident that consumers will pay $3,500 for an HDTV receiver. Dataquest is much less optimistic about consumers' acceptance at these prices.

Plasma is a new flat panel display technology that could potentially reduce the cost of HDTV receivers. Fujitsu is about a year ahead of other plasma panel competitors. It previewed a 42-inch model at the COMDEX show in November 1995. Production is expected to begin in October 1996 at 10,000 units per month for ¥500,000 each (about $5,000 for the display alone).

Problems with Wide-Screen TVs and HDTV Receivers

The following are problems presented by wide-screen TVs and HDTV receivers:

- Will not fit on standard TV production and assembly lines, therefore more labor and cost is required to transport the work-in-progress from one station to the next

- Too wide to fit through a standard-size doorway
- Too wide to fit in standard wall unit furniture
- Electron gun must be quite far from the screen so it can scan its full width at a reasonable speed
- As screen gets wider, glass must be thicker (and heavier) for structural strength. Difficult to mold a flat screen
- Proposed viewing distance for HDTV is half that for standard NTSC TVs. Therefore, the number of viewers within the optimal distance will be more than halved.
- Very heavy—about 200kg
- Very expensive

Standards and Organizations

Grand Alliance: Digital HDTV Grand Alliance (United States). The alliance of the seven companies that proposed four all-digital HDTV systems to ACATS in 1993. Formed on May 24, 1993, the seven member companies are AT&T Microelectronics, Zenith Electronics Corporation, General Instrument Corporation (GI), Massachusetts Institute of Technology, Philips Consumer Electronics, Thomson Consumer Electronics, and David Sarnoff Research Center. AT&T and GI jointly built the video encoder, Philips constructed the decoder, Sarnoff and Thomson cooperated in building the transport subsystem, and Zenith built the modulation subsystem.

SDTV: Standard-Definition (digital) TV. FCC-approved standard for digital TV using standard-resolution NTSC displays within an HDTV broadcast system. Hitachi is the leading developer of down-conversion systems for turning HDTV signals into SDTV for display on standard TV sets.

MUSE HDTV: Multiple Sub-Nyquist Sampling Encoding (also known as Hi-Vision). Japanese standard for analog HDTV developed in 1968 by NHK. MUSE uses a display with interlaced scanning with 1,125 horizontal scanning lines at 60 fields per second. Since 1990, between nine and 11 hours of Hi-Vision has been transmitted every day by satellite in Japan. The commercial service launch for Hi-Vision is scheduled for late 1997. As of July 31, 1995, Hi-Vision TV sets cost about $5,618. A MUSE signal occupies 8 MHz of bandwidth. Narrow MUSE is a slimmed-down version occupying only 6 MHz of bandwidth. The system uses digital signal processing, but the frequency modulation is analog. Developed primarily by Sony.

MPT: Japan's Ministry of Posts and Telecommunications. In July of 1995, the MPT announced that Japan, too, would have a digital TV specification. The specification is similar to Europe's DVB. Digital satellite services are expected to begin in April 1996. Manufacturers of Hi-Vision HDTV sets strongly object being preempted. Full-scale broadcasting of Hi-Vision HDTV is still planned to start in 1997. MPT's Digital Broadcasting Systems Division director is Tomofumi Yasunari.

DVB: Digital Video Broadcasting Group, formed in September 1983. HDTV is no longer a priority in Europe, and HDTV efforts have been

replaced by the pan-European DVB standard for digital TV. DVB is headquartered in Geneva, operating under the auspices of the European Broadcast Union and the German Ministry of Telecommunications. Two standards exist: DVB-S for satellite using QPSK, and DVB-C for cable using 64-QAM. COFDM is still being considered for the terrestrial standard. MPEG-2 main level, main profile. PCMCIA II will be used for the physical interface to accommodate different conditional access systems (instead of smart cards).

DAVIC: Digital Audio Visual Interoperability Council. Standard-setting organization for digital TV, formed in January 1994, headquartered in Europe, following the DVB project. The chairman is Dr. Leonardo Chiariglione. DAVIC Spec 1.0 was completed at a meeting in Melbourne, Australia, and presented at the International Television Symposium in Montreux, Switzerland, in June 1995. The chairman of the Set-Top Unit Technical Committee is K. Shimamura of NTT. The U.S. contact is Robert Luff, chief technical officer of Broadband Communications Group at Scientific-Atlanta. DAVIC spec 1.1 is planned for June 1996, and DAVIC spec 1.2 is planned for December 1996.

Current Specifications

Tables 4-19 through 4-21 present major HDTV technical specifications.

Table 4-19
Grand Alliance Specification

	Specification
Resolutions and Frame Rates	1280 x 720; progressive 24-, 30-, 60 frames per second 1920 x 1080; progressive 24-, 30 frames per second 1920 x 1080; interlaced 60-frames per second
Video Compression	MPEG-2 main level, high profile
Audio Compression	Dolby AC-3 digital audio (ACATS standard A/52)
Modulation	8-VSB
Data Rate	20 Mbps
Bandwidth	6-MHz bandwidth per channel (cable version can fit two HDTV signals within 6 MHz)
Others	188-byte MPEG-2 transport packets, packetized data transport structure with headers and descriptors; 4-byte header, 184-byte payload HDTV signal will be compressed by a factor of more than 60 to 1, from 1.2 billion bits per second to less than 20 million bits per second.

Source: Dataquest (December 1995)

Table 4-20
SDTV Specification

	Specification
Resolutions	640 x 480 (4:3 aspect ratio, VGA) 704 x 480 (16:9 aspect ratio, CCIR Rec. 601)
Frame Rates	60 interlaced fields per second, 24-, 30-, and 60 frames per second (progressive)
Video Compression	MPEG-2 main level, main profile
Audio Compression	Dolby AC-3 digital audio
Modulation	8-VSB

Source: Dataquest (December 1995)

Table 4-21
DAVIC 1.0 Specification

	Specification
Resolution	640 x 480
Video Compression	MPEG-2 main level, main profile
Audio Compression	Musicam
Modulation	64-QAM for hardwired networks (cable and telco)
Upstream Data Rates	1.544 Mbps and 256 Kbps

Source: Dataquest (December 1995)

Receiver Production and Market

Dataquest's forecast for worldwide production of HDTV receivers is shown in Table 4-22 and Figure 4-14. The North American market and production forecasts are presented in Tables 4-23 and 4-24, respectively. Table 4-25 shows sizes and prices for current HDTV models on the market. The following are some notes about market and production trends:

- Full-scale broadcasting of Hi-Vision HDTV is planned to start in 1997.
- Matsushita announced in August 1995 that it will be raising production of HDTV receivers from 4,000 per month to 10,000 per month. This will mean full capacity for its Ibaraki factory in Osaka Prefecture.
- 1995 sales of color TVs in Japan equaled 8.4 million units (EIAJ); wide-screen TVs (HDTV and NTSC) represented 3 million to 4 million of those units. In 1993, 1.4 million wide-screen units were sold. Some wide-screen TVs from Hitachi and Matsushita will now include a MUSE-to-NTSC converter.
- By April 1995, 30,000 MUSE receivers had been sold, as well as 100,000 MUSE-to-NTSC converters.

Manufacturers of HDTV Sets

Manufacturers of HDTV receivers are as follows:

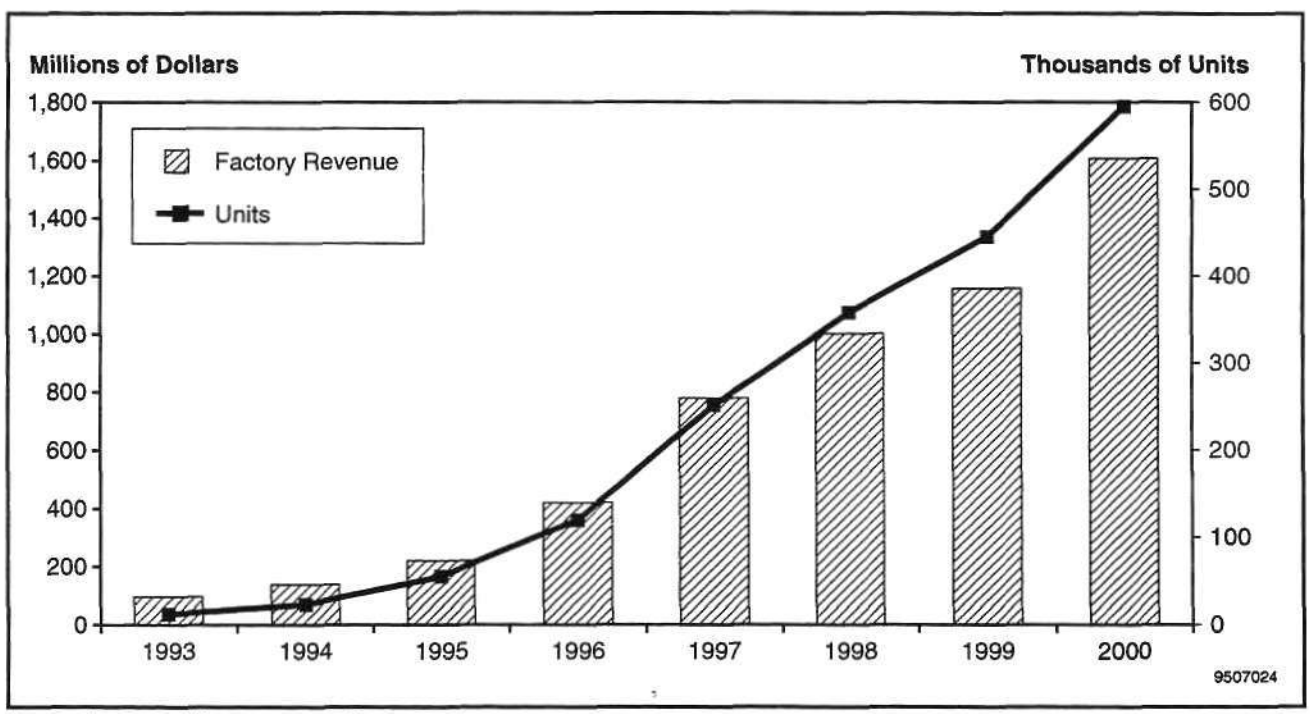
- Sony (also front- and rear-projection models)
- Toshiba
- Matsushita (Panasonic, JVC brands, also rear-projection models)
- Mitsubishi (also front- and rear-projection models)
- Sanyo
- Sharp (also front-projection models)
- Hitachi (also rear-projection models)
- Ikegami (also front-projection models)

Table 4-22
Worldwide HDTV Receiver Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	12	23	55	120	251	358	445	595	61.0
Factory ASP ($)	8,000	6,000	4,000	3,500	3,100	2,800	2,600	2,700	-7.6
Factory Revenue ($M)	96	138	220	420	778	1,002	1,157	1,607	48.8
Semiconductor Content ($)	700	540	450	400	363	340	315	300	-7.8
Semiconductor TAM ($M)	8.4	12.4	24.8	48.0	91.1	121.7	140.2	178.5	48.5

Source: Dataquest (December 1995)

Figure 4-14
Worldwide HDTV Receiver Production Forecast



Source: Dataquest (December 1995)

Table 4-23
North American HDTV Receiver Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1997-2000
Units (K)	0	0	0	0	1	8	15	35	227.1
Factory ASP ($)	0	0	0	0	3,100	2,800	2,600	2,700	-4.5
Factory Revenue ($M)	0	0	0	0	3	22	39	95	212.4

Source: Dataquest (December 1995)

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Table 4-24
North American HDTV Receiver Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1997-2000
Units (K)	0	0	0	0	1	8	15	35	227.1
Factory ASP ($)	0	0	0	0	3,100	2,800	2,600	2,700	-4.5
Factory Revenue ($M)	0	0	0	0	3	22	39	95	212.4
Semiconductor Content ($)	0	0	0	0	363	340	315	300	-6.2
Semiconductor TAM ($M)	0	0	0	0	0.4	2.7	4.7	10.5	207.0

Source: Dataquest (December 1995)

Table 4-25
Sizes and Prices of HDTV Sets (Fourth Quarter of 1995)

Size	Type	Price (Yen)
20 Inches	MUSE-to-NTSC only	-
24 Inches	MUSE-to-NTSC only	-
28 Inches	Hi-Vision HDTV	400,000
32 Inches	Hi-Vision HDTV	500,000
36 Inches	Hi-Vision HDTV	700,000
52 Inches	Rear Projection	750,000
60 Inches	Rear Projection	-
70 Inches	Rear Projection	-
Up to 200 Inches	Front-Screen Projection (Mitsubishi and Sony are the leaders)	

Source: Dataquest (December 1995)

Semiconductor Opportunities

Clearly, HDTVs will be a semiconductor-rich opportunity. Increasingly, intellectual property in DSP-based digital transmission, video manipulation, compression, and audio, to name a few areas, will be crucial for market participation. Key chip function opportunities include the following:

- Digital tuning (MCU controlled)
- Demodulation circuits for VSB
- Moving Picture Expert Group (MPEG)-2 video decoder
- Digital video processing
- Forward error correction
- Transport depacketizer
- AC-2 (Dolby) six-channel CD audio decode
- Audio DAC and amplification
- 1MB to 2MB DRAM for decompression buffer
- Video RAMDAC (10 bit, 135 MHz)
- Infrared on-screen control display controls

- Closed captioning/ghost cancellation circuits
- Optionally: modem interfaces (for interactivity) and decryption

DVD (Digital Video Disc) and Video-CD

In September 1995, Philips, Sony, and Toshiba announced an agreement to develop a single standard for the high-density digital video disc. DVD is the next generation of compact disc technology that is predicted to impact significantly the world of consumer VCRs, as well as computer delivery of digital content, because of its several-gigabyte storage capabilities. The standard puts an end to a format war between two camps that was similar to the one that occurred in the early 1980s between the opposing consumer videotape camps, beta and VHS.

The agreement ended almost 10 months of format competition between the two primary camps: Multimedia CD (MMCD), led by Sony and Philips, and the Superdensity (SD) alliance, led by Toshiba, Matsushita, and Time Warner. The agreement between the two camps began lengthy negotiations to develop the final specification for DVD. From the perspective of the different manufacturers, perhaps the most important issue to be resolved is intellectual property rights. An immediate difficulty is the sheer number of companies involved in the DVD-format unification. At least nine have staked claims to become license holders: Sony, Philips Electronics, Thomson Multimedia, Hitachi, Matsushita, Toshiba, Mitsubishi, Pioneer, and JVC. In the announcement of the initial agreement, the parties stated their intent to release a final specification in December 1995. Delays in a final specification could affect the goal of bringing DVD players to the market in 1996. A preliminary forecast for the worldwide DVD market based on currently available information is presented in Table 4-26 and Figure 4-15. Some of the important elements of the DVD format that have been agreed to are as follows:

- 4.7GB per layer, single- and/or double-layer and side
- Backward-compatibility with all current CDs
- MPEG-2 the compression specification choice
- Compatibility between computer-based and consumer-based (television) products
- Technical specifications
- 0.6mm x 2 substrate thickness, bonded disc
- EFM Plus modulation/demodulation
- Reed-Solomon error-correction code

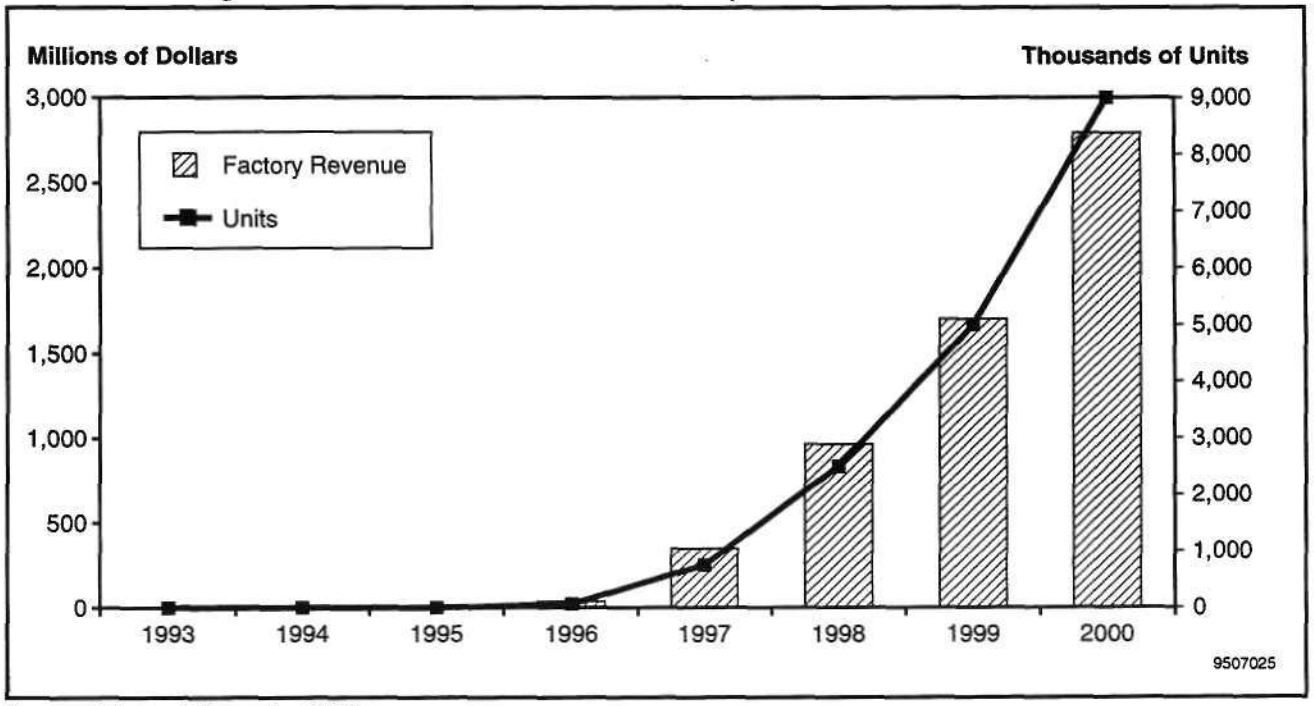
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Table 4-26
Worldwide Digital Video Disc Preliminary Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	0	0	0	60	750	2,500	5,000	9,000	NM
Factory ASP ($)	0	0	0	575	460	385	340	310	NM
Factory Revenue ($M)	0	0	0	35	345	963	1,700	2,790	NM
Semiconductor Content ($)	0	0	0	145	115	97	88	85	NM
Semiconductor TAM ($M)	0	0	0	8.7	86.3	242.5	440.0	765.0	NM

NM = Not meaningful
Source: Dataquest (December 1995)

Figure 4-15
Worldwide Digital Video Disc (DVD) Preliminary Production Forecast



Source: Dataquest (December 1995)

Some of the important issues related to the rollout and development of DVD players are as follows:

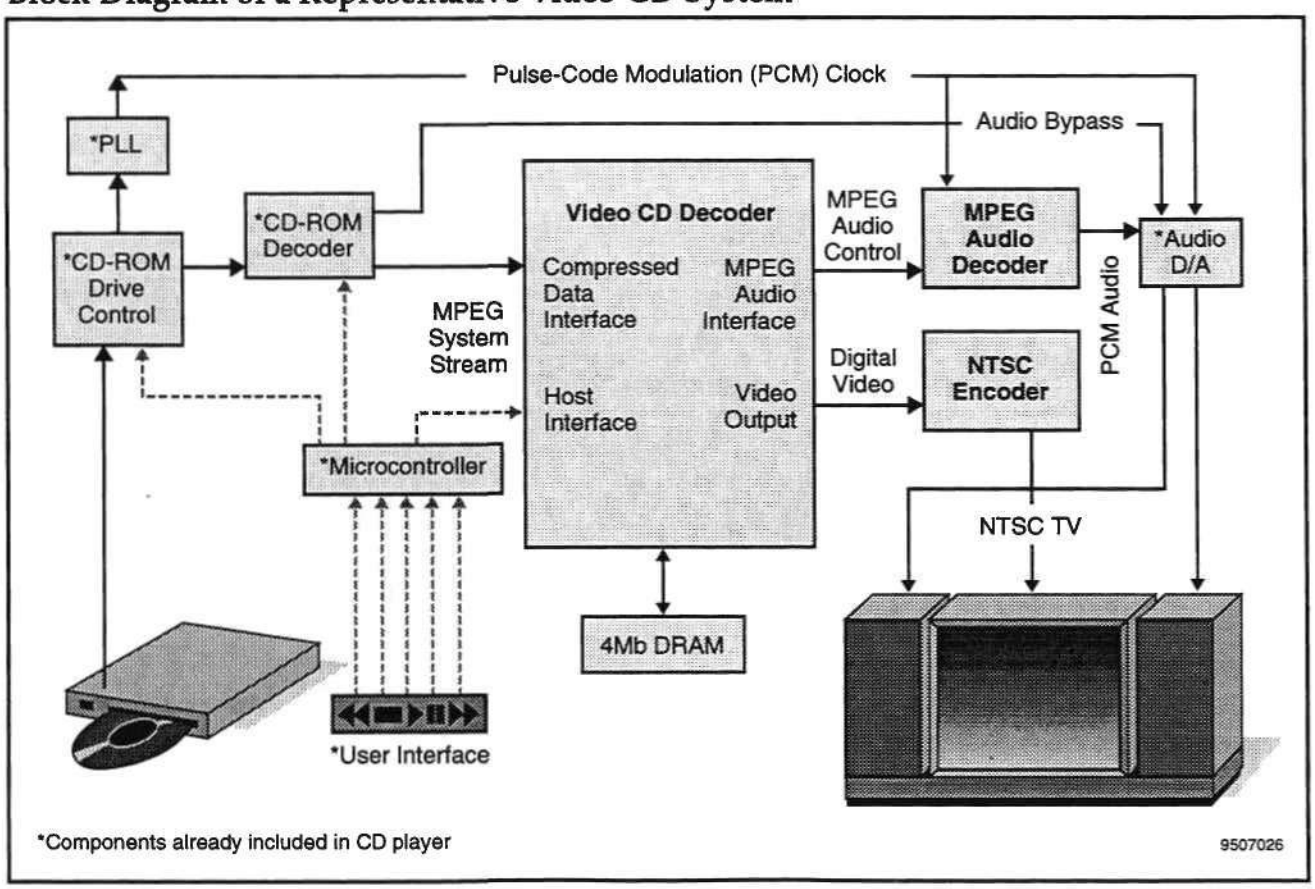
- Initial pricing for DVD players was targeted at $500. It appears that the initial players will have a hard time hitting that price, and it will probably be closer to $600. Critical components such as the red-laser diodes will drive higher initial costs; as they come down the price curve, it will be possible to lower system prices.
- There are concerns about the availability and supply of 635/650nm red-laser diodes, which are a key element in DVD's high-density storage capacity. Prototype and sample diodes were produced in 1995; however, manufacturers are still wavering about when volume production will be possible. Although this is a concern for manufacturers anxious to ramp production of DVD players quickly, it is not certain that market

demand will materialize to meet the production plans of DVD manufacturers during 1996 and 1997. Pricing will be a hurdle in early market growth.

- Initially, players will be ROM only and eventually RAM and erasable. The draft format of a rewritable disc called the DVD-RAM was determined in late 1995. The rewritable DVD-RAM uses phase change technology to store information, applying heat from the laser to change the recording layer from a polycrystalline structure to an amorphous state. The draft specification calls for a capacity between 2.6GB and 3GB, with the wavelength of the laser diode in the range of 650nm to 680nm.

The early-generation video disc player, Video-CD, continues to show promising growth, particularly in the Japan and Asia/Pacific karaoke market. These players use MPEG-1 technology and allow 74 minutes of storage for full-motion video. Figure 4-16 shows a block diagram for a Video-CD system. A DVD system will be similar to this diagram, with key differences being the use of 16Mb of DRAM and MPEG-2 technology. At 352 x 240/288 pixels, Video-CD's resolution is limited but could still find applications in portable players and minicomponent systems, many of which will use LCD displays. There are currently about 30 Video-CD models and 900 software titles available in Japan. One of the major manufacturers, Sharp, expects the market for MPEG-1-based Video-CD players to

Figure 4-16
Block Diagram of a Representative Video-CD System



Source: Dataquest (December 1995)

reach 400,000 units in 1995 and 900,000 units in 1996. C-Cube Microelectronics announced major design-wins for its MPEG decompression chips in Sony and Sharp Video-CD players. C-Cube has set an aggressive schedule to narrow the ultimate cost differential between audio CD and Video-CD systems to $30. Its initial MPEG-1 devices should allow manufacturers to produce Video-CD players for about $100 over the cost of audio CD products. The company hopes to halve that to $50 by 1997.

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Chapter 5
Interactive Products and Personal Electronics

Interactive consumer products include those that allow users real-time control of information presented on the TV screen. The primary examples covered here include interactive television and associated set-top decoder boxes and video games. Some visionaries are projecting that these technologies may merge at least partially in the coming decade with each other or with the standard TV set.

Interactive Television and Set-Top Box Definitions

"Set-top box" is a generic term that means different things to different industries. The seven product categories presented in Table 5-1 have all been referred to as "set-top boxes," based merely on their location in relation to the TV set.

This section will focus on the first category, pay TV receivers. Within the combined pay TV industries, the terminology used is "subscriber terminal." Figure 5-1 presents a diagram of an interactive system that shows how a subscriber terminal would be used in a cable, satellite, or telephone system. The following terms are also synonymous with pay TV receivers:

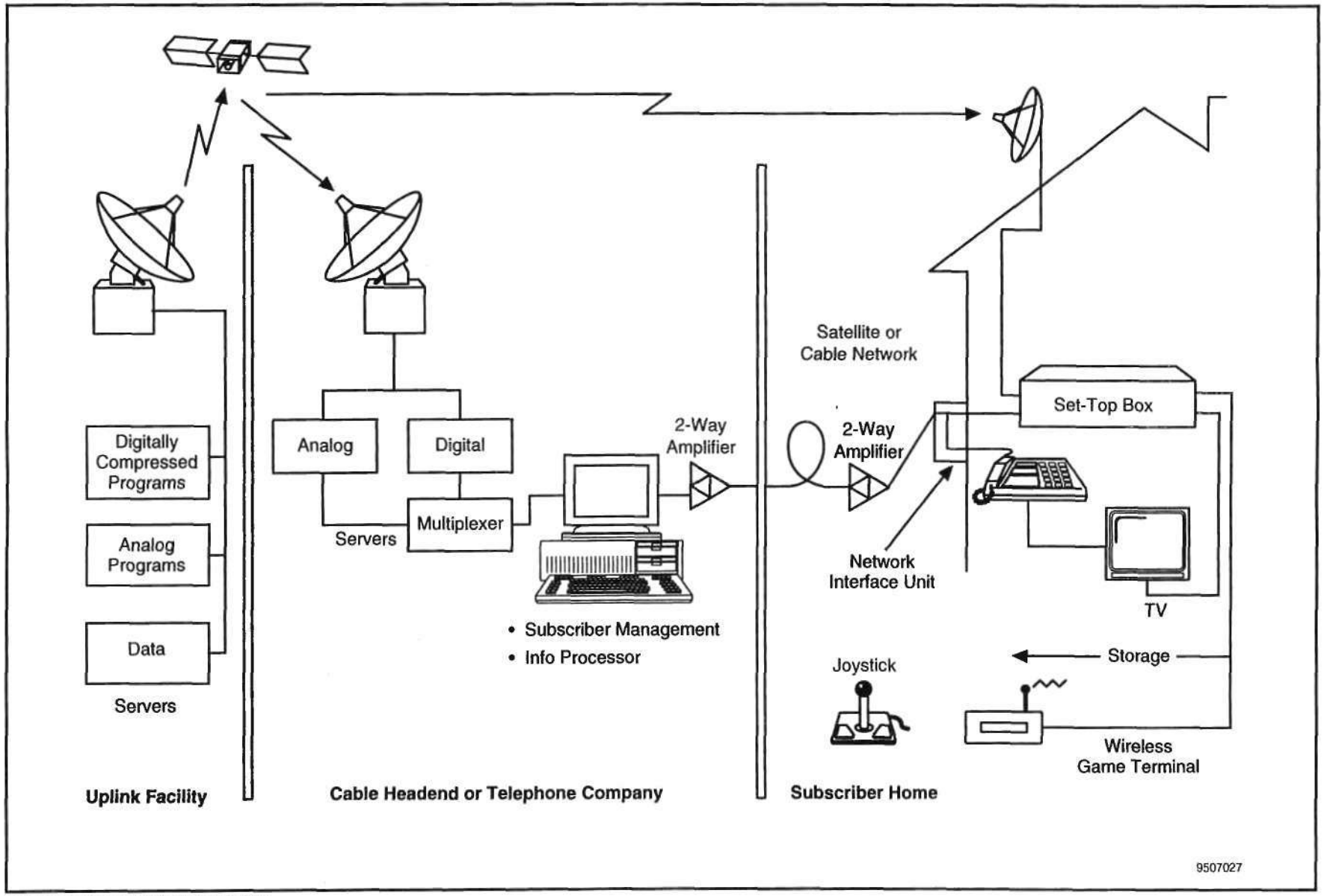
- Integrated receiver/decoder (IRD): satellite industry
- Customer-premises equipment (CPE): telco industry
- Subscriber terminal, cable converter: cable industry
- Compuverter, pay TV receivers

Table 5-1
Descriptions of Various Products Referred to as "Set-Top Boxes"

Product	Description
Pay TV Receivers	Includes cable, DBS, C-band satellite, MMDS, LMDS, and now telco
Dedicated Game Consoles	Examples: Sony PlayStation and Sega Saturn
Read-Only Multimedia Computers	Examples: 3DO and Philips CD-I. Formerly known at Dataquest as TV CD-ROM players. This category is being replaced by dedicated game consoles.
Backchannel Transmitters	Allow user to play along with networked sports and game shows—TV Answer, for example
Audio and Data Decoders	Used for nonvideo signals transmitted out-of-band in the vertical blanking interval, in-band video, or in-band audio. Include digital cable radio and closed captioning.
Navigational Systems	A special type of data decoder for electronic programming guides. Dedicated hardware systems exist, but most are being integrated into pay TV receivers. Examples include StarSight, Prevue Network, and Interactive TV Guide
Data Storage Devices	Examples are VCR-Plus and Sega Channel Game Adapter

Source: Dataquest (December 1995)

Figure 5-1
Interactive Television Systems



Source: Dataquest (December 1995)

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Subscriber terminals are further divided into the following four subcategories by technology:

- Nonaddressable analog
- Addressable analog
- Advanced analog (includes addressability and upstream communications)
- Digital

A digital set-top box includes a digital video decoder for receiving digitally-encoded TV signals. The compression schemes are typically MPEG-2, but also include General Instrument's DigiCipher I and DigiCipher II. The difference between addressable analog boxes and advanced analog boxes is that advanced boxes also include an embedded modem for upstream communications. Embedded modems are the basic semiconductor components for receiving interactive services. Cable modems fall into a separate category, more closely related to PC modems than to set-top boxes. As subscriber terminals move from nonaddressable to addressable to advanced analog and finally to digital, almost every major component maker is eyeing this market as a major application area.

Markets for Subscriber Terminals

The following six network systems represent potential markets for subscriber terminals:

- Cable TV
- C-band satellite (also known as full-view satellite)
- Ku-band satellite (also known as DBS and DTH)
- Wireless cable (also known as MMDS)
- Cellular cable (also known as LMDS)
- Telco

Production and Market Forecast

Analog terminals will be buoyed temporarily by new sales in the wireless cable market. However, shipments of new digital terminals will overtake their analog predecessors by 1997. Now the cable industry is planning to introduce hybrid boxes capable of receiving both analog and digital signals. Because these boxes will include the expensive digital decoders and demodulators, we have included their projected sales in the digital terminals category.

Because of the controlled nature of the cable equipment business, analog converter boxes have maintained their selling price of about $105 for the last 10 years! As digital boxes become more prevalent, the average selling prices (ASPs) for analog boxes will finally begin to erode. There is a significant opportunity for system makers to reduce both the costs and the margins for DBS receivers over time. In fact, manufacturers will need to do just that in order to increase the size of their market from innovators to early adopters, and possibly to the mass market.

Tables 5-2 through 5-4 show Dataquest's forecast for worldwide analog set-top box production, the North American analog set-top box market, and North American analog set-top box production, respectively. Figures 5-2, 5-3, and 5-4 and Table 5-5 present the forecast for worldwide digital cable and satellite set-top box production, average selling price, and revenue. Tables 5-6 and 5-7 show the North American market and production forecast for digital set-top boxes.

Table 5-2
Worldwide Analog Cable/Satellite Set-Top Box Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	10,719	12,233	11,505	11,388	10,200	7,591	7,030	6,839	-9.9
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0
Factory Revenue ($M)	1,104	1,382	1,312	1,127	887	594	527	486	-18.0
Semiconductor Content ($)	42	46	47	41	38	35	32	30	-8.6
Semiconductor TAM ($M)	450.2	562.7	540.7	466.9	387.6	265.7	225.0	205.2	-17.6

Source: Dataquest (December 1995)

Table 5-3
North American Analog Cable/Satellite Set-Top Box Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	4,860	5,490	4,500	4,230	3,600	2,700	2,250	1,710	-17.6
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0
Factory Revenue ($M)	501	620	513	419	313	211	169	121	-25.0

Source: Dataquest (December 1995)

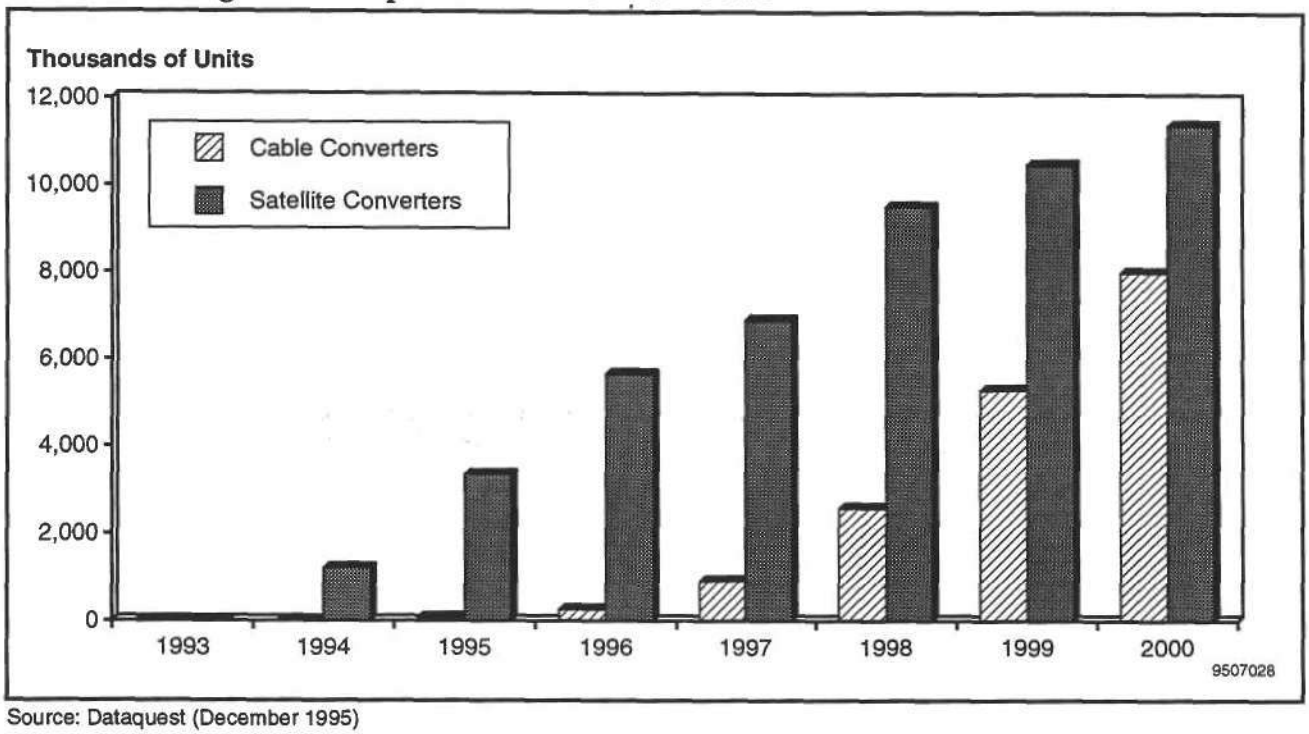
Table 5-4
North American Analog Cable/Satellite Set-Top Box Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	5,400	6,100	5,000	4,700	4,000	3,000	2,500	1,900	-17.6
Factory ASP ($)	103	113	114	99	87	78	75	71	-9.0
Factory Revenue ($M)	556	689	570	465	348	235	188	135	-25.0
Semiconductor Content ($)	42	46	47	41	38	35	32	30	-8.6
Semiconductor TAM ($M)	226.8	280.6	235.0	192.7	152.0	105.0	80.0	57.0	-24.7

Source: Dataquest (December 1995)

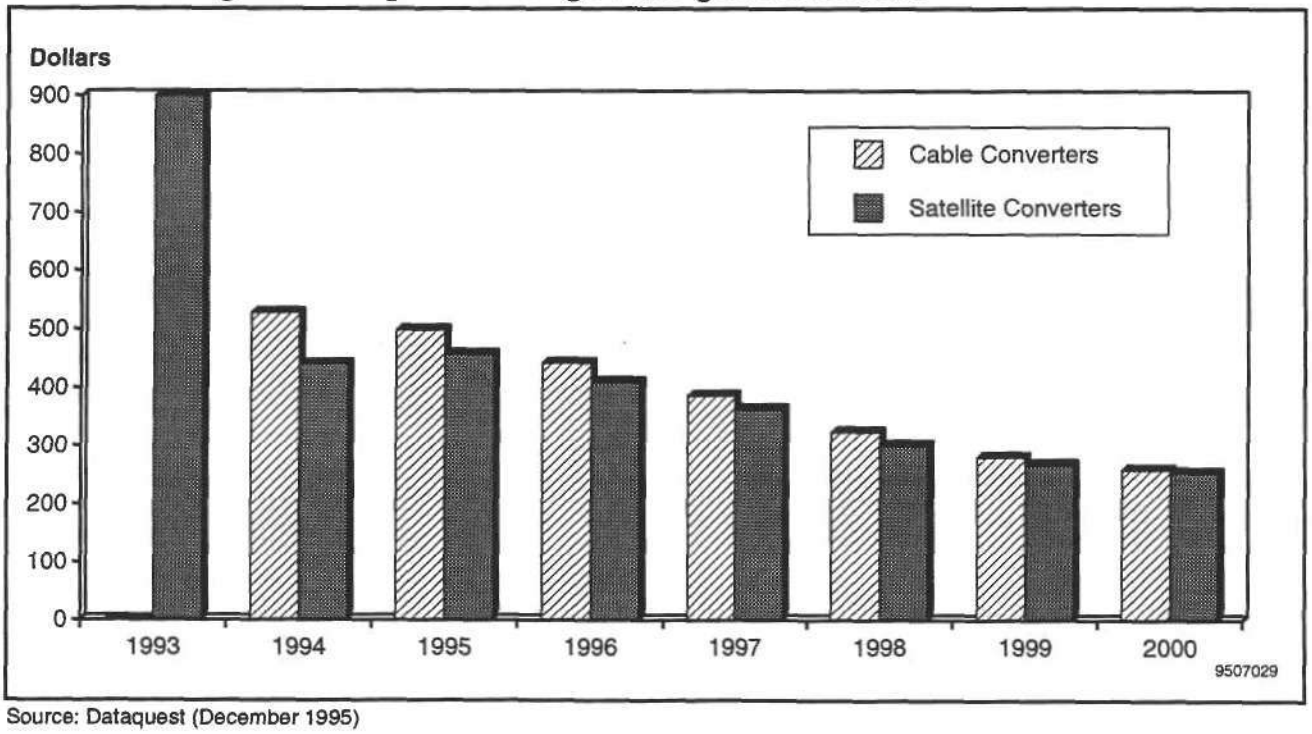
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Figure 5-2
Worldwide Digital Set-Top Box Production Forecast



Source: Dataquest (December 1995)

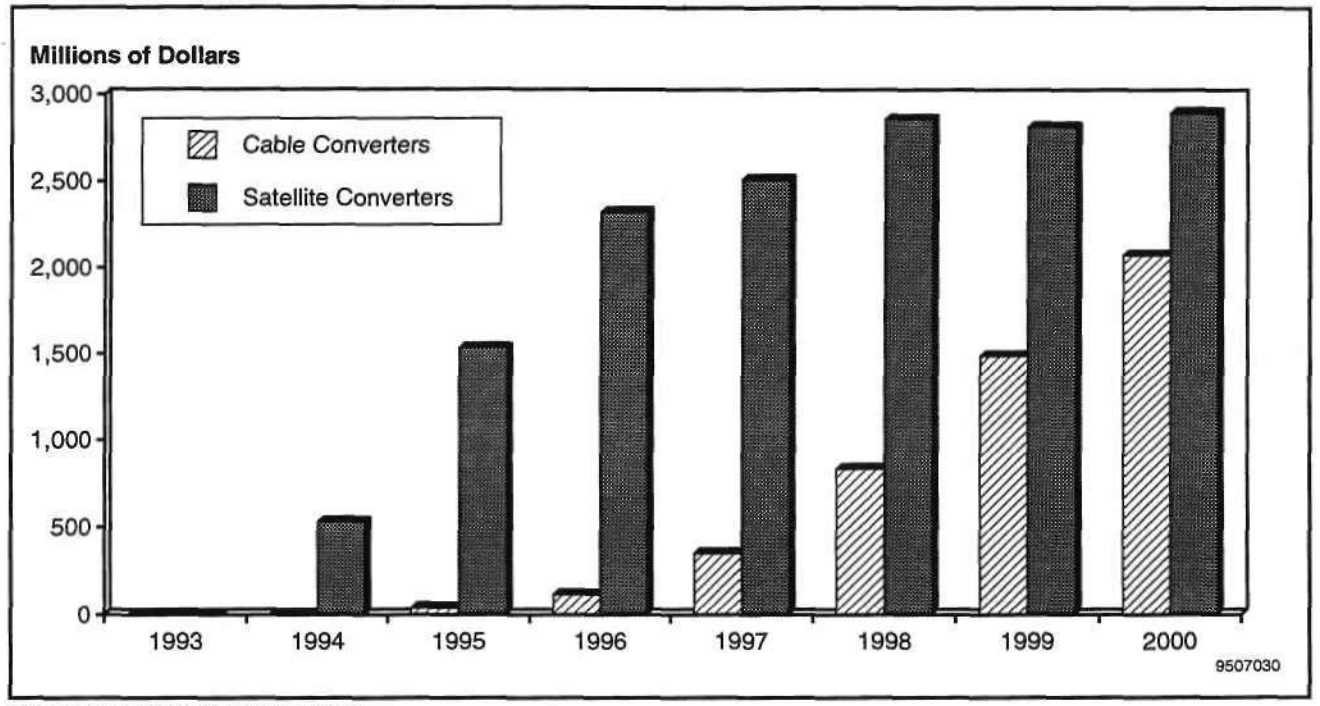
Figure 5-3
Worldwide Digital Set-Top Box Average Selling Price Forecast



Source: Dataquest (December 1995)

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Figure 5-4
Worldwide Digital Set-Top Box Revenue Forecast



Source: Dataquest (December 1995)

Table 5-5
Worldwide Digital Cable and Satellite Decoder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Cable Converters									
Units (K)	0	7	77	260	907	2,580	5,300	8,000	153.1
Factory ASP ($)	0	528	499	442	386	323	280	259	-12.3
Factory Revenue ($M)	0	4	38	115	351	834	1,485	2,069	121.9
Semiconductor Content ($)	0	236	204	183	177	172	168	160	-4.7
Semiconductor TAM ($M)	0	2	16	48	160	444	889	1,282	141.1
Satellite Converters									
Units (K)	1	1,205	3,350	5,656	6,901	9,510	10,490	11,400	27.8
Factory ASP ($)	900	440	458	410	363	300	268	254	-11.1
Factory Revenue ($M)	1	530	1,533	2,318	2,508	2,855	2,811	2,894	13.6
Semiconductor Content ($)	400	223	210	196	187	179	172	165	-4.7
Semiconductor TAM ($M)	0	269	703	1,107	1,291	1,702	1,803	1,880	21.8

Source: Dataquest (December 1995)

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Table 5-6
North American Digital Cable and Satellite Decoder Market Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Cable Converters									
Units (K)	0	5	42	54	96	225	1,350	3,150	136.8
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1
Factory Revenue ($M)	0	2	18	21	33	63	338	756	110.5
Satellite Converters									
Units (K)	0	1,071	2,565	3,600	3,780	4,950	5,400	5,940	18.3
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1
Factory Revenue ($M)	0	467	1,108	1,404	1,304	1,386	1,350	1,426	5.2

Source: Dataquest (December 1995)

Table 5-7
North American Digital Cable and Satellite Decoder Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Cable Converters									
Units (K)	0	5	47	60	107	250	1,500	3,500	136.8
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1
Factory Revenue ($M)	0	2	20	23	37	70	375	840	110.5
Semiconductor Content ($)	0	222	207	194	182	171	162	154	-5.7
Semiconductor TAM ($M)	0	1.1	9.7	11.6	19.5	42.8	243.0	539.0	123.2
Satellite Converters									
Units (K)	0	1,190	2,850	4,000	4,200	5,500	6,000	6,600	18.3
Factory ASP ($)	0	436	432	390	345	280	250	240	-11.1
Factory Revenue ($M)	0	519	1,231	1,560	1,449	1,540	1,500	1,584	5.2
Semiconductor Content ($)	0	222	207	194	182	171	162	154	-5.7
Semiconductor TAM ($M)	0	264.2	590.0	776.0	764.4	940.5	972.0	1,016.4	11.5

Source: Dataquest (December 1995)

Technology Requirements

Figure 5-5 presents a generic block diagram of the type of technology required in interactive terminals. A generic set-top box will require a variety of technologies ranging from RF to CMOS (see Table 5-8). Likewise, the opportunities will range from standard products to ASICs as the box OEMs differentiate through design and cost structure. There are many layers of software involved and companies like Microsoft are heavily involved in creating standard application program interfaces (API) to handle the various application programs managing the interactive services. The communication features are initially designed as modules that upgrade the basic terminal.

As shown in Table 5-9, the interactive terminal will require more features in the coming years including embedded two-way capability, greater

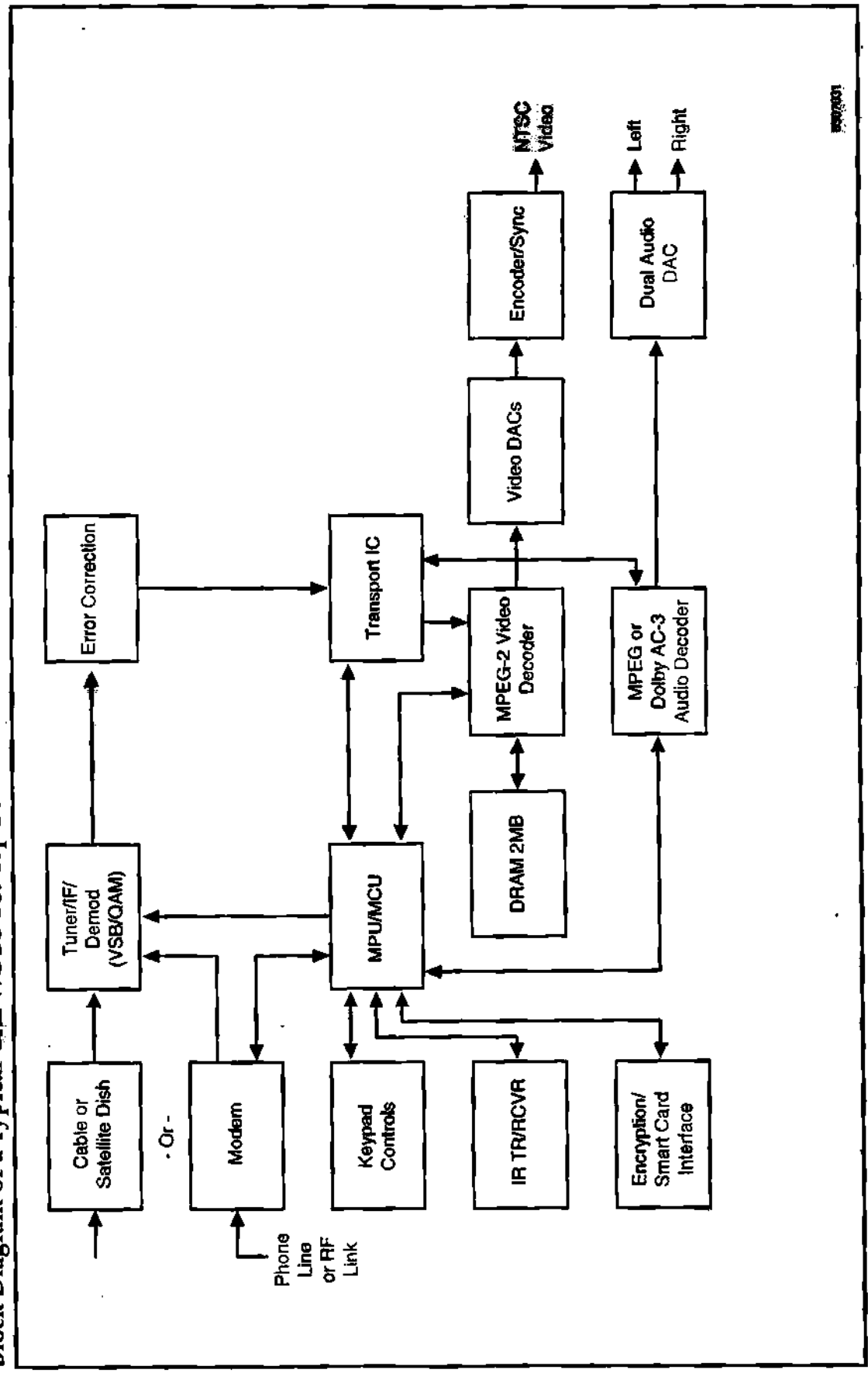


Figure 5-5
Block Diagram of a Typical CATV/DBS Set-Top Box

Source: Dataquest (December 1995)

Table 5-8
Semiconductor Opportunities in Interactive TV

Semiconductor Function	Technology
Broadband Up/Down Conversion	Bipolar/GaAs
IF Processing	Bipolar
Modulation/Demodulation (VSB, QAM)	CMOS, Bipolar
ATM/Sonet Physical	Opto, Bipolar, and BiCMOS
ATM/Network Protocol	CMOS
Transport Layer and Error Correction	CMOS
Video Standard Decode/Encode	Bipolar/CMOS
Video DAC	Bipolar
Video Conversion, Scaling	CMOS
Video Compression (MPEG-2, DigiCipher)	CMOS
Audio Conversion	Bipolar/CMOS
Audio Compression (AC-3, MPEG)	CMOS
DRAM	CMOS
VRAM/Field memory	CMOS
Fast DRAM (SDRAM, FRAM)	CMOS
SRAM	CMOS
MPU (32/64-Bit RISC)	CMOS
Encryption (Decryption) Functions	CMOS
Modem (up to V Fast)	CMOS
ASICs (for Above Functions)	CMOS/Bipolar

Source: Dataquest (December 1995)

Table 5-9
Interactive Television Technology Evolution

Category	1993	1995	1997
Transmission	Cable: analog; cable: digital test, 80 channels, FM subcarrier; fiber-optic/ADSL tests	Cable: analog/digital, 500 channels, IVDS, FM, VBI; Fiber-optic, ATM tests; QAM	Cable/DBS: digital/ two-way, IVDS, FM, VBI; fiber-optic, ATM; QAM
Processing	Addressing, pay-per-view; DBS down conversion; bipolar/CMOS ASIC	Digital video, audio; MPEG decompression, error correction; bipolar/ CMOS ASIC	Digital video, audio; MPEG decompression, error correction; bipolar/ CMOS ASIC
Memory	Minimal	2MB	2MB
Others		Modular design; security/ decryption; digital radio	Modular design; security/ decryption

Source: Dataquest (December 1995)

processing power, and supporting higher bandwidth transmission links. We expect the set-top box of 1995 to be capable of digital reception, decompression, and audio/video processing. The video decompression standard will be a version of MPEG-2, and audio decompression will be Dolby AC-3 or MPEG. Line transmission opportunities include 8-level vestigial side band (8 VSB) or higher or 64-level QAM or higher. Error correction will be needed to clean up the fast-moving bit stream, decryption for privacy, and a transport layer function for network overhead.

Approximately 2MB of DRAM or tailored field memory will be required for buffering. Many of the functions will be ASIC-based initially with the overall design controlled by the decoder box companies. Eventually, standard functions will dominate as cost reduction becomes paramount.

Manufacturers and Products

Thomson has emerged as the leading supplier of digital set-top boxes. Figure 5-6 presents a block diagram of Thomson's DirecTV Satellite decoder terminal. In 1994, Thomson Consumer Electronics (also known as Thomson Multimedia) shipped 591,000 DSS systems, of which 498,880 were receiving authorized programming from DirecTV or USSB by March 8, 1995. Table 5-10 displays the worldwide market share for leading manufacturers of digital cable and satellite decoder terminals in 1995.

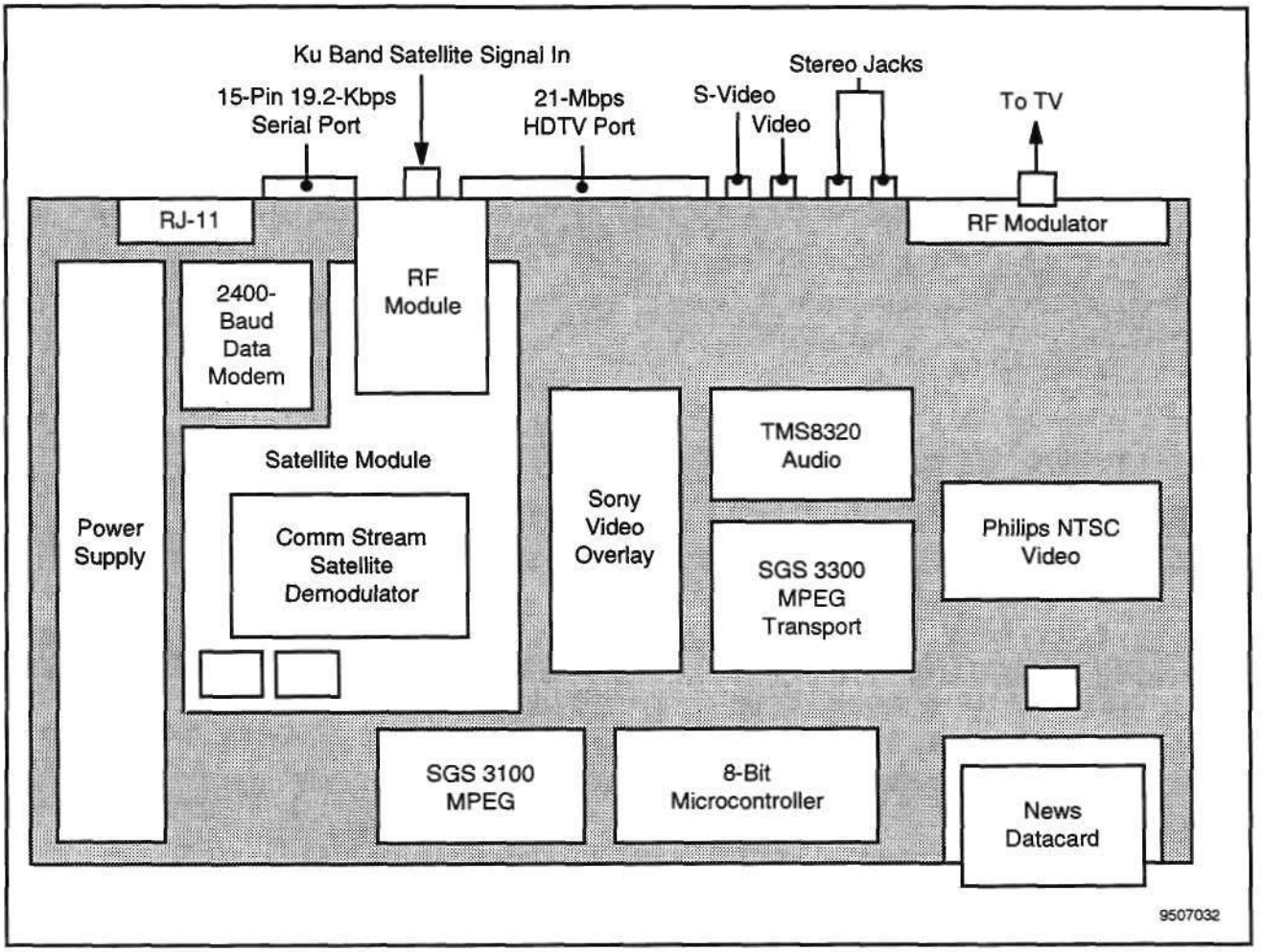
General Instrument has traditionally been the leader in subscriber terminals, producing 3.9 million analog boxes for the cable industry in 1994. Scientific-Atlanta held the No. 2 spot with 1.7 million analog boxes in 1994. In Europe, Pace Micro Technology of West Yorkshire, England, claims to be the leading supplier of analog set-top boxes. Pace supplies boxes for the cable, satellite, and wireless cable markets. The company has recently opened a U.S. office in Denver, Colorado.

We should note that changes occur in the cable equipment market very slowly. For instance, in 1982, GI shipped 2 million analog converter boxes. Eleven years later, in 1993, GI's shipments were up to 3 million units. The cable industry in the United States is slow to change because the nation is wired with a patchwork of 11,460 cable operators, each with a slightly different system.

However, with new network systems for delivering pay TV signals (DBS, wireless, telco), the market has opened up for suppliers from the computer, communications, and consumer electronics industries. For instance, Hewlett-Packard (HP) arrived on the cable scene in a big way in 1994, but soon found out that GI still controlled the head-end equipment and, ultimately, the way data could be transmitted and received.

Sony was the most significant new player to enter the market in 1995. Sony's RCA-DSS-compatible receivers succeeded in displacing HP from the No. 3 spot it held in 1994. Besides Thomson Consumer Electronics and Sony, six more manufacturers have been licensed to manufacture DSS boxes and are expected to begin shipping in 1996. DirecTV Inc., a unit of Hughes Electronics Corporation, is the trademark holder of DSS. Table 5-11 lists advanced subscriber terminals and their manufacturers.

Figure 5-6
Block Diagram of Thomson's DirecTV Box



Source: Dataquest (December 1995)

Table 5-10
Worldwide Digital Cable and Satellite Decoder Revenue Market Share, 1995 (Percentage)

Vendor	Revenue Market Share
Thomson	50.2
General Instrument	35.9
Sony	12.0
Pioneer	1.2
Apple	0.3
AT&T	0.2
Others	0.2
Total	100.0

Source: Dataquest (December 1995)

Table 5-11
Advanced Subscriber Terminal Manufacturers and Their Products (Digital Boxes Unless Otherwise Noted)

Manufacturer	Product
Adaptive Micro-Ware Inc.	DAVID (with Mitsubishi and Stellar One)
Apple Computer Inc.	M4120 (first generation) intend to OEM
AT&T Network Systems	Digital Home Terminal
Compression Labs Inc.	Media Access and Magnitude
Divicom	Navigator 1000
EchoStar Communications	DISH DBS (1996)
General Instrument Corporation	CFT-2000 (analog), CFT-2200 DigiDock, CFT-2900 TCI, Primestar, DigiCipher I, and DigiCable
Hewlett-Packard Co.	Kayak
Hughes Network Systems Inc.	DirectPC, RCA-DSS compatible (1996)
IBM	Videoway Terminal (analog)
LG Electronics (Goldstar)	GIV-101
Mitsubishi Electronics America	STB-1000 (with Adaptive Micro-Ware and Stellar One)
Pace Micro Technology	DGT400
Philips Consumer Electronics	Media Access, Consumer IRDs, and Magnavox for EchoStar
Pioneer North America	BA-9000, BAV-1000 Command Station, BA-6700 for Quantum (these are all analog, digital is Canal Plus DBS in France)
Samsung Electronics America	(No details at press time)
Scientific-Atlanta Inc.	8600xD and 8600xDI (hybrid analog/digital boxes)
Sony Electronics Inc.	DSS SAS-BS1, SAS-BA1, and SAS-AD1
Stellar One Corporation	Stellar 1000 (with Adaptive Micro-Ware and Mitsubishi)
Tee-Comm Electronics Inc.	StarTrak Digital IRD
Thomson Consumer Electronics	RCA DSS-1 and now DSS-2
Toshiba America Corporation	(Components for FSN, RCA-DSS-compatible in 1996)
TV/COM International	(no details at press time)
Uniden	RCA-DSS-compatible (1996)
Zenith Electronics Corporation	Media Access

Source: Dataquest (December 1995)

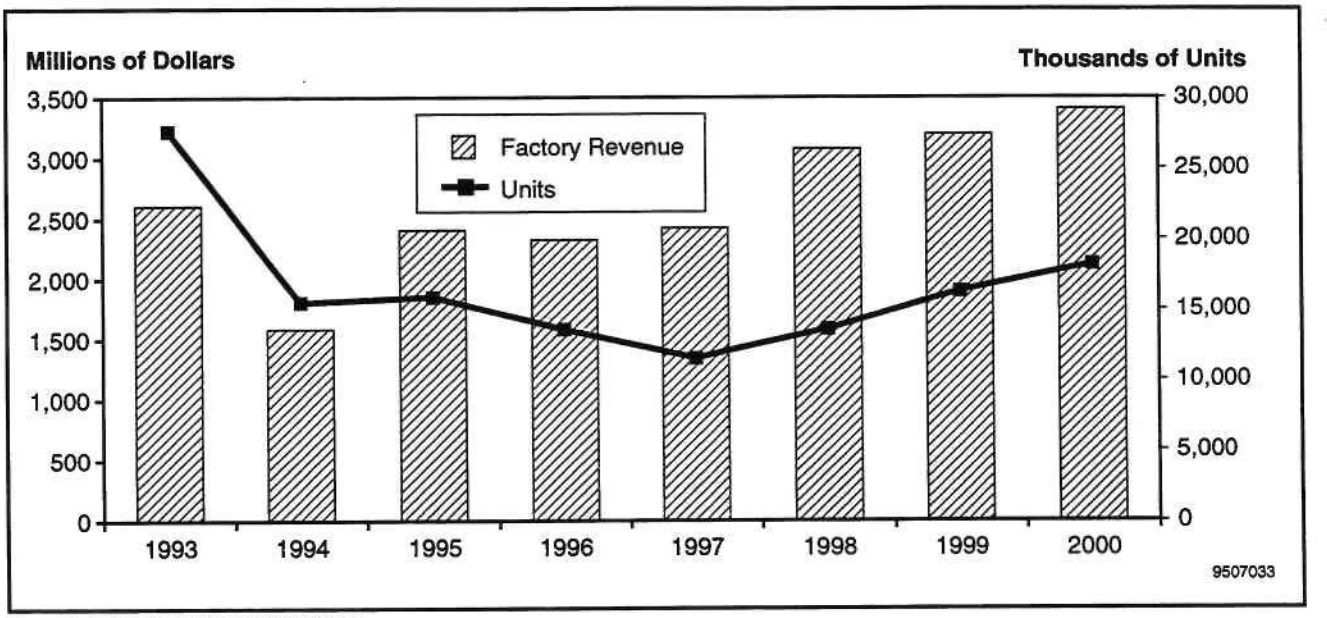
Interactive Video Games

Figures 5-7 and 5-8 and Tables 5-12 through 5-14 present the production forecast for handheld and console video games. Figure 5-9 and Table 5-15 show the production forecast for game cartridges.

Figures 5-10 and 5-11 show the distribution of regional production for video game controllers and game cartridges. Figure 5-12 presents the market share for video game controllers.

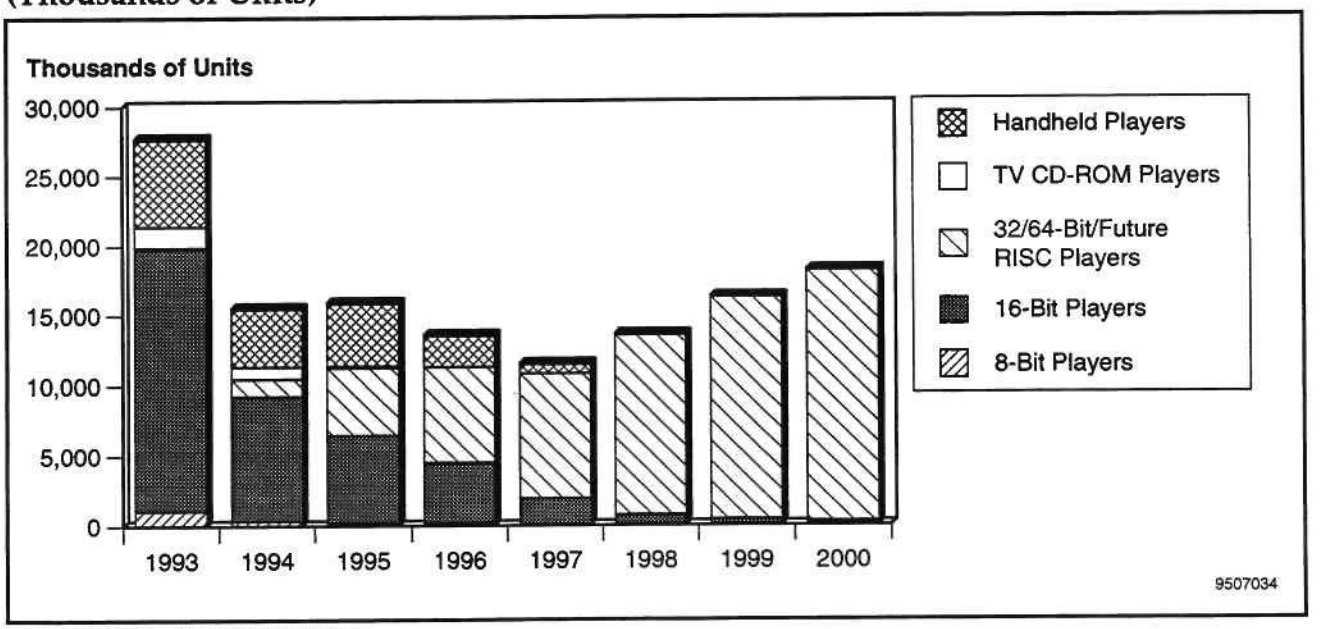
The major news in the video game market during 1995 was the introduction of 32/64-bit next-generation video game controllers by major players in the industry and the entry of Sony into the video game hardware market. Exciting new video game platforms such as Saturn, Playstation, Ultra-64, Virtual Boy, M2, and Jaguar captured the attention of the video game

Figure 5-7
Worldwide Video Game Controller Production Revenue and Unit Shipment Forecast (Millions of Dollar)



Source: Dataquest (December 1995)

Figure 5-8
Worldwide Video Game Controller Unit Shipment Forecast, by Type (Thousands of Units)



Source: Dataquest (December 1995)

Table 5-12
Worldwide Video Game Controller Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	27,641	15,472	15,859	13,532	11,500	13,572	16,266	18,197	2.8
Factory ASP ($)	94	102	152	172	211	227	197	187	4.3
Factory Revenue ($M)	2,605	1,584	2,404	2,323	2,422	3,075	3,196	3,405	7.2
Semiconductor Content ($)	34	45	87	105	136	150	131	124	7.3
Semiconductor TAM ($M)	945	698	1,384	1,420	1,560	2,030	2,128	2,253	10.2

Note: Includes handhelds
Source: Dataquest (December 1995)

Table 5-13
Worldwide Video Game Controller Unit Shipment Forecast, by Type (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
8-Bit Players	1,110	400	280	182	0	0	0	0	-100.0
16-Bit Players	18,710	8,860	6,202	4,341	1,954	781	469	328	-44.5
32/64-Bit/Future RISC Players	100	1,237	4,802	6,809	8,886	12,791	15,797	17,869	30.1
TV CD-ROM Players	1,525	860	120	0	0	0	0	0	-100.0
Handheld Players	6,196	4,115	4,455	2,200	660	0	0	0	-100.0
Total	27,641	15,472	15,859	13,532	11,500	13,572	16,266	18,197	2.8

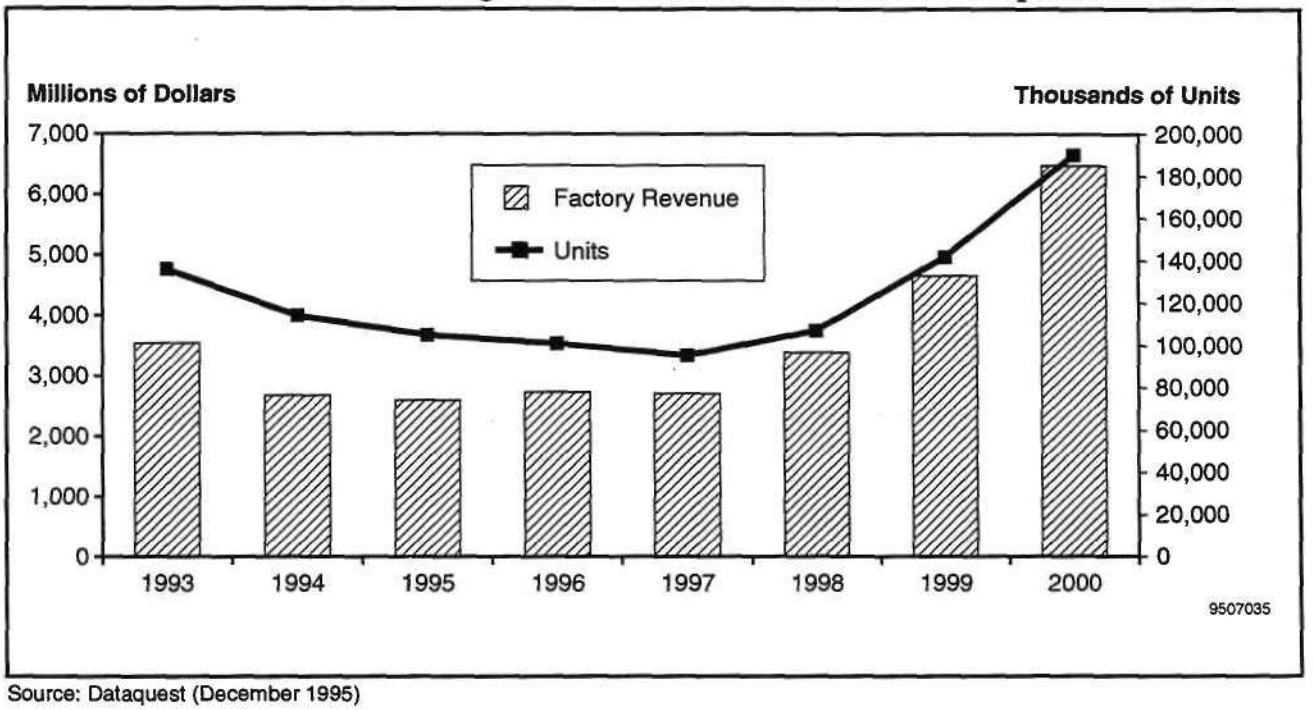
Source: Dataquest (December 1995)

Table 5-14
North American Video Game Controller Production Forecast

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	65	65	80	80	80	85	92	101	4.8
Factory ASP ($)	135	129	123	118	114	109	105	101	-3.8
Factory Revenue ($M)	9	8	10	9	9	9	13	10	0.8
Semiconductor Content ($)	42	40	38	37	35	34	33	33	-2.8
Semiconductor TAM ($M)	2.7	2.6	3.0	3.0	2.8	2.9	4.1	3.3	1.9

Note: Includes handhelds
Source: Dataquest (December 1995)

Figure 5-9
Worldwide Video Game Cartridge Production Revenue and Unit Shipment Forecast



Source: Dataquest (December 1995)

Table 5-15
Worldwide Video Game Cartridge Production Forecast

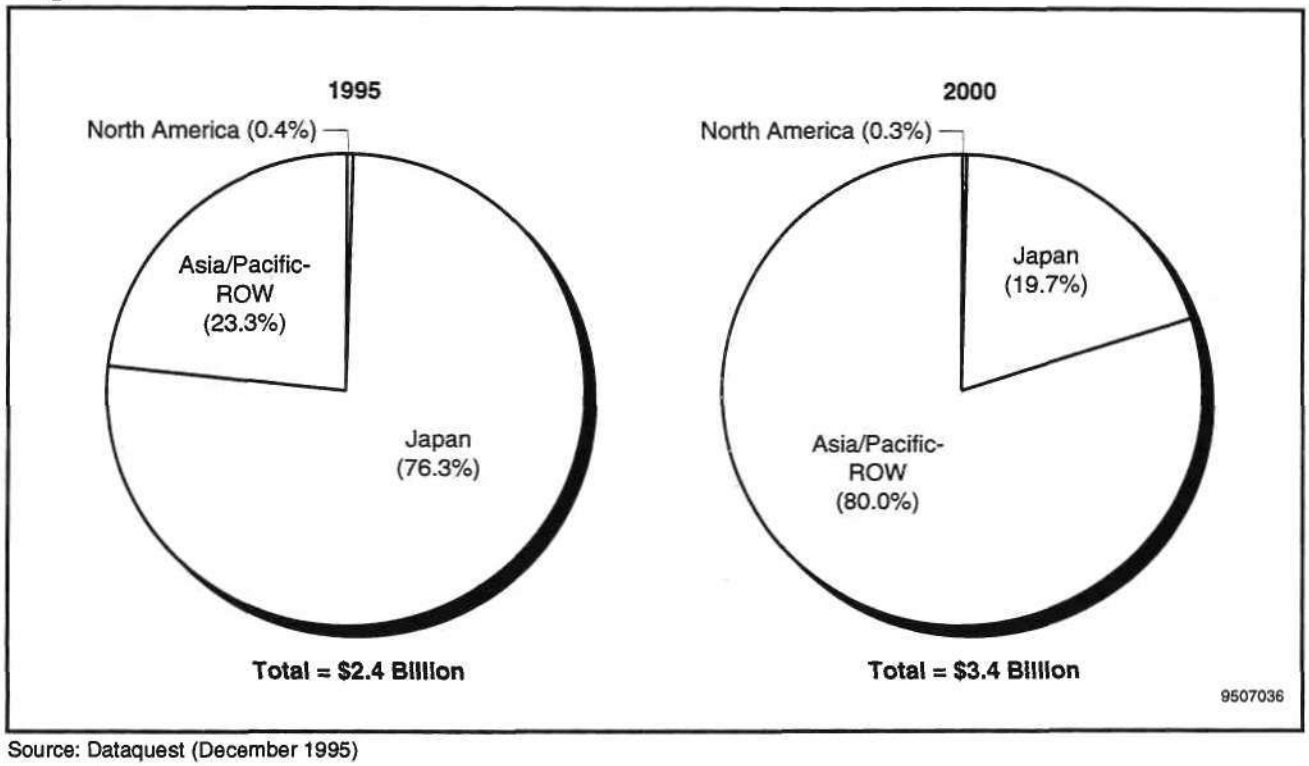
	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Units (K)	135,884	114,077	104,896	100,879	95,210	106,998	141,713	190,107	12.6
Factory ASP ($)	26	23	25	27	28	32	33	34	6.7
Factory Revenue ($M)	3,536	2,676	2,591	2,729	2,704	3,382	4,651	6,480	20.1
Semiconductor Content ($)	9	9	9	10	10	11	11	11	4.9
Semiconductor TAM ($M)	1,222.5	1,003.0	926.4	979.2	979.6	1,131.7	1,543.7	2,133.7	18.2

Source: Dataquest (December 1995)

industry. Following the 8- and 16-bit market cycles, these 32/64-bit controllers are expected to drive the next wave of video game sales and technology.

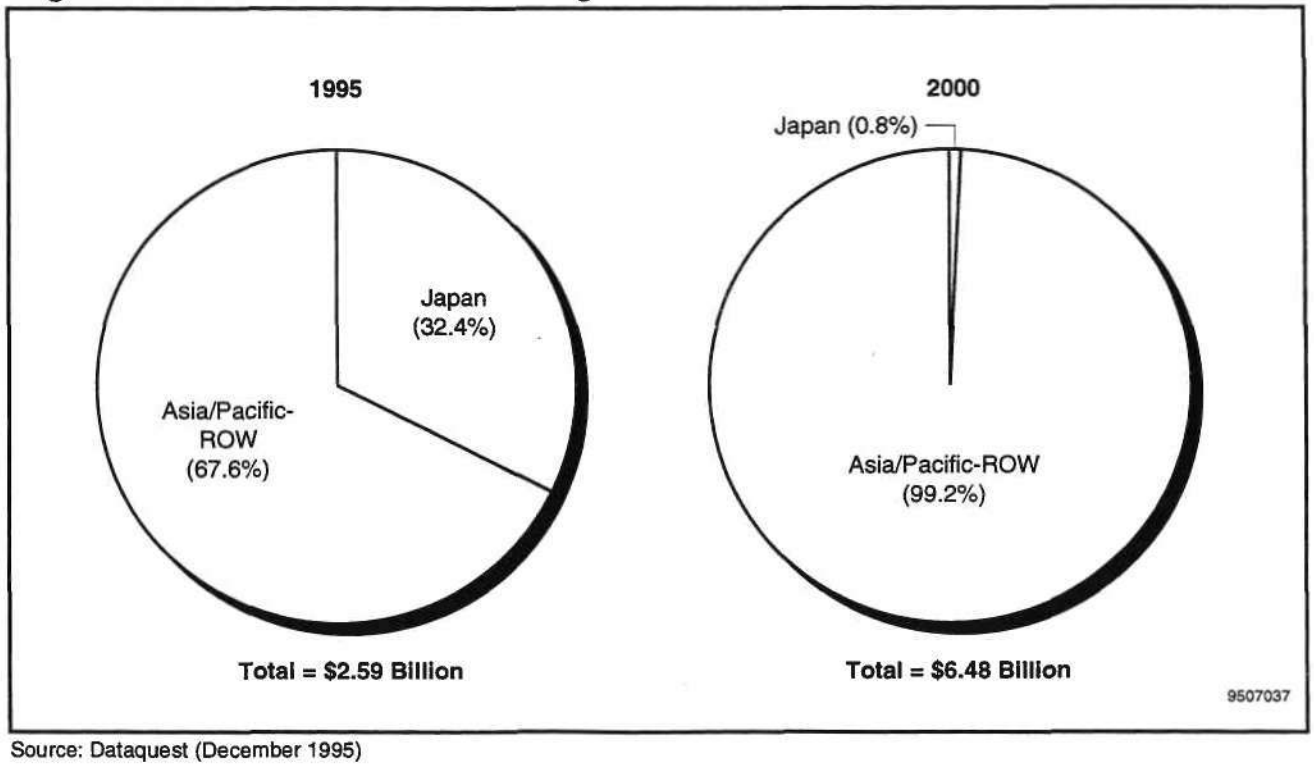
Dataquest predicts that worldwide shipments of these new video game controllers will climb to almost 18 million by the year 2000. With the semiconductor content in this new generation of controllers leaping to over 66 percent of manufacturing cost, the semiconductor market driven by these new video game controllers will reach $2.3 billion by the year 2000. This forecast is based on the average factory price of new video game controllers dropping below $200 by the year 2000. If prices decline more rapidly, the unit shipments and semiconductor market could grow even

Figure 5-10
Regional Share of Video Game Controller Production Revenue



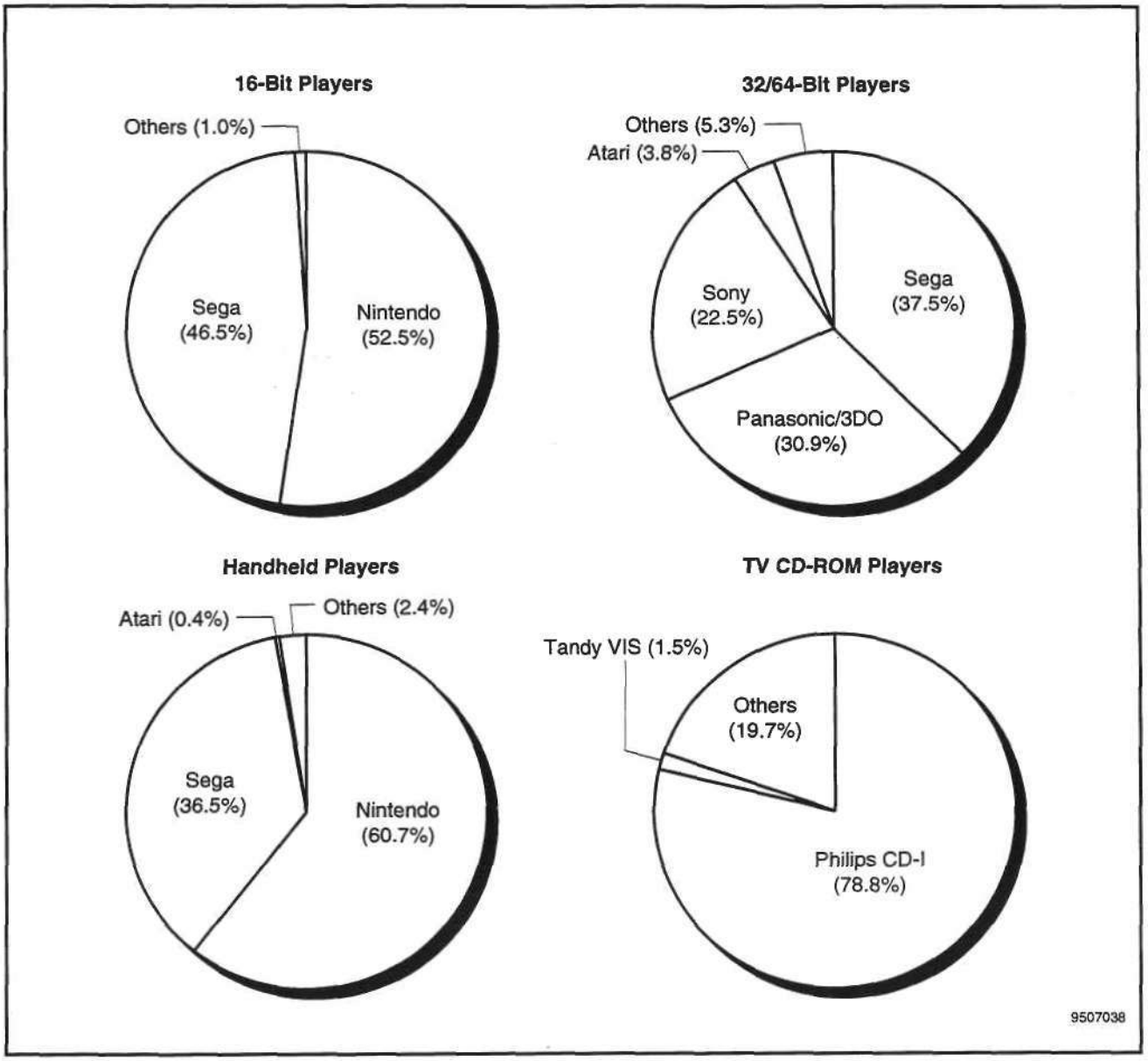
Source: Dataquest (December 1995)

Figure 5-11
Regional Share of Video Game Cartridge Production Revenue



Source: Dataquest (December 1995)

Figure 5-12
Worldwide Video Game Market Share, 1994



Source: Dataquest (December 1995)

larger. Some of the important market, technology, and production trends are as follows:

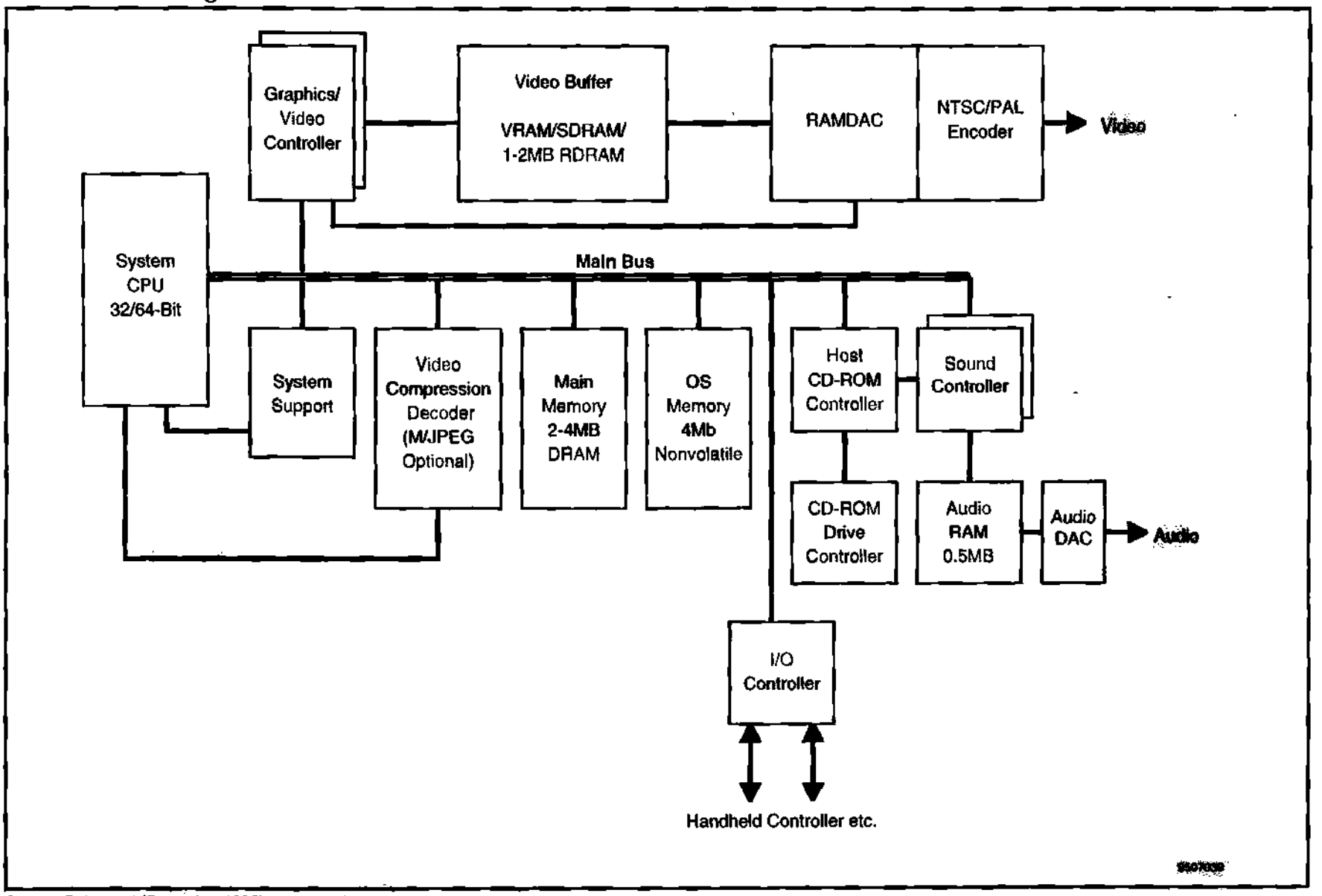
- The higher prices of the new 32-bit video game controllers reduced sales during 1995 and resulted in enhanced 16-bit games capturing the largest market share for software during the 1995 Christmas season.
- Sony entered the video game market with the introduction of its 32-bit Sony PlayStation for $299. This platform uses a CD-ROM drive instead of cartridges for the software. At the heart of the PlayStation is LSI Logic's custom 32-bit R3000 RISC processor.

- Sega launched two new platforms, the Sega Saturn and the Genesis Nomad. The Saturn was introduced in the United States at a price of $399 and also incorporates a CD-ROM drive instead of cartridges. The Saturn employs two 32-bit Hitachi SH2 processors in its design. It has been widely rumored that Sega is considering the PowerPC for future designs. After experiencing lackluster sales, Sega reduced the price to $299 to compete more effectively with the Sony PlayStation. The Genesis Nomad is Sega's first portable 16-bit video game system. It is compatible with the library of more than 600 Sega Genesis game cartridges.
- Nintendo delayed the introduction of its Ultra-64 platform until spring 1996 and focused its energy on the 16-bit market for another year. Initially, this delay was viewed as a serious setback for Nintendo that would make it difficult to recapture market share. However, with the lower-than-expected sales for 32-bit controllers during 1995, Nintendo could capture a significant advantage if its platform can demonstrate solid performance at the $249 price point. There have been some rumors that Nintendo would launch its Ultra-64 for $200. Part of the cost savings that would allow it to bring these controllers to the market at a lower price comes from its decision to stay with cartridges instead of CD-ROMs, which require the inclusion of a costly CD-ROM player in the controller. The Ultra-64 achieves a high level of integration in its design through use of a custom RISC processor developed by Silicon Graphics and Rambus DRAM. Nintendo is working on a new storage device for the Ultra 64 to overcome the limit on the amount of information that can be delivered in a cartridge. The device is expected to be some kind of magnetic recording disk, but it probably will not be revealed until late 1996.
- Nintendo did bring a new platform to the market during 1995, the Virtual Boy. The Virtual Boy game unit breaks the mold of the console-attached-to-TV standard. It is difficult to classify this product as either a handheld device or a console device because it delivers a very different gaming experience. The Virtual Boy provides visually immersive, three-dimensional gaming using a self-contained display that resembles a large pair of goggles. A 32-bit RISC processor running at 20 MHz and a dual-LED display create a smooth, three-dimensional display. The game platform was introduced in the United States in August 1995 at $180. The price was dropped to $160 three months later in reaction to consumer resistance to higher-priced games.
- Following the loss of support from AT&T, Toshiba, Creative Labs, and Sanyo for the 3DO platform, 3DO sold exclusive rights to control the use of its M2 64-bit platform to Matsushita Electric. 3DO effectively relinquished control over the technology's application in most markets in exchange for $100 million in licensing fees plus royalties from Matsushita. The 3DO M2 system employs the PowerPC in its design.
- The dramatic rise in the value of the yen has created a major challenge for Japanese manufacturers of video games. The strong yen has forced these companies to begin moving production of video game players offshore to meet critical price targets for increasing consumer demand.

Figure 5-13 presents a generic block diagram of a RISC video game controller. Key chip opportunities include:

- 32/64-bit RISC or CISC MPU

Figure 5-13
Generic Block Diagram of RISC Video Game Controller



Source: Dataquest (December 1995)

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- 2MB to 4MB DRAM (VRAM for some designs)
- 1MB to 2MB VRAM, SDRAM, or RDRAM
- 32KB SRAM
- CMOS ASIC (100,000 to 200,000 gates) graphics/sound processing
- NTSC/PAL encode
- Sound DAC/amplification
- M/JPEG decompression (optional)
- CD-ROM drive controller

Cameras, Watches, and Clocks

Table 5-16 presents the North American production in these areas. Production for the most part has moved to Asia for all but the very high-end products.

Digital Cameras

The term "digital camera" is used to refer both to video cameras that are mounted on a PC for use in videoconferencing applications and to still cameras that record images on memory chips or a disk instead of film. The digital cameras discussed in this section use the latter definition. Digital cameras were originally targeted at vertical markets such as real estate, fashion, and law enforcement. However, to the pleasant surprise of manufacturers, consumers are purchasing digital cameras and driving a stronger-than-expected market. A number of new companies are jumping into this market. The merger of the camera and a computer represents the easiest way to get photographs into a PC. Images can be transferred to the hard drive of a computer, where they can be viewed, edited, or added to documents. Although the images created by digital cameras are inferior to the quality achieved by traditional film cameras, the image that can be captured in a PC through a digital camera is superior to the method of using a scanner to transfer a photo into a computer. The picture quality of the latest digital cameras is comparable to S-VHS or hi-8 video images.

Some of the digital camera models available in the market are Kodak's DC 40, Apple's QuickTake 100 and 150, Casio's QV-10, Logitech's FotoMan Pixtura, Ricoh's DC-1 and RDC-1, Toshiba's PROSHOT, Minolta's RD-175, Epson's Photo PC, and Chinon's ES-1000 and ES-3000. New product

Table 5-16
North American Revenue from Production of Cameras, Watches, and Clocks (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Cameras	24	25	27	28	29	29	30	30	2.4
Watches	110	115	120	127	131	136	142	148	4.2
Clocks	60	62	66	69	72	75	78	81	4.3
Total	194	202	213	224	232	241	251	259	4.0

Source: Dataquest (December 1995)

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announcements are expected from Panasonic, Polaroid, and Canon in the coming months. Prices for digital cameras range from $500 for cameras such as the Epson Photo PC and the Chinon ES-1000 to $1,800 for the advanced Ricoh RDC-1. Even with these high prices, industry observers expect market sales to be four times higher in 1996 than in the previous two years combined. Recent announcements from major manufacturers would support this prediction.

- Chinon has been a major manufacturer of digital cameras, producing digital still cameras for U.S. makers on an OEM basis since 1992. The company manufactures cameras for Apple, Kodak, and Logitech. In December it announced two new cameras under its own name. It also announced that it would triple its monthly production capacity from an estimated 20,000 units per month in December 1995.
- Casio started producing 3,000 cameras per month in March 1995 and boosted its monthly output to 10,000 units per month in September as its camera became one of the most popular models on the market. It also announced their plan to invest ¥300 million to expand production capacity to 30,000 units per month by the end of 1995.

One of the most impressive digital cameras to come to the market in 1995 was the Ricoh RDC-1, which received *Byte Magazine*'s Best of COMDEX/ Fall '95 Award. The RDC-1 was designed for multimedia applications in business and government. It can record a maximum of 492 still images, four motion scenes with sound (five seconds each) or about 100 minutes of sound on a 24MB PC card. Images can be transferred directly to a PC or transmitted via a modem. The camera can also be connected directly to a television or an optional 2.5-inch LCD monitor. The camera will begin selling in the United States in April 1996.

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Chapter 6
Appliances and Other Consumer Equipment

Figures 6-1 through 6-3 and Tables 6-1 through 6-2 present production and market forecast for appliance and other consumer electronics.

Highlights in the markets for appliances and other consumer equipment are as follows:

- Generally appliances are following replacement market economics in the developed countries. Because of prohibitive transportation costs, most appliances are produced in the end-use market.
- New models are incorporating an increasing amount of user features based on MCU (4-bit, mostly) control.
- Motor-driven appliances such as refrigerators, washers, and dryers are gradually moving to solid-state controls for direct-drive motors.
- The "green" movement is forcing more appliance power conservation with solid-state controls as a way of accomplishing design objectives.

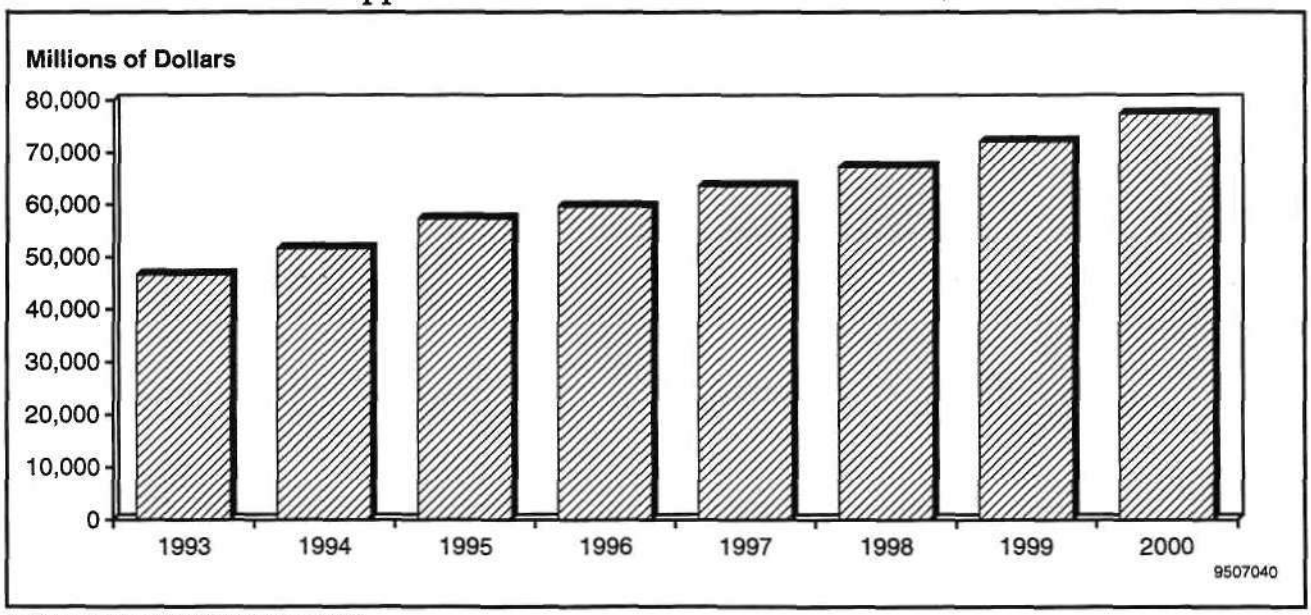
Microwave Ovens

Tables 6-3 and 6-4 detail the market for microwave ovens.

Refrigerators

Tables 6-5 and 6-6 detail the market for refrigerators.

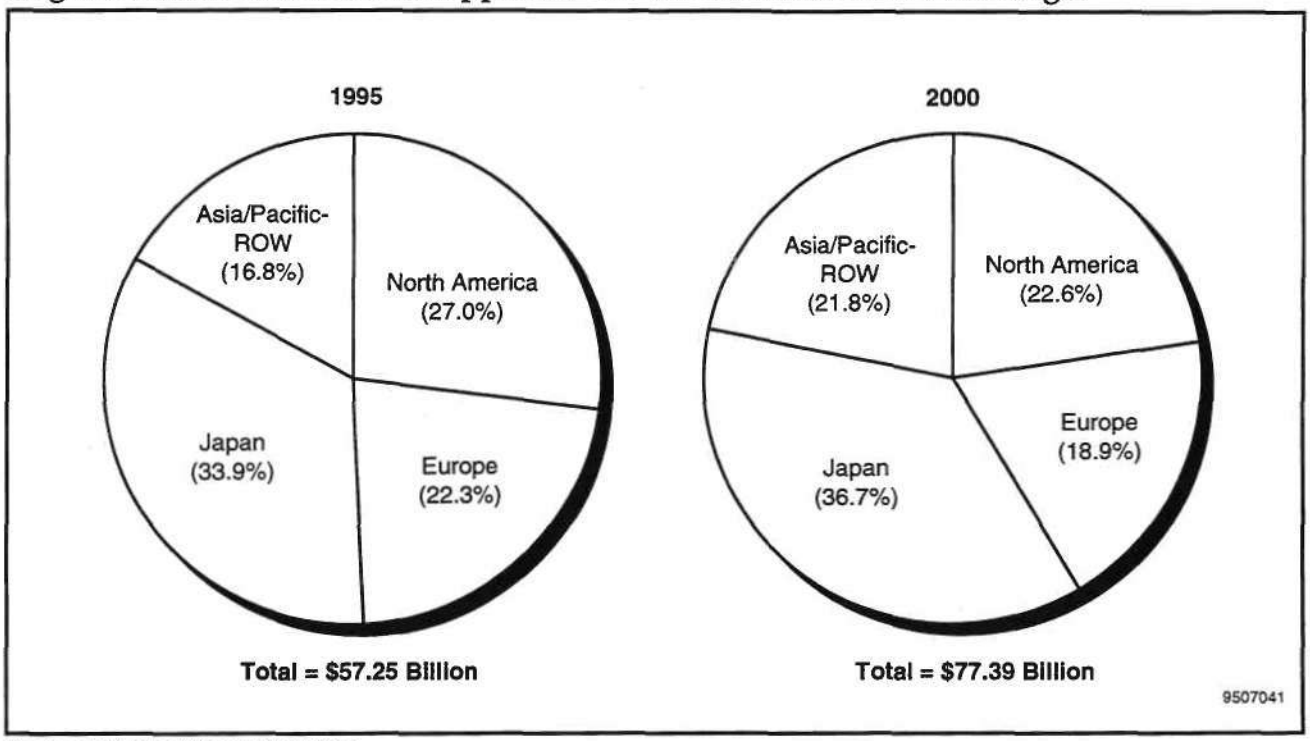
Figure 6-1
Worldwide Electronic Appliance Production Revenue Forecast (Millions of Dollars)



Source: Dataquest (December 1995)

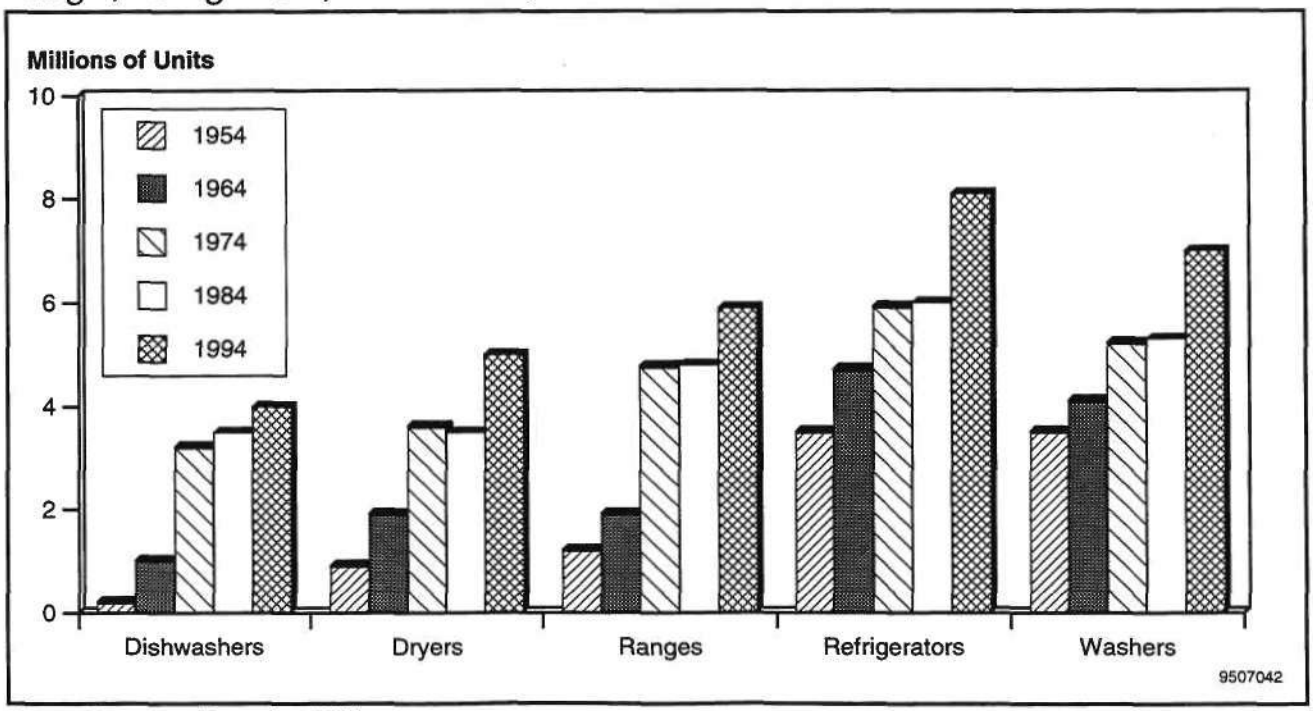
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Figure 6-2
Regional Share of Electronic Appliance Production Revenue (Percentage)



Source: Dataquest (December 1995)

Figure 6-3
U.S. Major Appliance Unit Shipments, 1954 to 1994 (Includes Dishwashers, Dryers, Ranges, Refrigerators, and Washers)



Source: Dataquest (December 1995)

Table 6-1
North American Appliance Production Revenue Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Range and Oven (Gas and Electric)	1,154	1,239	1,286	1,324	1,372	1,400	1,466	1,515	3.3
Microwave Oven	574	627	657	688	713	734	764	795	3.9
Clothes Washer and Dryer	3,518	3,724	3,879	3,842	3,997	4,036	4,233	4,343	2.3
Dishwasher	1,168	1,284	1,341	1,376	1,434	1,439	1,538	1,595	3.5
Refrigerator	5,228	5,606	5,792	5,693	5,872	6,018	6,357	6,519	2.4
Room Air Conditioner	2,027	2,463	2,515	2,428	2,528	2,559	2,689	2,735	1.7
Total	13,669	14,942	15,470	15,351	15,917	16,186	17,047	15,987	0.7

Source: Dataquest (December 1995)

Table 6-2
North American Appliance Market Revenue Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Range and Oven (Gas and Electric)	7,390	7,843	7,636	7,700	7,816	7,972	8,091	8,172	1.4
Microwave Oven	8,945	9,844	9,697	9,862	10,059	10,260	10,465	10,674	1.9
Clothes Washer	7,472	7,739	7,484	7,613	7,803	8,014	8,214	8,379	2.3
Clothes Dryer	5,581	5,873	5,623	5,768	5,941	6,132	6,316	6,473	2.9
Dishwasher	4,509	5,038	4,847	4,956	5,129	5,334	5,521	5,703	3.3
Refrigerator	8,920	9,517	9,384	9,486	9,676	9,918	10,116	10,319	1.9
Freezer	1,767	1,860	1,843	1,867	1,904	1,952	1,991	2,030	2.0
Room Air Conditioner	3,384	4,532	4,697	4,389	4,301	4,344	4,388	4,432	-1.2
Total	47,968	52,246	51,211	51,641	52,629	53,925	55,102	56,183	1.9

Source: Dataquest (December 1995)

Dishwashers

Tables 6-7 and 6-8 detail the market for dishwashers.

Washers

Tables 6-9 and 6-10 detail the market for washers.

Dryers

Tables 6-11 and 6-12 detail the market for dryers.

Air Conditioners

Tables 6-13 and 6-14 details the market for air conditioners.

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Table 6-3
U.S. Microwave Oven Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sharp	22.9	22.2
General Electric	15.5	20.6
Panasonic	10.4	8.9
Sears/Kenmore	9.9	9.7
Tappan	6.3	5.8
Whirlpool	4.8	6.7
Goldstar	4.8	3.6
Magic Chef	4.6	2.9
Emerson	4.1	2.5
Samsung	3.7	2.4
Others	13.0	14.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-4
U.S. Microwave Oven Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sharp	23.8	23.8
General Electric	14.0	17.9
Sears/Kenmore	9.8	9.5
Panasonic	9.5	8.5
Tappan	6.0	5.6
Whirlpool	5.4	7.4
Magic Chef	5.3	3.6
Emerson	4.7	2.6
Goldstar	4.5	3.5
Samsung	3.9	2.8
Others	13.1	14.8
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-5
U.S. Refrigerator Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	19.4	20.2
General Electric	18.0	20.1
Whirlpool	13.5	14.0
Amana	13.3	14.5
Hotpoint	6.0	4.8
Frigidaire	5.6	4.9
Admiral	3.1	2.6
KitchenAid	3.0	3.8
Maytag	2.8	3.4
Magic Chef	2.7	2.1
Others	12.6	9.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-6
U.S. Refrigerator Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

Brand	Unit Market Share	Revenue Market Share
Sears/Kenmore	19.2	20.2
General Electric	18.9	20.6
Whirlpool	12.8	13.1
Amana	12.1	13.6
Frigidaire	6.3	5.4
Hotpoint	5.6	4.6
Maytag	3.9	4.5
KitchenAid	3.1	3.7
Admiral	2.9	2.7
Magic Chef	2.5	2.0
Others	12.7	9.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-7
U.S. Dishwasher Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	20.6	19.9
Maytag	19.5	21.4
General Electric	18.8	18.3
Whirlpool	17.1	16.2
KitchenAid	8.6	11.3
Hotpoint	3.4	2.5
Frigidaire	2.9	2.5
Magic Chef	1.4	1.1
Tappan	1.3	0.9
White/Westinghouse	1.1	0.8
Others	5.3	5.1
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-8
U.S. Dishwasher Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	21.8	21.3
Maytag	19.4	21.2
General Electric	18.0	18.1
Whirlpool	15.1	14.3
KitchenAid	9.8	12.3
Hotpoint	3.4	2.4
Frigidaire	2.9	2.6
Tappan	1.7	1.3
Magic Chef	1.5	1.3
White/Westinghouse	1.4	1.0
Others	5.0	4.2
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-9
U.S. Clothes Washer Brand Share Leaders, First Quarter 1994 through First Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	26.6	26.8
Whirlpool	20.4	20.2
Maytag	15.7	18.4
General Electric	11.6	10.7
Hotpoint	4.1	3.4
Amana	3.9	3.9
Frigidaire	2.8	2.7
White/Westinghouse	2.7	2.7
Roper	2.3	1.8
KitchenAid	1.8	1.9
Others	8.1	7.5
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-10
U.S. Clothes Washer Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	28.7	28.7
Whirlpool	20.1	20.0
Maytag	15.7	18.3
General Electric	9.3	8.6
Amana	4.3	4.4
Hotpoint	3.5	2.9
Roper	3.1	2.4
White/Westinghouse	2.9	2.7
Frigidaire	2.4	2.3
KitchenAid	1.9	2.1
Others	8.1	7.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-11
U.S. Clothes Dryer Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	27.7	27.6
Whirlpool	19.0	19.4
Maytag	14.5	17.5
General Electric	14.4	13.2
Hotpoint	4.0	3.5
Amana	3.0	2.9
White/Westinghouse	3.1	2.8
Roper	2.5	2.1
Frigidaire	2.3	2.1
Speed Queen	1.8	1.9
Others	7.5	7.0
Total	99.8	100.0

Source: *The Scout Report®/The Polk Company*

Table 6-12
U.S. Clothes Dryer Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	29.0	28.9
Whirlpool	19.6	20.3
Maytag	13.9	16.7
General Electric	13.2	12.0
Hotpoint	3.5	2.9
Amana	3.0	2.9
Roper	2.6	2.2
Frigidaire	2.6	2.2
White/Westinghouse	2.6	2.1
Speed Queen	1.4	1.5
Others	8.6	8.3
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-13
U.S. Room Air Conditioner Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	16.4	17.2
Fedders	14.1	12.0
Whirlpool	11.4	11.5
General Electric	10.3	9.8
Amana	5.9	6.2
Carrier	5.8	6.0
White/Westinghouse	5.5	4.9
Emerson	4.5	4.8
Friedrich	4.1	5.7
Frigidaire	4.0	4.6
Others	18.0	17.3
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 6-14
U.S. Room Air Conditioner Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percentage)

	Unit Market Share	Revenue Market Share
Sears/Kenmore	18.9	19.1
Fedders	16.6	14.9
Whirlpool	10.7	10.8
General Electric	9.4	9.1
Carrier	6.4	7.5
Amana	6.1	6.1
Frigidaire	5.4	5.9
White/Westinghouse	4.7	3.7
Emerson	4.6	4.8
Friedrich	4.3	5.9
Others	12.9	12.2
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Ranges

Tables 6-15 and 6-16 detail the market for ranges.

Table 6-15
U.S. Electric Range Market Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share
General Electric	39.0
Electrolux (Frigidaire)	19.0
Whirlpool	19.0
Maytag (Magic Chef, Hardwick, Jenn Air)	13.0
Raytheon (Caloric)	6.0
Brown	2.0
Peerless Premier	1.0
Others	1.0
Total	100.0

Source: Appliance Magazine

Table 6-16
U.S. Gas Range Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percentage)

	Unit Market Share
General Electric (Roper)	25.0
Electrolux (Frigidaire)	24.0
Maytag (Magic Chef, Hardwick, Jenn Air)	24.0
Raytheon (Caloric)	20.0
Brown	3.0
Peerless Premier	3.0
Others	1.0
Total	100.0

Source: Appliance Magazine

Other Consumer Equipment

Tables 6-17 and 6-18 detail the market for other consumer equipment.

Top OEMs in home security systems are as follows:

- Honeywell
- Black & Decker
- Sony
- Audiovox
- Yale

Table 6-17
Worldwide Revenue from Production of Other Consumer Equipment (Millions of Dollars)

Year	Revenue
1993	12,310
1994	13,623
1995	16,262
1996	17,215
1997	18,518
1998	19,598
1999	20,543
2000	22,313
1995-2000 CAGR (%)	6.5

Source: Dataquest (December 1995)

Table 6-18
North American Revenue from Production of Other Consumer Equipment (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Automatic Garage Door Opener	352	411	435	464	485	510	537	562	5.3
Others	944	983	1,026	1,075	1,107	1,145	1,186	1,226	3.6
Total	1,296	1,394	1,461	1,539	1,592	1,655	1,723	1,788	4.1

Source: Dataquest (December 1995)

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Chapter 7
Emerging Opportunities

"Smart Home" Electronics

Although home bus technology to date has been an elusive market, it is worth keeping tabs on. These house LANs create a communications pathway among the home's appliances, HVAC systems, computing and cable equipment, and outside agencies such as the power company so that energy use can be optimized and outside communications can be automatic.

Leading bus contenders in the United States include:

- CEBus—An EIA-supported protocol that has been designated as interim standard IS-60 and is in the progress of balloting.
- LonWorks—A proprietary approach advocated by Echelon Corporation

One CEBus offering is from Intellon Corporation, which has a power line radio-frequency modem IC using spread spectrum technology capable of 10-Kbps data rates. Intellon recently tested its technology on the TCI and Microsoft set-top box platform. Echelon network controllers are made by Motorola and Toshiba.

In May 1995 a major feud erupted between CEBus proponents and LonWorks supporters. The fight resulted from the EIA's proposal to the FCC that it adopt AVBus as a standard for the control channel between set-top boxes and cable-ready TVs and VCRs. AVBus is a subset of the CEBus protocol. Echelon protested that this would grant CEBus an unfair advantage in competition for the home automation market. It believes that adoption of this standard in set-top boxes would limit access to the home by other standards because of the higher cost incurred by the need to implement a protocol converter. The CEO of Echelon claimed adoption of CEBus by the FCC for set-top boxes would be "almost like the FCC picking a winning PC operating system in 1980" before DOS, Macintosh, and Windows were invented. Claims and counterclaims are also being made about patent rights and whether one protocol or another is an "open standard."

Both standards are developing expanded trials of their systems while they seek to enlist the support of more manufacturers. For example, 50,000 homes were scheduled to have LonWorks devices installed in 1995. Intellon announced plans to participate in joint trials with Tele-Communications Inc. (TCI) and Microsoft using CEBus technology. Costs are also being reduced for implementing this technology in consumer products such as refrigerators, hot water heaters, and air conditioners. Motorola and Toshiba are now quoting prices between $2 and $3 for "Neuron" controller chips, compared to $15 a few years ago.

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New Influential Regions in the World

It is important to keep an eye on several developing regions around the world as household disposable income rises, creating a new generation of consumers. About two-thirds of the world's population uses relatively few consumer electronic items, and a huge market awaits patient consumer electronics and appliance companies (and their suppliers).

Expect basic goods such as refrigerators, cookware (rice cookers, among others), personal/portable stereos, and color TVs to be in demand first. Markets such as China, India, Indonesia, Malaysia, Brazil, and Mexico are indicating huge potential. In most cases, these markets are best served by joint venture with local companies.

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Market Analysis



Semiconductor Application Markets Worldwide

Market Analysis

High-Speed LANs, Remote Access, and New Broadband Services Drive New Chip Opportunities

Abstract: *This article presents an overview of a variety of high-growth opportunities for chips in wireline communications systems. Opportunities in LAN, WAN, and public infrastructure systems are examined. 100-Mbps LANs, ATM systems, V.34 and ISDN modems, and broadband local loop systems are just some of the opportunities considered.*
By Gregory Sheppard

Notable Nodes

Just when we all got used to arcane terms like Ethernet, FDDI, and V.32 bis, a whole new wave of terms and acronyms hit the market, each representing an opportunity for purveyors of focused chips. Figure 1 presents a way of analyzing communications chip opportunities, breaking the market into seven separate nodes—desktop, hub/backbone, voice, WAN, public infrastructure, personal, and home. Each of these areas has its own market dynamics and competitive solutions. This document will focus on wireline systems; the wireless opportunities are covered in other Semiconductor Application Markets Worldwide documents.

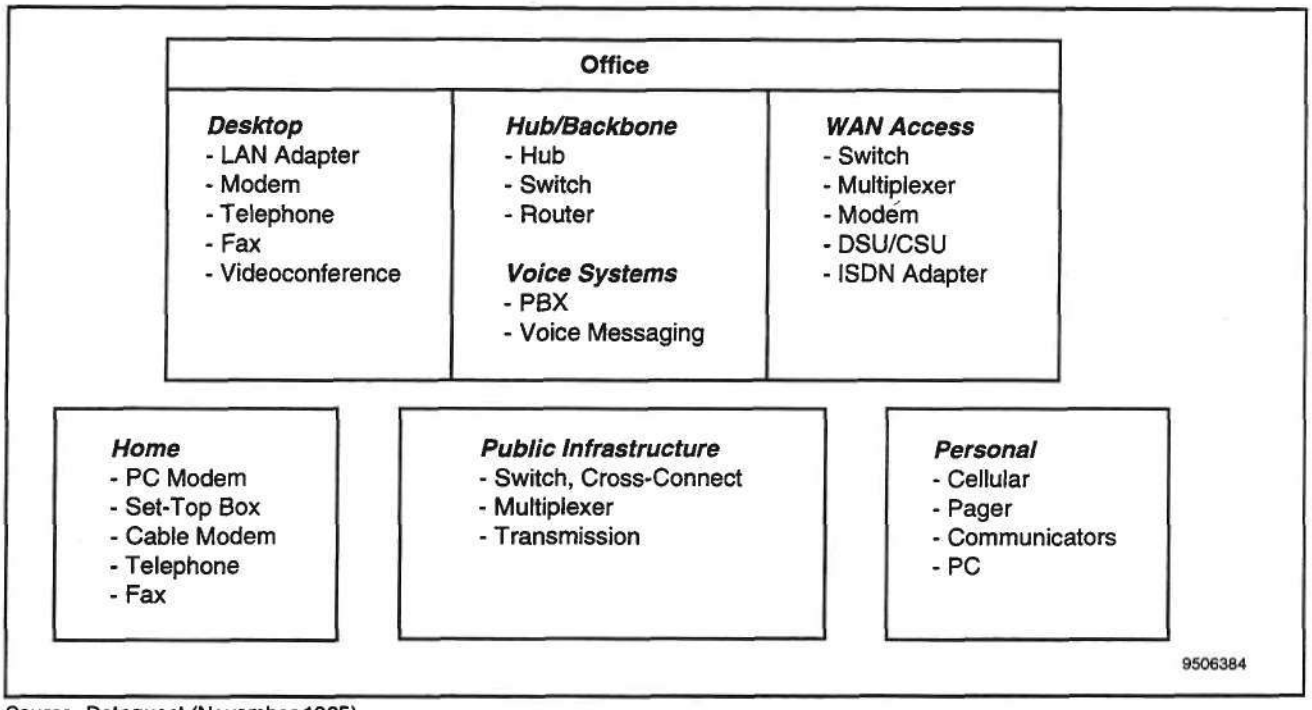
Comparison of Opportunities

Figure 2 summarizes the semiconductor market opportunity for a variety of communications systems in networking, voice applications, and the public infrastructure. Taken as a group, LAN network interface cards (NICs), hubs and switches, and internetworking (routers and bridges) are by far the fastest-growing opportunities for wired communications chips. Not far behind is the public transmission category, which will grow to be a $2.8 billion semiconductor application by 1999.

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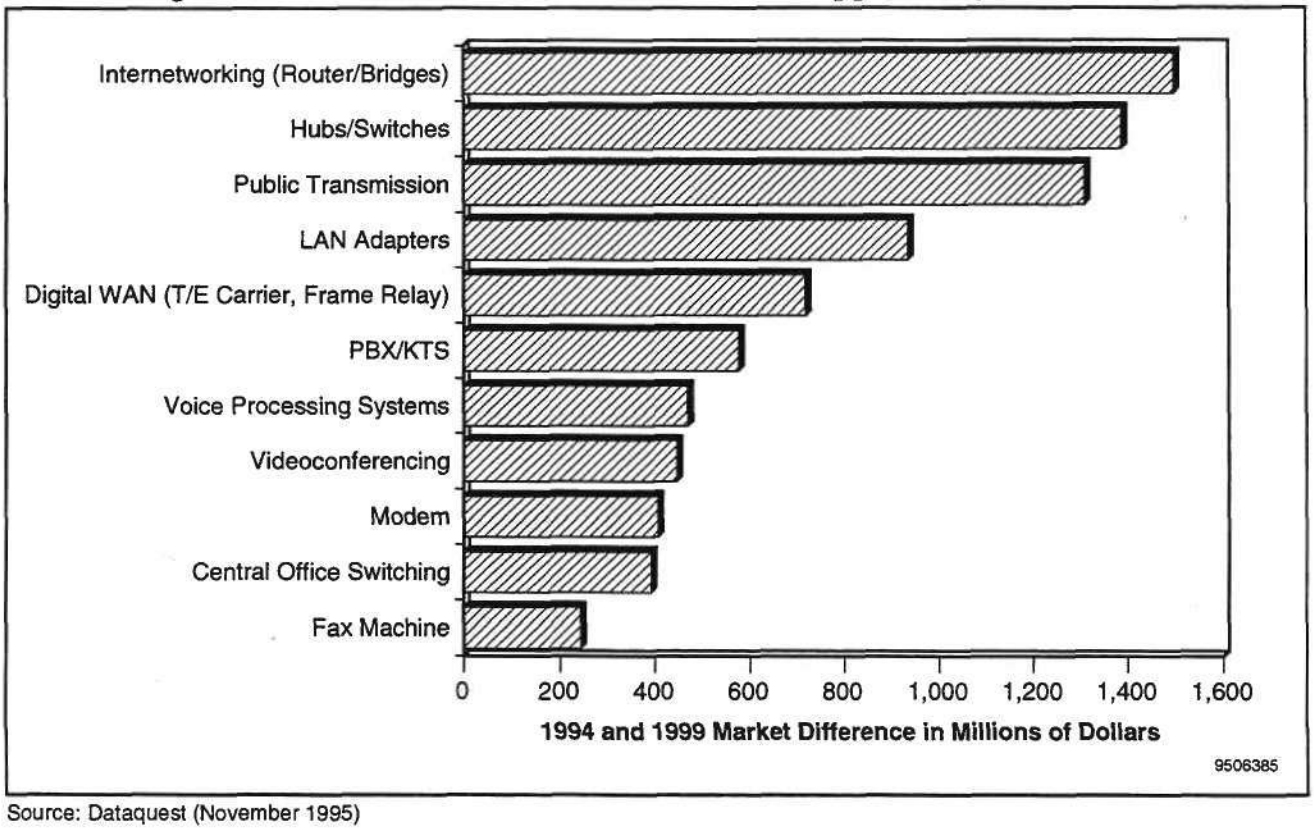
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Figure 1
Seven Nodes of Communication



Source: Dataquest (November 1995)

Figure 2
Networking and Public Infrastructure Semiconductor Opportunity, Worldwide



Source: Dataquest (November 1995)

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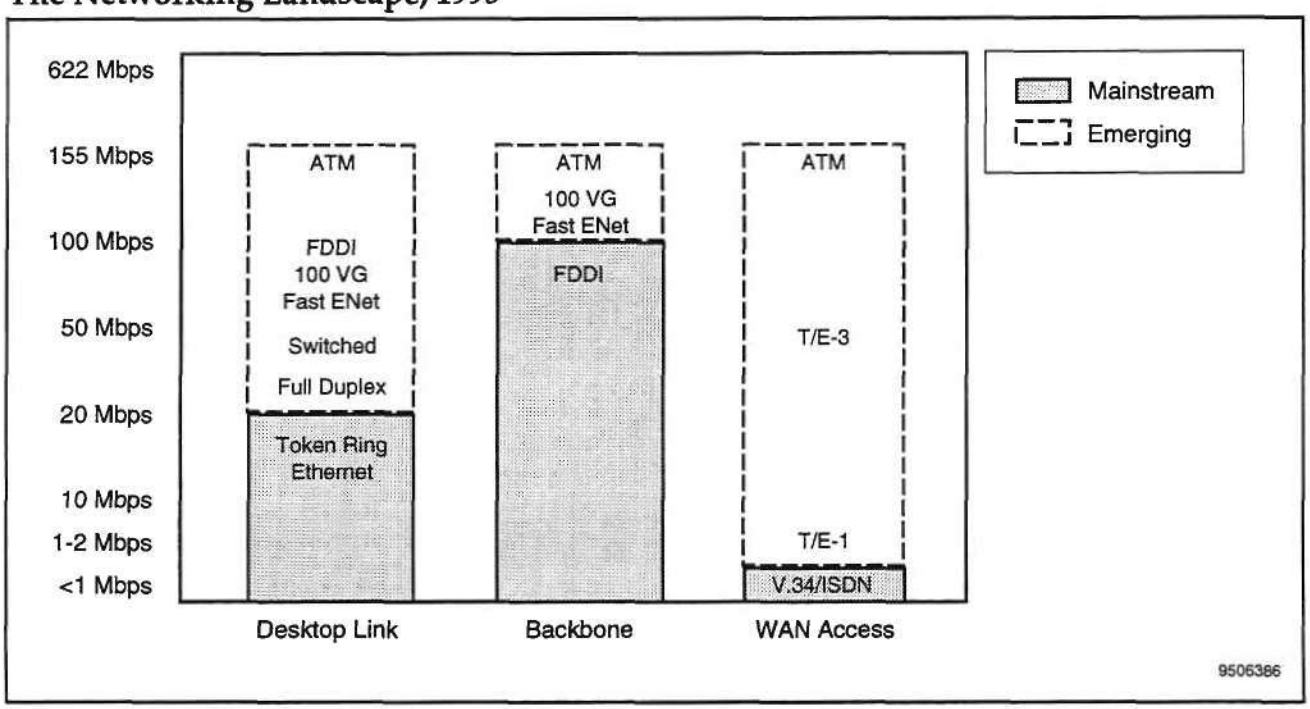
Clogged LAN Arteries to Get Bigger

In 1995, we are witnessing the introduction of a variety of approaches to enhance the throughput of LAN systems. Figures 3 and 4 present a variety of high-speed LAN and WAN approaches and their evolution over the next few years. Key drivers of increased LAN bandwidth needs include the increasing number of client/server systems that use the server as an applications host as well as for file storage, increasing fax traffic over the LAN, increasing use of groupware like Lotus Notes that requires replicated data bases, and gradually increasing multimedia traffic (toward the end of the decade), such as simultaneous voice and data and videoconferencing.

Other drivers include the ongoing penetration of LAN connectivity. The small office/home office market is connecting rapidly, and regions like Japan and Asia/Pacific are connecting in earnest for the first time. Table 1 presents Dataquest's forecast of LAN connectivity percentages.

Key technology trends for the desktop include the penetration of full-duplex Ethernet (20 Mbps) and 16-Mbps Token Ring and the rise in switch-based hubs capable of effectively dedicating a full 10 Mbps (or 16 Mbps) to each desktop node. Next on the LAN horizon is the emergence of NICs and hubs that are capable of supporting both 10-Mbps and 100-Mbps data rates. Also, 100-Mbps backbone ports are beginning to displace or complement FDDI in certain applications. The Fast Ethernet version of 100-Mbps technologies should capture about two-thirds of the market, while the 100 VG-AnyLAN version will capture the rest. Enterprise backbone systems are now beginning to turn to asynchronous transmission mode (ATM) technology, which is scalable to rates up to 2.4 Gbps. ATM is emerging as a legitimate backbone technology, and standards are beginning to stabilize.

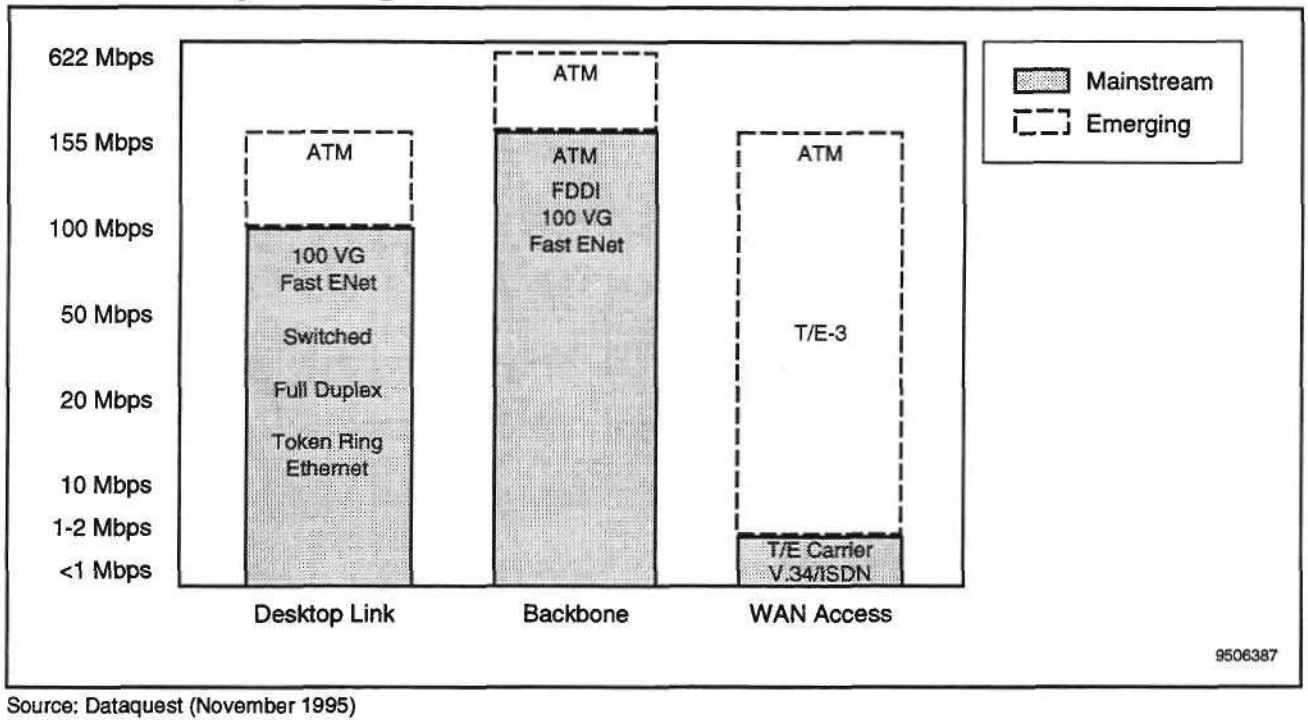
Figure 3
The Networking Landscape, 1995



Source: Dataquest (November 1995)

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Figure 4
The Networking Landscape, 1998



Source: Dataquest (November 1995)

Table 1
PC LAN Connectivity (Percent)

	1993	1994	1995	1996	1997	1998
North America	51	64	72	78	82	85
Europe	48	57	67	75	77	79
Japan	10	15	20	28	37	47
ROW	5	12	22	40	65	80

Source: Dataquest (November 1995)

WAN Bottleneck to Get Help, or World Wide Web to Get a Boost

The wide area network (WAN) traditionally has been the neglected cousin in terms of cost-effective breakthroughs in bandwidth. Data and multimedia traffic can race around the building or campus at 100 Mbps but, once it leaves the campus for the WAN or switched network, the traffic is forced through an eye dropper-like connection. This is changing with a variety of new technologies and increased competition with WAN service providers. The rates charged for various WAN services, such as ISDN basic rate, 56 Kbps (DSO), fractional T1, and T1/E1 (1.5/2.0 Mbps), have all dropped substantially in the past two years, helping to stimulate higher volumes of supporting hardware.

Frame relay, the principal replacement for X.25 packet services, is really beginning to take hold in the United States and Europe. Switched multimegabit data service (SMDS), which can operate up to T3/E3 rates, is emerging rapidly as a metropolitan WAN service.

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Perhaps the biggest impact of all in the WAN area is the astronomical growth of the Internet (alias the World Wide Web), America Online, CompuServe, and other online services. The growing multimedia content of these services is prompting a movement to higher-speed WAN terminals like V.34 (28.8 Kbps) modems and digital basic rate ISDN (128 Kbps) terminal adapters ("digital modems"). Sales of both V.34 and ISDN modems are rising dramatically, in the United States and Europe especially. Remote access to office files for telecommuters is also prompting the fast modem market.

Telcos versus Cable Companies, Part II: Getting Real

As sound business thinking catches up with the hype, new residential broadband networks still represent a significant semiconductor growth opportunity. One by one, almost every U.S. telephone company has announced a major restructuring or delay in the rollout of residential broadband capability for video-on-demand (VOD) and other services. European telcos are still pursuing broadband plans.

We believe the real stimulant for broadband services will be the competitive threat posed by alternative service providers like cable companies. This race will stimulate broadband investment in the near term. As VOD and related services continue to evolve toward lower costs, consumers may become more willing to use these advanced services. Figure 5 presents the variety of alternatives vying to solve the residential broadband price/performance equation.

Hybrid fiber-coax (HFC) involves deploying fiber-optic cabling as close as possible to a few hundred homes and then running coaxial cable to each house. This essentially duplicates the bandwidth of cable companies and is viewed as cost-prohibitive by many telcos. Asymmetrical digital subscriber loop (ADSL) is back on the scene as a viable lower-cost alternative to HFC. ADSL employs a DSP technique to shape the 6-Mbps-and-over multimedia datastream to fit on an existing twisted-pair line. Multipoint-multichannel distribution system (MMDS) is a wireless method allowing telcos to distribute high bandwidth to consumers. This, too, is receiving serious consideration as an alternative to HFC.

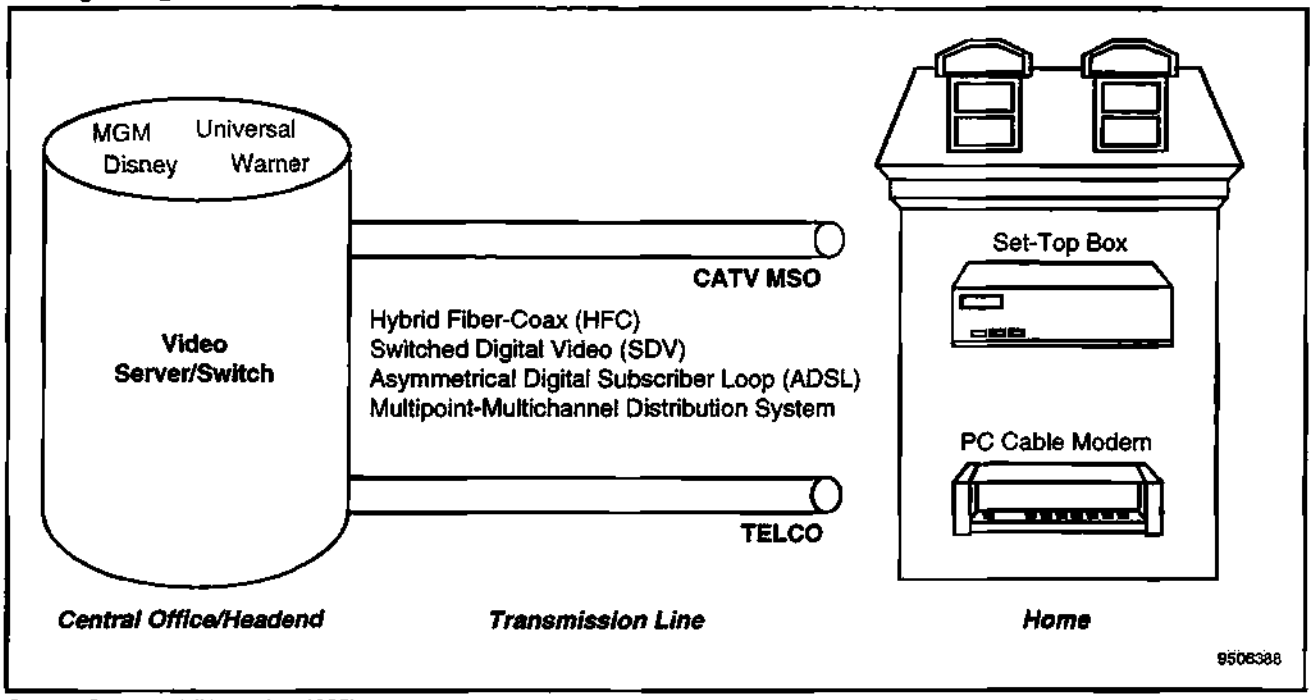
Dataquest Perspective

As is evident in this document, we are optimistic about chip opportunities in wireline communications systems. The evolution of the PC from a standalone productivity tool to a communications terminal is creating unprecedented demand for high-performance LAN and WAN systems. Also, potential deregulation in the United States, privatization in Europe, and first-time dial tone in many other countries are driving unprecedented capital spending on public infrastructure switching and transmission systems.

As we have reported many times, application-specific products and memory will be key in many of these systems. Demand will continue to grow for highly integrated chipsets that implement protocol processing and physical-media dependent functions. Expect memory such as DRAM, SRAM, and flash to increase usage in almost every box because of digital processing and features like remote code updates and system management.

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Figure 5
Competing Broadband Solutions



Source: Dataquest (November 1995)

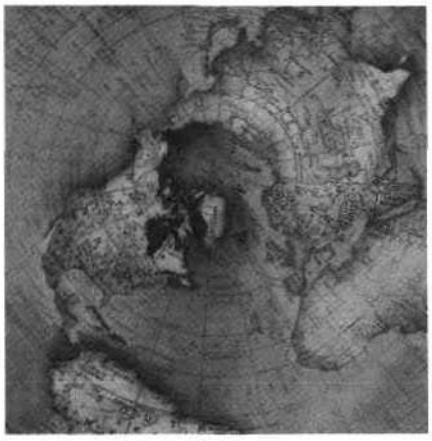
Microprocessor horse power and the use of standard logic, linear, and power chips will continue to rise as well.

The bottom line is that these specialized communications markets can no longer be treated as just another horizontal application. Time to market, R&D avoidance (good telecom designers are hard to find), and differentiation will drive wireline communications chip opportunities more than ever before.

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North American Semiconductor Consumption by Application Market



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North American Semiconductor Consumption by Application Market



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North American Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of North American semiconductor consumption in electronic equipment. This is the second of two forecasts that Dataquest now publishes biannually. The first forecast was published in the Market Statistics 1995 document titled *North American Semiconductor Consumption by Application Market* (SAMM-WW-MS-9502, published June 19, 1995). This second forecast reflects changes in the North American electronic-equipment and semiconductor markets since spring. It also reflects data revisions and updates suggested by Dataquest's continuing research of these dynamic markets.

Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

The tables in this document present data to answer the following types of questions:

- What general electronic equipment areas are driving semiconductor demand?
- What is the semiconductor-value composition of various categories of electronic equipment?
- What is the use of particular semiconductor categories such as MOS memory across the various electronic equipment areas?

The electronic equipment forecast contained in this document may be found in its entirety and in detail down to the level of specific equipment system groups in the Market Statistics 1995 document titled *Worldwide and North American Electronic Equipment Production Forecast* (SAMM-WW-MS-9504, published October 23, 1995).

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety in the Market Trends 1995 document titled *Semiconductor Five-Year Forecast Trends—Fall 1995* (SCND-WW-MT-9502, published October 23, 1995). Estimates in this document may differ slightly from estimates in the two aforementioned documents because of rounding.

The tables in this document are organized as follows:

- Tables 1 to 28 cover semiconductor consumption of the six broad application markets, by major semiconductor device group.
- Tables 29 to 56 cover consumption of the major semiconductor device category, by the six broad application markets.

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- Tables 57 to 60 cover total semiconductor consumption by each electronic equipment system group.

The following four tables are associated with each application market or semiconductor device category:

- Revenue levels, 1990-1994
- Revenue levels, 1995-1999
- Revenue growth, 1990-1994
- Revenue growth, 1995-1999

Segmentation

The following two sections outline market segments specific to this document. The first section outlines the electronic equipment segments. The second section outlines the semiconductor device segments. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the 1994 Dataquest Guide titled *Semiconductor Market Definitions* (SEMI-WW-GU-9501, published November 6, 1994).

Electronic Equipment Segmentation

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For purposes of semiconductor consumption analysis, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecom
  - Public telecom

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- Mobile communications
- Broadcast and studio equipment
- Other communications

- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment

- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment

- Military/civilian aerospace
- Transportation

Semiconductor Device Segmentation

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optical semiconductor devices.

For purposes of semiconductor consumption analysis, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

- Total semiconductor
  - Total integrated circuit
    - Bipolar digital
    - MOS digital
      - MOS memory
      - MOS microcomponents
      - MOS logic
    - Analog (monolithic plus hybrid)
  - Total discrete
  - Total optical semiconductor

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Definitions

The following three sections list the definitions used by Dataquest to present the data in this document. The first section gives the electronic equipment definitions. The second section gives the semiconductor device definitions. The third section gives the definition of the North American region. Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the *Dataquest High-Technology Guide: Segmentation and Glossary.* Definitions for semiconductor devices also can be found in the *Dataquest Semiconductor Market Definitions Guide.*

Electronic Equipment Definitions

Application markets are disaggregated into electronic equipment system groups, which are further disaggregated into specific types of electronic equipment systems. The electronic equipment hierarchy is described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and PC/motherboard upgrades (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data Storage[2]: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. (See "Line Item Definitions" for more discussion of how revenue is allocated across regions.)

[2]Worldwide mass storage production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of all equipment categories including rigid disk drive, flexible disk drive, optical disk drive, and tape drive, as estimated by the Dataquest Computer Systems and Peripherals Worldwide group. Also, Dataquest now includes solid-state storage such as flash memory cards in this category. Because most production of these cards is in Japan and Asia/Pacific, we do not include this subcategory in the North American forecast.

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- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Note: The category "PC/motherboard upgrades" replaces the category "personal computers" and now includes motherboards offered for sale for use in personal computers.

Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T-carriers/TDM multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, WAN switching systems; premise voice systems, such as premise switching equipment (PBX telephone equipment and key telephone systems) and call processing equipment (voice messaging, interactive voice response systems, and automatic call distributors); and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Note: The category "T-carrier/TDM multiplexers" replaces the category "T1 multiplexers" and includes a slightly broader range of equipment now tracked by Dataquest. Similarly, the category "WAN switching systems" replaces the category "packet data switching systems" and includes a slightly broader range of equipment now tracked by Dataquest. The category "premise voice systems" combines the former categories "premise switching equipment" and "call processing equipment."

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.

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- Manufacturing Systems/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, portable/personal stereos, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Note: The category "portable/personal stereos" is a new one and tracks portable stereo systems for personal use.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace[3]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows,

[3]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics.

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memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Semiconductor Device Definitions

Semiconductor device categories comprise specific types of semiconductor devices, as follows:

Total semiconductor (total integrated circuit + total discrete + total optical semiconductor): Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total integrated circuit (digital monolithic bipolar IC + digital monolithic MOS IC + analog IC): An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die, while a hybrid IC is one in which discrete circuits are integrated onto a small number of dies.

Bipolar digital IC (bipolar digital memory IC + bipolar digital logic IC): A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

MOS digital IC (MOS digital memory IC + MOS digital microcomponent IC + MOS digital logic IC): Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed-technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

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MOS digital memory IC (DRAM + SRAM + EPROM + EEPROM + flash memory + mask ROM + other MOS digital memory IC): Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS digital microcomponent IC (MOS digital microprocessor + MOS digital microcontroller + MOS digital microperipheral + MOS digital signal processor + programmable digital signal processor): Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS digital logic IC (MOS digital application-specific IC + MOS digital standard logic IC + other MOS logic IC): Defined as a MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC (monolithic analog IC + hybrid IC): A monolithic analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package. A hybrid IC is defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total discrete (transistor + diode + thyristor + other discrete): A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total optical semiconductor (LED lamp/display + optocoupler + CCD + laser diode + photosensor + other optical semiconductor): Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definition

North America includes Canada, Mexico, and the United States (50 states).

Line Item Definitions

The following two sections discuss definitions of the table line items specific to this document. The first section defines the line items associated with electronic equipment; the second section defines the line items associated with the semiconductor devices.

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Electronic Equipment Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singapore operation (which is factory revenue) and the European distributor or final user.

Personal computers are a particularly challenging example of a product whose production increasingly spans both time and geography. Today, it is not at all uncommon for personal computers to be assembled from components fabricated throughout the world. Moreover, the final assembly of a personal computer often occurs at a place far removed from the source of the computer's semiconductors. Dataquest considers a personal computer to be produced in the region where the majority of the computer's semiconductor value is generated. For instance, a personal computer whose electronic components are assembled in Asia/Pacific but whose final assembly into a system is done by a North American distributor in North America is considered produced in Asia/Pacific. This convention guarantees production is located in the region where semiconductor consumption is both the most likely and greatest. The computer is in turn valued at the factory cost of the North American distributor. This convention guarantees the final system is valued at a figure comparable to traditional factory selling price.

Semiconductor Device Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product

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that is used internally is valued at the market price rather than at the transfer or factory price.

Data Sources

The historical electronic equipment production estimates presented in this document have been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce (DOC) estimates of manufacturers' shipments
- Trade associations
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today.

Forecast and Input/Output Ratio Methodology

The following three sections discuss the forecast methodology used by Dataquest in this document. The first section gives the electronic equipment forecast methodology. The second section gives the semiconductor forecast methodology. The third section discusses the interpretation of I/O ratios and the methodology of the allocation of the aggregate semiconductor forecast across specific electronic equipment markets.

Electronic Equipment Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This establishes a five-year trend growth path or "envelope" for electronic system production.

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The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general comprises annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Aggregate Semiconductor Consumption Forecast Methodology

Dataquest publishes a five-year forecast of semiconductor device revenue twice a year, in April and October. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a three-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronic equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest's Semiconductors Worldwide service and its Semiconductor Equipment, Materials, and Manufacturing Worldwide service, in conjunction with various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

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The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The I/O ratio reflects the relationship between the dollar value of semiconductors in a type of electronic system and the revenue generated by that system. The ratio is typically expressed as a percentage.

For example, if a piece of electronic equipment (such as a personal computer) sells for $1,000 and has $100 worth of semiconductors in it, the I/O ratio is expressed as:

$$\text{I/O ratio} = \frac{\text{Semiconductor Value—(Dollars In)}}{\text{Equipment Revenue (Dollars Out)}} = \frac{\$100}{\$1{,}000} = 0.10 \text{ or } 10 \text{ percent}$$

Dataquest estimates semiconductor consumption by electronic equipment segment by combining sample information from electronic system semiconductor content analyses, and surveys of electronic manufacturers' semiconductor procurement and semiconductor manufacturers' shipments by application market with modeled semiconductor consumption. The semiconductor content analyses typically are performed on equipment that sell in high volume or otherwise significantly impact the semiconductor market. These analyses include personal computers, rigid disk drives, and cellular telephones.

The semiconductor consumption model makes use of the following inputs:

- Historical electronic equipment production and the current electronic equipment production forecast
- Historical semiconductor consumption (both aggregate and by electronic equipment segment) and the current semiconductor device revenue forecast
- Information about long-run market trends or long-term systems technology trends

Given these inputs, semiconductor consumption by equipment segment is estimated in an iterative procedure subject to the following constraints and conditions:

- The sum of semiconductor consumption across all equipment markets fully exhausts aggregate semiconductor consumption.

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- Market fluctuations in the aggregate semiconductor consumption forecast are realistically and appropriately mapped into the individual equipment segments' semiconductor consumption forecasts.

The procedure is iterative in the respect that modeled results are checked against prior beliefs, expectations, and sample information about each equipment segment's semiconductor consumption, and that this prior information is then used to tune the model such that modeled consumption estimates converge to their respective expected values.

The model combines two important sources of market variation: variation because of nonperiodic market fluctuations about the market's long-run trend growth path; and variation because of shifts in the market's long-run trend growth path.

It is necessarily the case that nonperiodic fluctuation in the aggregate semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Furthermore, because of a variety of factors, some device markets are relatively more volatile than other device markets. It is an observed fact that there is relatively more volatility in the MOS memory market—owing to price volatility—than in the analog market. Therefore, fluctuation in the MOS memory market "explains" more fluctuation in the aggregate semiconductor market than does fluctuation in the analog market. The model takes given inputs and assumptions and proportionally distributes fluctuations in the aggregate semiconductor market according to the equipment markets' respective long-run semiconductor device composition trends.

For example, because the data processing application market in general—and the computer equipment segment in particular—consumes proportionally more MOS memory devices than does equipment in the industrial market, other things being equal, it is reasonable to expect total semiconductor consumption to be more volatile in the data processing market than in the industrial market.

Semiconductor markets, in general, are relatively more volatile than are the electronic equipment markets. By construction, then, the I/O ratios tend to reflect this difference in volatility. Users of the I/O ratios, therefore, are cautioned to focus on long-run trends in the I/O ratios and growth rates rather than on the year-to-year movement in their values.

Production and I/O Ratio Re-Estimation and Revaluation

The historical and forecast electronic equipment production and semiconductor consumption by application market estimates contained in this book have undergone a thorough audit and review and have been re-estimated and restated to reflect primary or secondary information previously unavailable. Please note the following:

- Computer systems production has been re-estimated and revalued to equal the value of the worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting

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of system sales of storage devices, keyboards, and displays. Also, computer systems' semiconductor consumption includes semiconductor shipments to U.S. PC marketers for postproduction use.

- Communications, industrial, consumer, and transportation production have been re-estimated and revalued to reflect revisions made by the Dataquest Telecommunications group, or secondary-sources estimates.
- Military/civil aerospace production has been re-estimated and revalued to reflect U.S. DOC estimates of U.S. defense and civil (aerospace) electronics. Also, spending on items such as nonrecurring engineering expenses (NRE), R&D, and testing have been eliminated to arrive at a more accurate equipment production estimate.

Economic Assumptions

Slower Growth Expected in Major European, North American, and Asian Markets

Dun & Bradstreet's most recent quarterly survey of more than 11,000 global executives in 16 countries revealed expectations for slower near-term growth in net sales, net profits, selling prices, and employment in nearly every region of the world. The overall picture has continued to reveal a steady decline in worldwide business expectations since the beginning of 1995. On balance, however, the number of global executives predicting expansion still outnumbered those expecting lower sales and profits, thus suggesting some expansion in the world economy over the months to come.

Executives in nearly every region generally forecast a mature business cycle characterized by slow, steady growth over the near term accompanied by moderate inflationary pressures. Longer-term forecasts from Dun & Bradstreet subsidiary A.C. Nielsen suggest these circumstances are likely to prevail through the end of the decade. These forecasts indicate the world's developed economies are likely to experience modest but gradually accelerating growth over the next few years. The experience of the world's emerging economies will continue to be varied. Pacific Basin economies will continue to post impressive rates of growth. In contrast, Latin American economies are expected to experience only slight near-term growth because of ongoing economic crises in Mexico and Brazil. For the longer term, however, growth is likely to be impressive once these crises are resolved.

Expectations for Growth in Net Sales and Net Profits Decline in All Regions

Global expectations for growth in net sales and net profits over the near term continued the steady decline that marked the first half of the year. Dun & Bradstreet's World Indices for net sales and net profits dropped five and six points to 45 and 33, respectively. These declines were largely the result of marked declines in Pacific Basin and European indices. North American indices exhibited little change largely because results for Mexico were unavailable. The World Index for selling prices also declined, dropping seven points to 26. Here the decline was driven by

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expectations of reduced inflationary pressures in every region surveyed. The slow pressure to raise prices is an encouraging signal that production is keeping pace with healthy levels of demand. Dun & Bradstreet's World Indices for inventories and employment levels also each dropped two points to 13 and 16, respectively. Executives in every region but North America appear to expect slightly slower growth in finished goods inventories and employment levels.

North America: Mexico Still Reeling from Devaluation of the Peso

Mexico continues to suffer spiraling inflation and economic instability stemming from devaluation of the peso. These circumstances made it virtually impossible to draw a sharp picture of expectations for the near-term course of the Mexican economy. Fortunately, Mexico and its Latin American trading partner Brazil represent the only exceptions to a basically stable global outlook. Excluding Mexico, North America should experience the strongest near-term growth of all regions. North America's continued strength as a market for exports is one of the main factors buoying optimism in global expectations. Longer-term growth forecasts for North America are as follows.

- Mexico's real gross domestic product (GDP) is now forecast to decline 3.0 percent in 1995, following 3.5 percent growth in 1994. Positive growth of 2.0 percent is expected in 1996. Growth is then anticipated to accelerate through the end of the decade, reaching 5.0 percent by 1999.
- The United States' GDP is now forecast to grow 2.9 percent in 1995, decelerating from 4.1 percent growth in 1994. Growth is expected to be robust through the end of 1995, thus making up for the slow growth observed in the spring. Growth is then anticipated to accelerate somewhat in 1996 to 3.2 percent and to remain at or near that level through the end of the decade.
- Canada's GDP is now forecast to grow 2.3 percent in 1995, decelerating from 4.5 percent growth in 1994. Growth is anticipated to accelerate to 2.7 percent in 1996 and then to average about 2.9 percent through the end of the decade. As in the United States, executives in Canada expressed strong optimism for net sales and net profits over the near term.

Dun & Bradstreet's quarterly International Survey of Business Expectations is modeled on its quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. Survey participants are asked whether they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven highly accurate, with quarterly forecasts closely paralleling actual performance.

The current international survey, completed in June 1995, uses similar sampling and interviewing procedures in all countries. Hence the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The Dun & Bradstreet index figures used here

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represent the net percentage of survey respondents expecting higher sales and profits, among others. The indices are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. GDP growth rates noted here are A.C. Nielsen's most current forecasts from August 1995.

North American Electronic Equipment Production Assumptions

North America electronic equipment production is now forecast to grow 7.5 percent to $232.9 billion in 1995. This contrasts with the 5.7 percent growth forecast in spring and marks a deceleration from the 9.4 percent growth experienced in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The continued expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1995 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP) over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- LAN equipment is expected to continue strong growth throughout the forecast period. In addition to new markets in the small/home office area, investment in higher-speed technology such as 100-Mbps and ATM will give renewed growth to the industry.
- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecasts. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market, which will increase competition with existing wireless communications services, is expected to fuel even greater growth. However, PCS is a very cost-conscious market, and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, we expect strong growth for mobile equipment in North America and worldwide.

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- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets. (Note: Better information in U.S. imports and exports has resulted in a revision to both historical and forecast revenue for North America.)
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets have also continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecom hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecom and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- The North America industrial electronics market will continue to be dominated by economic trends in the United States, principally growth in U.S. capital spending. The United States should remain a significant producer and net exporter of industrial electronics, especially test and measuring equipment. Canada and Mexico will continue to produce some industrial electronics locally, but will remain highly dependent on imports from the United States. Likewise, emerging Asian nations will continue to be consumers of U.S. production. (Note: North America industrial production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. capital spending.)
- The North America consumer electronics market will continue to be dominated by economic trends in the United States, chiefly growth in U.S. household income. The United States should remain a net

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importer of consumer electronics, despite growth in U.S. consumer electronics production. Mexico will remain a significant source of consumer electronics for North America and could well increase its share of U.S. and Canadian markets at the expense of Asia, given a favorable resolution of its current economic crises. (Note: North America consumer production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. household income.)

- U.S. military spending appears likely to increase over the next few years, based on the latest congressional budget proposals. Production of electronic warfare equipment is especially likely to increase in response. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.
- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems.

The most significant downside risk to the forecast continues to be the uncertainty surrounding U.S. economic policy. The growing U.S. trade and budget deficits present policy makers with numerous and challenging choices. Given the current fractious political environment and the uncertain state of economic knowledge concerning the links between the trade and budget deficits, it is not at all clear how policy makers will or even should proceed. The ongoing crisis in Mexico poses additional downside risk to the forecast. A prolonging of Mexico's economic woes accompanied by deepening social instability could well undermine the forecast. The most significant upside risk to the forecast remains a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

North American Semiconductor Consumption

North American semiconductor device revenue is forecast to grow 33.0 percent in 1995 to $47.8 billion, accelerating from 28.7 percent growth in 1994, and to grow at a 20.9 percent compound annual growth rate (CAGR) from 1994 to 1999, to $92.9 billion in 1999. The North American market forecast is predicted on the following assumptions:

- Data processing will remain the dominant market for semiconductors in North America. PC unit sales in North America will continue along the path of doubling over five years.
- Pentium processors are pushing up MPU revenue strongly. As we expect a long life for the Pentium, revenue growth will seem to slow in 1997 because the Pentium-to-Pentium Pro changeover may not occur as rapidly as 386-to-486-to-Pentium changeovers.

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- High-ASP semiconductors, such as the x86 processors and memory SIMMs, will continue to be strongly consumed in North America and added to PCs or motherboards manufactured in the Asia/Pacific region.
- Besides PC consumption, resource-hungry software applications for Windows 95, as well as Windows 95 itself, will continue to drive semiconductor consumption toward higher-performance MPUs and larger DRAM configurations.
- Because of the strong computer market, microcomponent and memory ICs cornered 59 percent of the semiconductors shipped to North America in 1993 and more than 61 percent in 1994. We expect this share to exceed 66 percent in 1995 as microcomponent and memory ICs will lead all other product types in growth at 33 percent and 49 percent, respectively, within the North American market. By 1999, microcomponent and memory ICs will account for more than 71 percent of semiconductor revenue in North America.
- MOS memory will enjoy a third year of stable prices into 1995 with the continuing tight supply of 4Mb and 16Mb DRAM. The DRAM boom will continue well into 1996, but strong capital spending in 1994 by Japanese and Korean DRAM suppliers will show up as excess supply and a decline in ASPs by late 1996. Despite falling ASPs, DRAM revenue will be supported by increasing unit shipments as the PC market moves toward higher levels of DRAM use.
- The 4Mb DRAM demand is showing continued strength through 1995, a break from past DRAM life cycles. This extended life is the result of limited acceptance of the x1 and x4 configurations of 16Mb DRAMs and the inability of vendors to supply the preferred x16 configuration. This has helped create price stability.
- MPUs will show a declining rate of growth toward the end of the forecast period as increased competition to the x86 family brings ASPs down.
- Discrete device growth (21.9 percent in 1994, 23.2 percent forecast for 1995) increasingly results from the use of power MOS-FETs and IGBTs in switching power supplies and as peripheral drivers and RF devices. MOS-FETs and IGBTs showed 30 percent and 100 percent growth in 1994, respectively, growth rates that are not flagging in 1995.

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Table 1
Revenue from North American Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	194,625	194,843	193,914	198,037	216,696
Total Semiconductor	16,540	16,990	20,430	27,926	35,939
Total IC	14,616	15,269	18,404	25,629	33,032
Bipolar Digital	1,577	1,331	1,232	1,173	967
MOS Digital	10,390	11,296	14,174	20,864	27,861
MOS Memory	4,325	4,510	5,707	8,785	12,458
MOS Microcomponent	3,381	3,916	5,282	7,620	9,657
MOS Logic	2,684	2,870	3,185	4,459	5,746
Analog (Monolithic + Hybrid)	2,649	2,642	2,998	3,592	4,204
Total Discrete	1,611	1,389	1,603	1,811	2,208
Total Optical Semiconductor	313	332	423	486	699

Source: Dataquest (November 1995)

Table 2
Revenue from North American Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	232,947	246,005	260,245	272,536	288,551
Total Semiconductor	47,805	60,307	71,508	80,947	92,908
Total IC	44,265	56,262	67,138	76,187	87,613
Bipolar Digital	872	740	635	533	444
MOS Digital	38,388	49,652	59,878	68,002	78,340
MOS Memory	18,638	24,547	29,893	32,622	37,480
MOS Microcomponent	12,880	16,960	20,740	24,650	28,445
MOS Logic	6,870	8,145	9,245	10,730	12,415
Analog (Monolithic + Hybrid)	5,005	5,870	6,625	7,652	8,829
Total Discrete	2,720	3,130	3,385	3,685	4,100
Total Optical Semiconductor	820	915	985	1,075	1,195

Source: Dataquest (November 1995)

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Table 3
Revenue Growth from North American Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.8	0.1	-0.5	2.1	9.4
Total Semiconductor	-3.1	2.7	20.2	36.7	28.7
Total IC	-3.2	4.5	20.5	39.3	28.9
Bipolar Digital	-3.6	-15.6	-7.4	-4.8	-17.6
MOS Digital	-5.4	8.7	25.5	47.2	33.5
MOS Memory	-25.1	4.3	26.5	53.9	41.8
MOS Microcomponent	20.9	15.8	34.9	44.3	26.7
MOS Logic	10.9	6.9	11.0	40.0	28.9
Analog (Monolithic + Hybrid)	6.9	-0.3	13.5	19.8	17.0
Total Discrete	-1.7	-13.8	15.4	13.0	21.9
Total Optical Semiconductor	-4.9	6.1	27.4	14.9	43.8

Source: Dataquest (November 1995)

Table 4
Revenue Growth from North American Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	7.5	5.6	5.8	4.7	5.9	5.9
Total Semiconductor	33.0	26.2	18.6	13.2	14.8	20.9
Total IC	34.0	27.1	19.3	13.5	15.0	21.5
Bipolar Digital	-9.8	-15.1	-14.2	-16.1	-16.7	-14.4
MOS Digital	37.8	29.3	20.6	13.6	15.2	23.0
MOS Memory	49.6	31.7	21.8	9.1	14.9	24.6
MOS Microcomponent	33.4	31.7	22.3	18.9	15.4	24.1
MOS Logic	19.6	18.6	13.5	16.1	15.7	16.7
Analog (Monolithic + Hybrid)	19.1	17.3	12.9	15.5	15.4	16.0
Total Discrete	23.2	15.1	8.1	8.9	11.3	13.2
Total Optical Semiconductor	17.3	11.6	7.7	9.1	11.2	11.3

Source: Dataquest (November 1995)

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Table 5
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Data Processing	67,032	65,588	59,477	57,374	64,317
Total Semiconductor	7,040	7,890	9,058	13,083	17,108
Total IC	6,834	7,687	8,833	12,824	16,736
Bipolar Digital	729	662	601	593	468
MOS Digital	5,732	6,651	7,869	11,832	15,892
MOS Memory	2,700	3,021	3,577	5,569	8,027
MOS Microcomponent	1,859	2,294	2,917	4,279	5,280
MOS Logic	1,173	1,335	1,376	1,983	2,585
Analog (Monolithic + Hybrid)	373	374	362	400	375
Total Discrete	139	122	134	151	194
Total Optical Semiconductor	67	81	91	108	178

Source: Dataquest (November 1995)

Table 6
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Data Processing	71,334	75,062	79,597	80,981	84,154
Total Semiconductor	23,019	28,678	33,874	37,477	42,191
Total IC	22,596	28,239	33,432	37,030	41,730
Bipolar Digital	414	336	275	217	169
MOS Digital	21,803	27,539	32,816	36,488	41,253
MOS Memory	11,836	15,211	18,284	19,642	22,196
MOS Microcomponent	6,941	8,880	10,700	12,500	14,161
MOS Logic	3,026	3,448	3,832	4,346	4,897
Analog (Monolithic + Hybrid)	380	364	341	325	308
Total Discrete	226	238	240	242	250
Total Optical Semiconductor	196	200	202	205	211

Source: Dataquest (November 1995)

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Table 7
Revenue Growth from North American Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Data Processing	6.1	-2.2	-9.3	-3.5	12.1
Total Semiconductor	-3.8	12.1	14.8	44.4	30.8
Total IC	-3.9	12.5	14.9	45.2	30.5
Bipolar Digital	-0.2	-9.2	-9.2	-1.4	-21.0
MOS Digital	-4.7	16.0	18.3	50.4	34.3
MOS Memory	-23.6	11.9	18.4	55.7	44.1
MOS Microcomponent	29.2	23.4	27.1	46.7	23.4
MOS Logic	12.3	13.8	3.1	44.2	30.3
Analog (Monolithic + Hybrid)	3.4	0.4	-3.3	10.4	-6.1
Total Discrete	0.5	-12.0	9.5	12.6	28.7
Total Optical Semiconductor	-6.7	20.2	13.0	18.3	64.8

Source: Dataquest (November 1995)

Table 8
Revenue Growth from North American Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Data Processing	10.9	5.2	6.0	1.7	3.9	5.5
Total Semiconductor	34.6	24.6	18.1	10.6	12.6	19.8
Total IC	35.0	25.0	18.4	10.8	12.7	20.0
Bipolar Digital	-11.5	-18.9	-18.2	-21.1	-22.2	-18.5
MOS Digital	37.2	26.3	19.2	11.2	13.1	21.0
MOS Memory	47.5	28.5	20.2	7.4	13.0	22.6
MOS Microcomponent	31.5	27.9	20.5	16.8	13.3	21.8
MOS Logic	17.0	14.0	11.1	13.4	12.7	13.6
Analog (Monolithic + Hybrid)	1.1	-4.0	-6.4	-4.7	-5.1	-3.9
Total Discrete	16.6	5.2	0.8	0.9	3.0	5.2
Total Optical Semiconductor	10.3	2.0	0.7	1.6	3.0	3.5

Source: Dataquest (November 1995)

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Table 9
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Communications	27,230	29,174	32,563	37,014	43,997
Total Semiconductor	3,053	2,916	4,052	5,798	7,682
Total IC	2,677	2,585	3,622	5,282	6,891
Bipolar Digital	284	210	211	206	156
MOS Digital	1,848	1,830	2,696	4,181	5,664
MOS Memory	732	659	1,022	1,605	2,305
MOS Microcomponent	523	564	904	1,375	1,744
MOS Logic	593	606	770	1,201	1,616
Analog (Monolithic + Hybrid)	545	545	715	895	1,070
Total Discrete	315	266	327	388	561
Total Optical Semiconductor	61	65	103	127	230

Source: Dataquest (November 1995)

Table 10
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Communications	49,235	54,651	59,407	65,255	72,043
Total Semiconductor	10,695	14,086	16,865	19,369	22,678
Total IC	9,641	12,794	15,410	17,730	20,780
Bipolar Digital	137	111	87	65	49
MOS Digital	8,077	10,855	13,150	15,044	17,555
MOS Memory	3,558	4,846	5,873	6,340	7,264
MOS Microcomponent	2,463	3,429	4,276	5,153	6,076
MOS Logic	2,056	2,580	3,002	3,552	4,215
Analog (Monolithic + Hybrid)	1,427	1,828	2,173	2,620	3,177
Total Discrete	762	944	1,066	1,202	1,395
Total Optical Semiconductor	292	348	389	437	503

Source: Dataquest (November 1995)

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Table 11
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Communications	8.1	7.1	11.6	13.7	18.9
Total Semiconductor	-5.2	-4.5	38.9	43.1	32.5
Total IC	-6.1	-3.4	40.1	45.8	30.5
Bipolar Digital	-7.9	-25.9	0.3	-2.6	-24.2
MOS Digital	-10.9	-1.0	47.4	55.1	35.5
MOS Memory	-33.2	-9.9	54.9	57.1	43.6
MOS Microcomponent	20.8	7.7	60.4	52.1	26.8
MOS Logic	8.6	2.3	27.0	55.9	34.6
Analog (Monolithic + Hybrid)	16.1	-0.1	31.2	25.2	19.6
Total Discrete	3.3	-15.5	22.8	18.7	44.6
Total Optical Semiconductor	-4.7	6.4	58.2	24.1	80.2

Source: Dataquest (November 1995)

Table 12
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Communications	11.9	11.0	8.7	9.8	10.4	10.4
Total Semiconductor	39.2	31.7	19.7	14.8	17.1	24.2
Total IC	39.9	32.7	20.4	15.1	17.2	24.7
Bipolar Digital	-12.3	-18.6	-21.9	-24.9	-25.3	-20.7
MOS Digital	42.6	34.4	21.1	14.4	16.7	25.4
MOS Memory	54.4	36.2	21.2	8.0	14.6	25.8
MOS Microcomponent	41.3	39.2	24.7	20.5	17.9	28.4
MOS Logic	27.3	25.5	16.3	18.3	18.7	21.1
Analog (Monolithic + Hybrid)	33.3	28.1	18.9	20.6	21.2	24.3
Total Discrete	35.7	23.9	12.9	12.7	16.1	20.0
Total Optical Semiconductor	27.1	19.1	11.8	12.5	15.0	17.0

Source: Dataquest (November 1995)

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Table 13
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Industrial	38,751	39,892	41,581	43,687	46,856
Total Semiconductor	2,185	2,084	2,863	3,718	4,856
Total IC	1,611	1,597	2,247	3,043	4,048
Bipolar Digital	160	114	127	113	102
MOS Digital	985	1,013	1,530	2,221	3,054
MOS Memory	268	252	420	653	895
MOS Microcomponent	370	403	662	948	1,347
MOS Logic	347	358	449	620	812
Analog (Monolithic + Hybrid)	465	469	590	709	893
Total Discrete	495	406	500	545	645
Total Optical Semiconductor	80	82	116	130	162

Source: Dataquest (November 1995)

Table 14
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Industrial	49,835	52,785	55,339	58,206	61,880
Total Semiconductor	6,596	8,720	10,547	12,542	14,998
Total IC	5,579	7,522	9,253	11,120	13,405
Bipolar Digital	98	90	79	68	57
MOS Digital	4,349	6,028	7,553	9,125	11,063
MOS Memory	1,443	2,091	2,700	3,155	3,881
MOS Microcomponent	1,895	2,673	3,385	4,208	5,077
MOS Logic	1,011	1,264	1,468	1,762	2,104
Analog (Monolithic + Hybrid)	1,132	1,405	1,621	1,927	2,286
Total Discrete	819	965	1,040	1,135	1,266
Total Optical Semiconductor	198	232	255	287	327

Source: Dataquest (November 1995)

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Table 15
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Industrial	4.8	2.9	4.2	5.1	7.3
Total Semiconductor	-0.1	-4.6	37.4	29.9	30.6
Total IC	1.3	-0.9	40.7	35.4	33.0
Bipolar Digital	-6.7	-28.5	11.3	-10.8	-10.3
MOS Digital	-2.0	2.8	51.1	45.1	37.5
MOS Memory	-31.3	-5.7	66.2	55.6	37.1
MOS Microcomponent	14.6	8.7	64.4	43.2	42.1
MOS Logic	18.9	3.0	25.4	38.2	30.9
Analog (Monolithic + Hybrid)	12.4	0.9	25.6	20.2	25.9
Total Discrete	-3.4	-18.0	23.3	8.9	18.4
Total Optical Semiconductor	-5.7	2.5	41.4	12.5	24.5

Source: Dataquest (November 1995)

Table 16
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Industrial	6.4	5.9	4.8	5.2	6.3	5.7
Total Semiconductor	35.9	32.2	21.0	18.9	19.6	25.3
Total IC	37.8	34.8	23.0	20.2	20.5	27.1
Bipolar Digital	-3.4	-8.7	-12.2	-14.3	-15.4	-10.9
MOS Digital	42.4	38.6	25.3	20.8	21.2	29.4
MOS Memory	61.3	44.9	29.1	16.9	23.0	34.1
MOS Microcomponent	40.6	41.1	26.6	24.3	20.7	30.4
MOS Logic	24.6	25.0	16.2	20.0	19.4	21.0
Analog (Monolithic + Hybrid)	26.8	24.1	15.4	18.9	18.6	20.7
Total Discrete	26.8	17.9	7.7	9.2	11.5	14.4
Total Optical Semiconductor	22.6	16.9	10.0	12.4	14.0	15.1

Source: Dataquest (November 1995)

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Table 17
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Consumer	21,471	21,046	21,650	23,659	25,821
Total Semiconductor	1,319	1,258	1,626	2,315	3,005
Total IC	1,088	1,063	1,394	2,039	2,677
Bipolar Digital	13	8	8	7	6
MOS Digital	558	530	768	1,251	1,733
MOS Memory	272	239	356	623	875
MOS Microcomponent	221	227	339	518	716
MOS Logic	65	64	74	110	141
Analog (Monolithic + Hybrid)	517	525	618	780	938
Total Discrete	215	180	214	257	305
Total Optical Semiconductor	15	15	17	20	22

Source: Dataquest (November 1995)

Table 18
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Consumer	26,805	27,203	28,626	29,689	30,911
Total Semiconductor	3,956	4,987	6,044	7,062	8,193
Total IC	3,561	4,547	5,571	6,549	7,637
Bipolar Digital	6	5	4	3	3
MOS Digital	2,474	3,330	4,237	5,046	5,987
MOS Memory	1,364	1,896	2,473	2,911	3,526
MOS Microcomponent	945	1,243	1,545	1,879	2,169
MOS Logic	165	192	218	256	292
Analog (Monolithic + Hybrid)	1,082	1,212	1,330	1,499	1,647
Total Discrete	371	415	448	488	530
Total Optical Semiconductor	24	24	25	25	26

Source: Dataquest (November 1995)

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Table 19
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Consumer	-0.3	-2.0	2.9	9.3	9.1
Total Semiconductor	-3.6	-4.6	29.2	42.4	29.8
Total IC	-3.6	-2.4	31.2	46.2	31.3
Bipolar Digital	-26.1	-35.7	-2.4	-6.2	-13.5
MOS Digital	-9.6	-5.1	45.0	62.8	38.5
MOS Memory	-23.6	-12.3	48.9	75.1	40.5
MOS Microcomponent	11.0	2.9	49.3	52.9	38.2
MOS Logic	4.3	-1.8	14.9	49.0	28.5
Analog (Monolithic + Hybrid)	4.7	1.4	17.8	26.3	20.2
Total Discrete	-2.9	-16.4	19.2	20.1	18.7
Total Optical Semiconductor	-8.2	3.8	10.8	13.9	14.4

Source: Dataquest (November 1995)

Table 20
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Consumer	3.8	1.5	5.2	3.7	4.1	3.7
Total Semiconductor	31.7	26.1	21.2	16.8	16.0	22.2
Total IC	33.0	27.7	22.5	17.5	16.6	23.3
Bipolar Digital	-11.4	-16.9	-15.8	-18.1	-21.0	-16.7
MOS Digital	42.8	34.6	27.2	19.1	18.6	28.1
MOS Memory	55.8	39.0	30.5	17.7	21.1	32.1
MOS Microcomponent	32.0	31.5	24.3	21.6	15.4	24.8
MOS Logic	16.7	16.3	13.9	17.3	14.0	15.6
Analog (Monolithic + Hybrid)	15.3	12.1	9.7	12.7	9.9	11.9
Total Discrete	21.4	12.1	7.8	8.9	8.8	11.7
Total Optical Semiconductor	7.5	1.8	0.9	2.7	1.9	2.9

Source: Dataquest (November 1995)

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Table 21
Revenue from North American Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	36,603	35,588	34,732	31,662	30,169
Total Semiconductor	1,991	1,870	1,762	1,712	1,692
Total IC	1,617	1,516	1,418	1,371	1,360
Bipolar Digital	359	307	255	224	204
MOS Digital	859	841	822	812	831
MOS Memory	297	285	277	274	283
MOS Microcomponent	202	202	197	196	202
MOS Logic	360	354	348	343	346
Analog (Monolithic + Hybrid)	399	368	340	335	325
Total Discrete	306	288	281	278	269
Total Optical Semiconductor	68	66	63	63	64

Source: Dataquest (November 1995)

Table 22
Revenue from North American Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Military/Civil Aerospace	29,621	29,920	30,397	31,016	31,714
Total Semiconductor	1,735	1,798	1,875	1,964	2,061
Total IC	1,398	1,465	1,544	1,623	1,707
Bipolar Digital	187	170	162	153	142
MOS Digital	898	984	1,069	1,140	1,221
MOS Memory	348	402	452	468	506
MOS Microcomponent	210	231	248	266	274
MOS Logic	340	351	368	406	441
Analog (Monolithic + Hybrid)	314	311	313	330	344
Total Discrete	274	272	269	274	283
Total Optical Semiconductor	63	62	63	66	70

Source: Dataquest (November 1995)

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Table 23
Revenue Growth from North American Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1990-1994
(Percentage Change)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	4.9	-2.8	-2.4	-8.8	-4.7
Total Semiconductor	-1.6	-6.1	-5.8	-2.8	-1.2
Total IC	-1.0	-6.2	-6.5	-3.3	-0.9
Bipolar Digital	-8.0	-14.6	-16.8	-12.4	-8.8
MOS Digital	0	-2.0	-2.3	-1.2	2.3
MOS Memory	-10.8	-4.1	-2.8	-1.3	3.5
MOS Microcomponent	6.1	0.4	-2.8	-0.4	2.8
MOS Logic	7.3	-1.7	-1.7	-1.5	1.0
Analog (Monolithic + Hybrid)	4.0	-7.7	-7.5	-1.5	-3.1
Total Discrete	-4.3	-6.0	-2.4	-1.1	-3.3
Total Optical Semiconductor	-4.2	-3.0	-3.9	-0.8	1.4

Source: Dataquest (November 1995)

Table 24
Revenue Growth from North American Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1995-1999
(Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Military/Civil Aerospace	-1.8	1.0	1.6	2.0	2.3	1.0
Total Semiconductor	2.5	3.7	4.3	4.7	4.9	4.0
Total IC	2.9	4.7	5.4	5.2	5.2	4.7
Bipolar Digital	-8.4	-9.2	-4.7	-5.4	-7.4	-7.0
MOS Digital	8.0	9.6	8.6	6.7	7.1	8.0
MOS Memory	22.7	15.6	12.5	3.5	8.1	12.3
MOS Microcomponent	4.3	9.7	7.5	7.3	3.2	6.4
MOS Logic	-1.8	3.4	4.9	10.2	8.6	5.0
Analog (Monolithic + Hybrid)	-3.4	-0.8	0.6	5.4	4.3	1.2
Total Discrete	1.8	-0.7	-1.0	2.0	3.3	1.1
Total Optical Semiconductor	-1.2	-1.2	1.4	5.4	6.0	2.0

Source: Dataquest (November 1995)

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Table 25
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Transportation	3,537	3,554	3,911	4,641	5,537
Total Semiconductor	952	971	1,069	1,299	1,596
Total IC	789	821	890	1,070	1,320
Bipolar Digital	32	29	29	30	30
MOS Digital	408	432	488	567	687
MOS Memory	55	53	56	62	73
MOS Microcomponent	206	226	263	303	368
MOS Logic	146	153	169	202	246
Analog (Monolithic + Hybrid)	349	360	373	473	602
Total Discrete	141	127	146	192	233
Total Optical Semiconductor	22	23	33	38	43

Source: Dataquest (November 1995)

Table 26
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Transportation	6,117	6,384	6,879	7,389	7,849
Total Semiconductor	1,804	2,038	2,303	2,533	2,786
Total IC	1,489	1,694	1,929	2,135	2,352
Bipolar Digital	30	28	28	27	25
MOS Digital	787	916	1,054	1,158	1,261
MOS Memory	89	101	111	106	107
MOS Microcomponent	426	506	587	644	688
MOS Logic	272	310	356	408	467
Analog (Monolithic + Hybrid)	671	750	847	951	1,067
Total Discrete	269	295	323	344	376
Total Optical Semiconductor	46	48	51	54	58

Source: Dataquest (November 1995)

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Table 27
Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Transportation Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Transportation	-9.3	0.5	10.0	18.7	19.3
Total Semiconductor	0	2.0	10.1	21.5	22.9
Total IC	0.1	4.1	8.5	20.1	23.4
Bipolar Digital	89.7	-9.5	0.6	3.0	1.5
MOS Digital	-1.6	5.8	13.1	16.2	21.1
MOS Memory	-11.4	-5.0	6.8	9.9	17.6
MOS Microcomponent	-2.7	9.4	16.6	15.1	21.6
MOS Logic	4.4	4.9	10.1	19.9	21.6
Analog (Monolithic + Hybrid)	-2.2	3.2	3.5	26.6	27.5
Total Discrete	-0.8	-10.0	15.2	31.0	21.7
Total Optical Semiconductor	4.5	4.5	42.3	15.9	13.7

Source: Dataquest (November 1995)

Table 28
Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Transportation Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Transportation	10.5	4.4	7.8	7.4	6.2	7.2
Total Semiconductor	13.0	13.0	13.0	10.0	10.0	11.8
Total IC	12.8	13.8	13.8	10.7	10.2	12.3
Bipolar Digital	-1.6	-4.7	-0.3	-6.2	-7.1	-4.0
MOS Digital	14.6	16.4	15.0	9.9	8.9	12.9
MOS Memory	22.9	13.1	9.7	-4.3	1.0	8.0
MOS Microcomponent	15.6	18.7	16.0	9.7	6.8	13.3
MOS Logic	10.7	13.8	15.0	14.6	14.3	13.7
Analog (Monolithic + Hybrid)	11.4	11.7	13.0	12.2	12.2	12.1
Total Discrete	15.4	9.9	9.2	6.7	9.3	10.0
Total Optical Semiconductor	6.6	4.1	6.6	5.0	6.8	5.8

Source: Dataquest (November 1995)

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Table 29
Revenue from Shipments of Bipolar Digital Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	1,577	1,331	1,232	1,173	967
Data Processing	729	662	601	593	468
Communications	284	210	211	206	156
Industrial	160	114	127	113	102
Consumer	13	8	8	7	6
Military/Civil Aerospace	359	307	255	224	204
Transportation	32	29	29	30	30

Source: Dataquest (November 1995)

Table 30
Revenue from Shipments of Bipolar Digital Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	872	740	635	533	444
Data Processing	414	336	275	217	169
Communications	137	111	87	65	49
Industrial	98	90	79	68	57
Consumer	6	5	4	3	3
Military/Civil Aerospace	187	170	162	153	142
Transportation	30	28	28	27	25

Source: Dataquest (November 1995)

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Table 31
Revenue Growth from Shipments of Bipolar Digital Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-3.6	-15.6	-7.4	-4.8	-17.6
Data Processing	-0.2	-9.2	-9.2	-1.4	-21.0
Communications	-7.9	-25.9	0.3	-2.6	-24.2
Industrial	-6.7	-28.5	11.3	-10.8	-10.3
Consumer	-26.1	-35.7	-2.4	-6.2	-13.5
Military/Civil Aerospace	-8.0	-14.6	-16.8	-12.4	-8.8
Transportation	89.7	-9.5	0.6	3.0	1.5

Source: Dataquest (November 1995)

Table 32
Revenue Growth from Shipments of Bipolar Digital Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	-9.8	-15.1	-14.2	-16.1	-16.7	-14.4
Data Processing	-11.5	-18.9	-18.2	-21.1	-22.2	-18.5
Communications	-12.3	-18.6	-21.9	-24.9	-25.3	-20.7
Industrial	-3.4	-8.7	-12.2	-14.3	-15.4	-10.9
Consumer	-11.4	-16.9	-15.8	-18.1	-21.0	-16.7
Military/Civil Aerospace	-8.4	-9.2	-4.7	-5.4	-7.4	-7.0
Transportation	-1.6	-4.7	-0.3	-6.2	-7.1	-4.0

Source: Dataquest (November 1995)

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Table 33
Revenue from Shipments of MOS Memory Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4,325	4,510	5,707	8,785	12,458
Data Processing	2,700	3,021	3,577	5,569	8,027
Communications	732	659	1,022	1,605	2,305
Industrial	268	252	420	653	895
Consumer	272	239	356	623	875
Military/Civil Aerospace	297	285	277	274	283
Transportation	55	53	56	62	73

Source: Dataquest (November 1995)

Table 34
Revenue from Shipments of MOS Memory Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	18,638	24,547	29,893	32,622	37,480
Data Processing	11,836	15,211	18,284	19,642	22,196
Communications	3,558	4,846	5,873	6,340	7,264
Industrial	1,443	2,091	2,700	3,155	3,881
Consumer	1,364	1,896	2,473	2,911	3,526
Military/Civil Aerospace	348	402	452	468	506
Transportation	89	101	111	106	107

Source: Dataquest (November 1995)

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Table 35
Revenue Growth from Shipments of MOS Memory Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-25.1	4.3	26.5	53.9	41.8
Data Processing	-23.6	11.9	18.4	55.7	44.1
Communications	-33.2	-9.9	54.9	57.1	43.6
Industrial	-31.3	-5.7	66.2	55.6	37.1
Consumer	-23.6	-12.3	48.9	75.1	40.5
Military/Civil Aerospace	-10.8	-4.1	-2.8	-1.3	3.5
Transportation	-11.4	-5.0	6.8	9.9	17.6

Source: Dataquest (November 1995)

Table 36
Revenue Growth from Shipments of MOS Memory Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	49.6	31.7	21.8	9.1	14.9	24.6
Data Processing	47.5	28.5	20.2	7.4	13.0	22.6
Communications	54.4	36.2	21.2	8.0	14.6	25.8
Industrial	61.3	44.9	29.1	16.9	23.0	34.1
Consumer	55.8	39.0	30.5	17.7	21.1	32.1
Military/Civil Aerospace	22.7	15.6	12.5	3.5	8.1	12.3
Transportation	22.9	13.1	9.7	-4.3	1.0	8.0

Source: Dataquest (November 1995)

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Table 37
Revenue from Shipments of MOS Microcomponent Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	3,381	3,916	5,282	7,620	9,657
Data Processing	1,859	2,294	2,917	4,279	5,280
Communications	523	564	904	1,375	1,744
Industrial	370	403	662	948	1,347
Consumer	221	227	339	518	716
Military/Civil Aerospace	202	202	197	196	202
Transportation	206	226	263	303	368

Source: Dataquest (November 1995)

Table 38
Revenue from Shipments of MOS Microcomponent Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	12,880	16,960	20,740	24,650	28,445
Data Processing	6,941	8,880	10,700	12,500	14,161
Communications	2,463	3,429	4,276	5,153	6,076
Industrial	1,895	2,673	3,385	4,208	5,077
Consumer	945	1,243	1,545	1,879	2,169
Military/Civil Aerospace	210	231	248	266	274
Transportation	426	506	587	644	688

Source: Dataquest (November 1995)

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Table 39
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	20.9	15.8	34.9	44.3	26.7
Data Processing	29.2	23.4	27.1	46.7	23.4
Communications	20.8	7.7	60.4	52.1	26.8
Industrial	14.6	8.7	64.4	43.2	42.1
Consumer	11.0	2.9	49.3	52.9	38.2
Military/Civil Aerospace	6.1	0.4	-2.8	-0.4	2.8
Transportation	-2.7	9.4	16.6	15.1	21.6

Source: Dataquest (November 1995)

Table 40
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	33.4	31.7	22.3	18.9	15.4	24.1
Data Processing	31.5	27.9	20.5	16.8	13.3	21.8
Communications	41.3	39.2	24.7	20.5	17.9	28.4
Industrial	40.6	41.1	26.6	24.3	20.7	30.4
Consumer	32.0	31.5	24.3	21.6	15.4	24.8
Military/Civil Aerospace	4.3	9.7	7.5	7.3	3.2	6.4
Transportation	15.6	18.7	16.0	9.7	6.8	13.3

Source: Dataquest (November 1995)

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Table 41
Revenue from Shipments of MOS Logic Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,684	2,870	3,185	4,459	5,746
Data Processing	1,173	1,335	1,376	1,983	2,585
Communications	593	606	770	1,201	1,616
Industrial	347	358	449	620	812
Consumer	65	64	74	110	141
Military/Civil Aerospace	360	354	348	343	346
Transportation	146	153	169	202	246

Source: Dataquest (November 1995)

Table 42
Revenue from Shipments of MOS Logic Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	6,870	8,145	9,245	10,730	12,415
Data Processing	3,026	3,448	3,832	4,346	4,897
Communications	2,056	2,580	3,002	3,552	4,215
Industrial	1,011	1,264	1,468	1,762	2,104
Consumer	165	192	218	256	292
Military/Civil Aerospace	340	351	368	406	441
Transportation	272	310	356	408	467

Source: Dataquest (November 1995)

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Table 43
Revenue Growth from Shipments of MOS Logic Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10.9	6.9	11.0	40.0	28.9
Data Processing	12.3	13.8	3.1	44.2	30.3
Communications	8.6	2.3	27.0	55.9	34.6
Industrial	18.9	3.0	25.4	38.2	30.9
Consumer	4.3	-1.8	14.9	49.0	28.5
Military/Civil Aerospace	7.3	-1.7	-1.7	-1.5	1.0
Transportation	4.4	4.9	10.1	19.9	21.6

Source: Dataquest (November 1995)

Table 44
Revenue Growth from Shipments of MOS Logic Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	19.6	18.6	13.5	16.1	15.7	16.7
Data Processing	17.0	14.0	11.1	13.4	12.7	13.6
Communications	27.3	25.5	16.3	18.3	18.7	21.1
Industrial	24.6	25.0	16.2	20.0	19.4	21.0
Consumer	16.7	16.3	13.9	17.3	14.0	15.6
Military/Civil Aerospace	-1.8	3.4	4.9	10.2	8.6	5.0
Transportation	10.7	13.8	15.0	14.6	14.3	13.7

Source: Dataquest (November 1995)

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Table 45
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,649	2,642	2,998	3,592	4,204
Data Processing	373	374	362	400	375
Communications	545	545	715	895	1,070
Industrial	465	469	590	709	893
Consumer	517	525	618	780	938
Military/Civil Aerospace	399	368	340	335	325
Transportation	349	360	373	473	602

Source: Dataquest (November 1995)

Table 46
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	5,005	5,870	6,625	7,652	8,829
Data Processing	380	364	341	325	308
Communications	1,427	1,828	2,173	2,620	3,177
Industrial	1,132	1,405	1,621	1,927	2,286
Consumer	1,082	1,212	1,330	1,499	1,647
Military/Civil Aerospace	314	311	313	330	344
Transportation	671	750	847	951	1,067

Source: Dataquest (November 1995)

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Table 47
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	6.9	-0.3	13.5	19.8	17.0
Data Processing	3.4	0.4	-3.3	10.4	-6.1
Communications	16.1	-0.1	31.2	25.2	19.6
Industrial	12.4	0.9	25.6	20.2	25.9
Consumer	4.7	1.4	17.8	26.3	20.2
Military/Civil Aerospace	4.0	-7.7	-7.5	-1.5	-3.1
Transportation	-2.2	3.2	3.5	26.6	27.5

Source: Dataquest (November 1995)

Table 48
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	19.1	17.3	12.9	15.5	15.4	16.0
Data Processing	1.1	-4.0	-6.4	-4.7	-5.1	-3.9
Communications	33.3	28.1	18.9	20.6	21.2	24.3
Industrial	26.8	24.1	15.4	18.9	18.6	20.7
Consumer	15.3	12.1	9.7	12.7	9.9	11.9
Military/Civil Aerospace	-3.4	-0.8	0.6	5.4	4.3	1.2
Transportation	11.4	11.7	13.0	12.2	12.2	12.1

Source: Dataquest (November 1995)

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Table 49
Revenue from Shipments of Discrete Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	1,611	1,389	1,603	1,811	2,208
Data Processing	139	122	134	151	194
Communications	315	266	327	388	561
Industrial	495	406	500	545	645
Consumer	215	180	214	257	305
Military/Civil Aerospace	306	288	281	278	269
Transportation	141	127	146	192	233

Source: Dataquest (November 1995)

Table 50
Revenue from Shipments of Discrete Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	2,720	3,130	3,385	3,685	4,100
Data Processing	226	238	240	242	250
Communications	762	944	1,066	1,202	1,395
Industrial	819	965	1,040	1,135	1,266
Consumer	371	415	448	488	530
Military/Civil Aerospace	274	272	269	274	283
Transportation	269	295	323	344	376

Source: Dataquest (November 1995)

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Table 51
Revenue Growth from Shipments of Discrete Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-1.7	-13.8	15.4	13.0	21.9
Data Processing	0.5	-12.0	9.5	12.6	28.7
Communications	3.3	-15.5	22.8	18.7	44.6
Industrial	-3.4	-18.0	23.3	8.9	18.4
Consumer	-2.9	-16.4	19.2	20.1	18.7
Military/Civil Aerospace	-4.3	-6.0	-2.4	-1.1	-3.3
Transportation	-0.8	-10.0	15.2	31.0	21.7

Source: Dataquest (November 1995)

Table 52
Revenue Growth from Shipments of Discrete Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	23.2	15.1	8.1	8.9	11.3	13.2
Data Processing	16.6	5.2	0.8	0.9	3.0	5.2
Communications	35.7	23.9	12.9	12.7	16.1	20.0
Industrial	26.8	17.9	7.7	9.2	11.5	14.4
Consumer	21.4	12.1	7.8	8.9	8.8	11.7
Military/Civil Aerospace	1.8	-0.7	-1.0	2.0	3.3	1.1
Transportation	15.4	9.9	9.2	6.7	9.3	10.0

Source: Dataquest (November 1995)

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Table 53
Revenue from Shipments of Optical Semiconductors to North America by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	313	332	423	486	699
Data Processing	67	81	91	108	178
Communications	61	65	103	127	230
Industrial	80	82	116	130	162
Consumer	15	15	17	20	22
Military/Civil Aerospace	68	66	63	63	64
Transportation	22	23	33	38	43

Source: Dataquest (November 1995)

Table 54
Revenue from Shipments of Optical Semiconductors to North America by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	820	915	985	1,075	1,195
Data Processing	196	200	202	205	211
Communications	292	348	389	437	503
Industrial	198	232	255	287	327
Consumer	24	24	25	25	26
Military/Civil Aerospace	63	62	63	66	70
Transportation	46	48	51	54	58

Source: Dataquest (November 1995)

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Table 55
Revenue Growth from Shipments of Optical Semiconductors to North America by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-4.9	6.1	27.4	14.9	43.8
Data Processing	-6.7	20.2	13.0	18.3	64.8
Communications	-4.7	6.4	58.2	24.1	80.2
Industrial	-5.7	2.5	41.4	12.5	24.5
Consumer	-8.2	3.8	10.8	13.9	14.4
Military/Civil Aerospace	-4.2	-3.0	-3.9	-0.8	1.4
Transportation	4.5	4.5	42.3	15.9	13.7

Source: Dataquest (November 1995)

Table 56
Revenue Growth from Shipments of Optical Semiconductors to North America by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	17.3	11.6	7.7	9.1	11.2	11.3
Data Processing	10.3	2.0	0.7	1.6	3.0	3.5
Communications	27.1	19.1	11.8	12.5	15.0	17.0
Industrial	22.6	16.9	10.0	12.4	14.0	15.1
Consumer	7.5	1.8	0.9	2.7	1.9	2.9
Military/Civil Aerospace	-1.2	-1.2	1.4	5.4	6.0	2.0
Transportation	6.6	4.1	6.6	5.0	6.8	5.8

Source: Dataquest (November 1995)

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Table 57
Revenue from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	16,540	16,990	20,430	27,926	35,939
Data Processing	7,040	7,890	9,058	13,083	17,108
Computers	5,049	5,619	6,750	10,033	13,598
Data Storage	722	741	587	558	523
Input/Output	936	1,158	1,309	1,915	2,184
Dedicated System	238	273	288	395	523
Other Data Processing	95	99	124	181	279
Communications	3,053	2,916	4,052	5,798	7,682
Premise Telecom	1,538	1,382	1,938	3,052	4,085
Public Telecom	524	483	554	747	1,023
Mobile Communications	551	652	1,032	1,234	1,562
Broadcast and Studio	121	113	154	218	270
Other Communications	320	287	374	547	742
Industrial	2,185	2,084	2,863	3,718	4,856
Security and Energy Management	167	159	215	312	407
Manufacturing System/Instruments	1,328	1,273	1,745	2,453	3,235
Medical Equipment	357	334	434	547	708
Other Industrial	333	318	469	407	506
Consumer	1,319	1,258	1,626	2,315	3,005
Audio	39	38	51	69	90
Video	497	467	529	738	1,029
Personal Electronics	11	10	14	19	24
Appliances	686	661	917	1,321	1,640
Other Consumer	85	82	115	168	222
Military/Civil Aerospace	1,991	1,870	1,762	1,712	1,692
Transportation	952	971	1,069	1,299	1,596

Source: Dataquest (November 1995)

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Table 58
Revenue from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Semiconductor	47,805	60,307	71,508	80,947	92,908
Data Processing	23,019	28,678	33,874	37,477	42,191
Computers	18,821	23,674	28,117	30,906	34,603
Data Storage	553	579	533	487	441
Input/Output	2,547	2,980	3,463	4,027	4,754
Dedicated System	723	971	1,214	1,451	1,723
Other Data Processing	375	473	547	606	670
Communications	10,695	14,086	16,865	19,369	22,678
Premise Telecom	5,580	7,143	8,358	9,511	10,931
Public Telecom	1,258	1,632	1,917	2,224	2,903
Mobile Communications	2,356	3,239	4,001	4,591	5,290
Broadcast and Studio	358	466	564	671	761
Other Communications	1,143	1,605	2,025	2,373	2,792
Industrial	6,596	8,720	10,547	12,542	14,998
Security and Energy Management	548	731	904	1,093	1,310
Manufacturing System/Instruments	4,446	5,893	7,091	8,408	10,084
Medical Equipment	951	1,268	1,573	1,911	2,310
Other Industrial	651	829	979	1,130	1,293
Consumer	3,956	4,987	6,044	7,062	8,193
Audio	132	184	236	297	371
Video	1,429	1,947	2,550	3,226	3,877
Personal Electronics	35	47	56	62	69
Appliances	2,022	2,338	2,615	2,810	3,106
Other Consumer	338	471	587	667	771
Military/Civil Aerospace	1,735	1,798	1,875	1,964	2,061
Transportation	1,804	2,038	2,303	2,533	2,786

Source: Dataquest (November 1995)

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Table 59
Revenue Growth from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Semiconductor	-3.1	2.7	20.2	36.7	28.7
Data Processing	-3.8	12.1	14.8	44.4	30.8
Computers	-5.2	11.3	20.1	48.6	35.5
Data Storage	2.6	2.6	-20.7	-4.9	-6.3
Input/Output	-0.2	23.7	13.1	46.3	14.1
Dedicated System	-3.2	14.9	5.6	37.2	32.3
Other Data Processing	-9.7	4.3	24.3	46.9	53.8
Communications	-5.2	-4.5	38.9	43.1	32.5
Premise Telecom	-6.7	-10.1	40.2	57.5	33.9
Public Telecom	-11.4	-7.9	14.8	34.8	37.0
Mobile Communications	13.5	18.3	58.3	19.6	26.6
Broadcast and Studio	-10.8	-6.7	36.7	41.5	23.8
Other Communications	-11.5	-10.4	30.4	46.2	35.6
Industrial	-0.1	-4.6	37.4	29.9	30.6
Security and Energy Management	3.5	-4.7	35.2	45.1	30.2
Manufacturing System/Instruments	-1.1	-4.1	37.0	40.6	31.9
Medical Equipment	-1.6	-6.4	30.2	25.9	29.5
Other Industrial	3.8	-4.5	47.5	-13.3	24.3
Consumer	-3.6	-4.6	29.2	42.4	29.8
Audio	1.6	-4.0	34.8	34.4	31.2
Video	-1.6	-6.1	13.3	39.6	39.4
Personal Electronics	21.5	-6.1	36.0	37.5	26.2
Appliances	-4.7	-3.6	38.7	44.2	24.1
Other Consumer	-9.7	-3.7	40.3	45.9	31.7
Military/Civil Aerospace	-1.6	-6.1	-5.8	-2.8	-1.2
Transportation	0	2.0	10.1	21.5	22.9

Source: Dataquest (November 1995)

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Table 60
Revenue Growth from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	33.0	26.2	18.6	13.2	14.8	20.9
Data Processing	34.6	24.6	18.1	10.6	12.6	19.8
Computers	38.4	25.8	18.8	9.9	12.0	20.5
Data Storage	5.7	4.7	-7.9	-8.6	-9.4	-3.4
Input/Output	16.6	17.0	16.2	16.3	18.1	16.8
Dedicated System	38.2	34.3	25.0	19.5	18.7	26.9
Other Data Processing	34.3	26.3	15.6	10.7	10.6	19.1
Communications	39.2	31.7	19.7	14.8	17.1	24.2
Premise Telecom	36.6	28.0	17.0	13.8	14.9	21.8
Public Telecom	23.0	29.7	17.4	16.0	30.5	23.2
Mobile Communications	50.8	37.5	23.5	14.7	15.2	27.6
Broadcast and Studio	32.7	30.3	21.0	18.9	13.5	23.1
Other Communications	54.1	40.4	26.1	17.2	17.7	30.3
Industrial	35.9	32.2	21.0	18.9	19.6	25.3
Security and Energy Management	34.8	33.3	23.8	20.9	19.9	26.4
Manufacturing System/Instruments	37.4	32.5	20.3	18.6	19.9	25.5
Medical Equipment	34.4	33.2	24.1	21.5	20.9	26.7
Other Industrial	28.7	27.3	18.2	15.4	14.4	20.7
Consumer	31.7	26.1	21.2	16.8	16.0	22.2
Audio	46.8	39.3	28.0	26.2	24.7	32.7
Video	38.8	36.3	30.9	26.5	20.2	30.4
Personal Electronics	47.3	34.3	20.2	9.8	11.4	23.8
Appliances	23.3	15.6	11.9	7.4	10.5	13.6
Other Consumer	52.6	39.1	24.6	13.7	15.5	28.3
Military/Civil Aerospace	2.5	3.7	4.3	4.7	4.9	4.0
Transportation	13.0	13.0	13.0	10.0	10.0	11.8

Source: Dataquest (November 1995)

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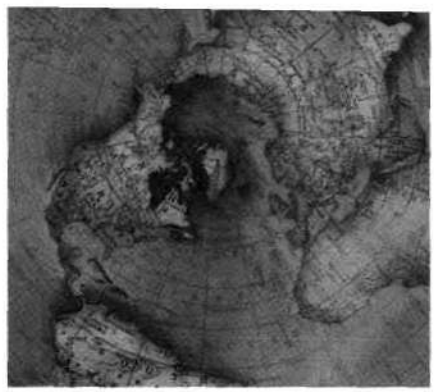
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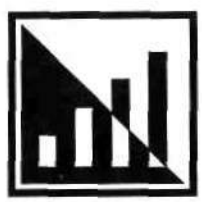
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Worldwide Semiconductor Consumption by Application Market



Market Statistics

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Worldwide Semiconductor Consumption by Application Market



Market Statistics

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Worldwide Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of worldwide semiconductor consumption in electronic equipment. This is the second of two forecasts that Dataquest now publishes biannually. The first forecast was published in the Market Statistics 1995 document titled *Worldwide Semiconductor Consumption by Application Market* (SAMM-WW-MS-9503, published June 26, 1995). This second forecast reflects changes in the world's electronic equipment and semiconductor markets since spring. It also reflects data revisions and updates suggested by Dataquest's continuing research of these dynamic markets.

Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

The tables in this document present data to answer the following types of questions:

- What general electronic equipment areas are driving semiconductor demand?
- What is the semiconductor-value composition of various categories of electronic equipment?
- What is the use of particular semiconductor categories such as MOS memory across the various electronic equipment areas?

The electronic equipment forecast contained in this document may be found in its entirety and in detail down to the level of specific equipment system groups in the Market Statistics 1995 document titled *Worldwide and North American Electronic Equipment Production Forecast* (SAMM-WW-MS-9504, published October 23, 1995).

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety in the Market Trends 1995 document titled *Semiconductor Five-Year Forecast Trends—Fall 1995* (SCND-WW-MT-9502, published October 23, 1995). Estimates in this document may differ slightly from estimates in the two aforementioned documents because of rounding.

The tables in this document are organized as follows:

- Tables 2 to 29 cover semiconductor consumption of the six broad application markets, by major semiconductor device group.
- Tables 30 to 57 cover consumption of the major semiconductor device category, by the six broad application markets.

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- Tables 58 to 61 cover total semiconductor consumption by each electronic equipment system group.

The following four tables are associated with each application market or semiconductor device category:

- Revenue levels, 1990-1994
- Revenue levels, 1995-1999
- Revenue growth, 1990-1994
- Revenue growth, 1995-1999

Segmentation

The following two sections outline market segments specific to this document. The first section outlines the electronic equipment segments. The second section outlines the semiconductor device segments. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the 1994 Dataquest Guide titled *Semiconductor Market Definitions* (SEMI-WW-GU-9501, published November 6, 1995).

Electronic Equipment Segmentation

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For purposes of semiconductor consumption analysis, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing

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- Communications
  - Premise telecom
  - Public telecom
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment
- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Semiconductor Device Segmentation

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optical semiconductor devices.

For purposes of semiconductor consumption analysis, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

- Total semiconductor
  - Total integrated circuit
    - Bipolar digital
    - MOS digital
      - MOS memory
      - MOS microcomponents
      - MOS logic
    - Analog (monolithic plus hybrid)
  - Total discrete
  - Total optical semiconductor

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Definitions

The following three sections list the definitions used by Dataquest to present the data in this document. The first section gives the electronic equipment definitions. The second section gives the semiconductor device definitions. The third section gives the definition of the worldwide regions. Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the *Dataquest High-Technology Guide: Segmentation and Glossary.* Definitions for semiconductor devices also can be found in the *Dataquest Semiconductor Market Definitions Guide.*

Electronic Equipment Definitions

Application markets are disaggregated into electronic equipment system groups, which are further disaggregated into specific types of electronic equipment systems. The electronic equipment hierarchy is described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as supercomputers and minicomputers), workstations, and PC/motherboard upgrades (including portable computers). Includes the value of central processing units (that is, boxes) only:
- Data Storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Note: The category "PC/motherboard upgrades" replaces the category "personal computers" and now includes motherboards offered for sale for use in personal computers.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

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Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T-carriers/TDM multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, WAN switching systems; premise voice systems, such as premise switching equipment (PBX telephone equipment and key telephone systems) and call processing equipment (voice messaging, interactive voice response systems, and automatic call distributors); and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Note: The category "T-carrier/TDM multiplexers" replaces the category "T1 multiplexers" and includes a slightly broader range of equipment now tracked by Dataquest. Similarly, the category "WAN switching systems" replaces the category "packet data switching systems" and includes a slightly broader range of equipment now tracked by Dataquest. The category "premise voice systems" combines the former categories "premise switching equipment" and "call processing equipment."

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing System/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.

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- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, portable/personal stereos, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Note: The category "portable/personal stereos" is a new one and tracks portable stereo systems for personal use.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and

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location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Semiconductor Device Definitions

Semiconductor device categories comprise specific types of semiconductor devices, as follows:

Total semiconductor (total integrated circuit + total discrete + total optical semiconductor): Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total integrated circuit (digital monolithic bipolar IC + digital monolithic MOS IC + analog IC): An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die, while a hybrid IC is one in which discrete circuits are integrated onto a small number of dies.

Bipolar digital IC (bipolar digital memory IC + bipolar digital logic IC): A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

MOS digital IC (MOS digital memory IC + MOS digital microcomponent IC + MOS digital logic IC): Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed-technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

MOS digital memory IC (DRAM + SRAM + EPROM + EEPROM + flash memory + mask ROM + other MOS digital memory IC): Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

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MOS digital microcomponent IC (MOS digital microprocessor + MOS digital microcontroller + MOS digital microperipheral + MOS digital signal processor + programmable digital signal processor): Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS digital logic IC (MOS digital application-specific IC + MOS digital standard logic IC + other MOS logic IC): Defined as a MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC (monolithic analog IC + hybrid IC): A monolithic analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package. A hybrid IC is defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total discrete (transistor + diode + thyristor + other discrete): A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total optical semiconductor (LED lamp/display + optocoupler + CCD + laser diode + photosensor + other optical semiconductor): Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

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  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The following two sections discuss definitions of the table line items specific to this document. The first section defines the line items associated with electronic equipment; the second section defines the line items associated with the semiconductor devices.

Electronic Equipment Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singapore operation (which is factory revenue) and the European distributor or final user.

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Personal computers are a particularly challenging example of a product whose production increasingly spans both time and geography. Today, it is not at all uncommon for personal computers to be assembled from components fabricated throughout the world. Moreover, the final assembly of a personal computer often occurs at a place far removed from the source of the computer's semiconductors. Dataquest considers a personal computer to be produced in the region where the majority of the computer's semiconductor value is generated. For instance, a personal computer whose electronic components are assembled in Asia/Pacific but whose final assembly into a system is done by a North American distributor in North America is considered produced in Asia/Pacific. This convention guarantees production is located in the region where semiconductor consumption is both the most likely and greatest. The computer is in turn valued at the factory cost of the North American distributor. This convention guarantees the final system is valued at a figure comparable to traditional factory selling price.

Semiconductor Device Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at the market price rather than at the transfer or factory price.

Data Sources

The historical electronic equipment production estimates presented in this document have been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce (DOC) estimates of manufacturers' shipments
- Trade associations
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today.

Forecast and Input/Output Ratio Methodology

The following three sections discuss the forecast methodology used by Dataquest in this document. The first section gives the electronic equipment forecast methodology. The second section gives the semiconductor forecast methodology. The third section discusses the

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interpretation of I/O ratios and the methodology of the allocation of the aggregate semiconductor forecast across specific electronic equipment markets.

Electronic Equipment Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This establishes a five-year trend growth path or "envelope" for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general comprises annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Aggregate Semiconductor Consumption Forecast Methodology

Dataquest publishes a five-year forecast of semiconductor device revenue twice a year, in April and October. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers

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of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a three-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronic equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest's Semiconductors Worldwide program and its Semiconductor Equipment, Materials, and Manufacturing Worldwide program, in conjunction with various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The I/O ratio reflects the relationship between the dollar value of semiconductors in a type of electronic system and the revenue generated by that system. The ratio is typically expressed as a percentage.

For example, if a piece of electronic equipment (such as a personal computer) sells for $1,000 and has $100 worth of semiconductors in it, the I/O ratio is expressed as:

$$\text{I/O ratio} = \frac{\text{Semiconductor Value—(Dollars In)}}{\text{Equipment Revenue (Dollars Out)}} = \frac{\$100}{\$1{,}000} = 0.10 \text{ or } 10 \text{ percent}$$

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Dataquest estimates semiconductor consumption by electronic equipment segment by combining sample information from electronic system semiconductor content analyses, and surveys of electronic manufacturers' semiconductor procurement and semiconductor manufacturers' shipments by application market with modeled semiconductor consumption. The semiconductor content analyses typically are performed on equipment that sell in high volume or otherwise significantly impact the semiconductor market. These analyses include personal computers, rigid disk drives, and cellular telephones.

The semiconductor consumption model makes use of the following inputs:

- Historical electronic equipment production and the current electronic equipment production forecast
- Historical semiconductor consumption (both aggregate and by electronic equipment segment) and the current semiconductor device revenue forecast
- Information about long-run market trends or long-term systems technology trends

Given these inputs, semiconductor consumption by equipment segment is estimated in an iterative procedure subject to the following constraints and conditions:

- The sum of semiconductor consumption across all equipment
- The sum of semiconductor consumption across all equipment markets fully exhausts aggregate semiconductor consumption.
- Market fluctuations in the aggregate semiconductor consumption forecast are realistically and appropriately mapped into the individual equipment segments' semiconductor consumption forecasts.

The procedure is iterative in the respect that modeled results are checked against prior beliefs, expectations, and sample information about each equipment segment's semiconductor consumption, and that this prior information is then used to tune the model such that modeled consumption estimates converge to their respective expected values.

The model combines two important sources of market variation: variation because of nonperiodic market fluctuations about the market's long-run trend growth path; and variation because of shifts in the market's long-run trend growth path.

It is necessarily the case that nonperiodic fluctuation in the aggregate semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Furthermore, because of a variety of factors, some device markets are relatively more volatile than other device markets. It is an observed fact that there is relatively more volatility in the MOS memory market—owing to price volatility—than in

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the analog market. Therefore, fluctuation in the MOS memory market "explains" more fluctuation in the aggregate semiconductor market than does fluctuation in the analog market. The model takes given inputs and assumptions and proportionally distributes fluctuations in the aggregate semiconductor market according to the equipment markets' respective long-run semiconductor device composition trends.

For example, because the data processing application market in general—and the computer equipment segment in particular—consumes proportionally more MOS memory devices than does equipment in the industrial market, other things being equal, it is reasonable to expect total semiconductor consumption to be more volatile in the data processing market than in the industrial market.

Semiconductor markets, in general, are relatively more volatile than are the electronic equipment markets. By construction, then, the I/O ratios tend to reflect this difference in volatility. Users of the I/O ratios, therefore, are cautioned to focus on long-run trends in the I/O ratios and growth rates rather than on the year-to-year movement in their values.

Production and I/O Ratio Re-Estimation and Revaluation

The historical and forecast electronic equipment production and semiconductor consumption by application market estimates contained in this book have undergone a thorough audit and review and have been re-estimated and restated to reflect primary or secondary information previously unavailable. Please note the following:

- Computer systems production has been re-estimated and revalued to equal the value of the worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. Also, computer systems' semiconductor consumption includes semiconductor shipments to U.S. PC marketers for postproduction use.
- Communications, industrial, consumer, and transportation production have been re-estimated and revalued to reflect revisions made by the Dataquest Telecommunications group, or secondary-sources estimates.
- Military/civil aerospace production has been re-estimated and revalued to reflect U.S. DOC estimates of U.S. defense and civil (aerospace) electronics. Also, spending on items such as nonrecurring engineering expenses (NRE), R&D, and testing have been eliminated to arrive at a more accurate equipment production estimate.

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Economic Assumptions

Slower Growth Expected in Major European, North American, and Asian Markets

Dun & Bradstreet's most recent quarterly survey of more than 11,000 global executives in 16 countries revealed expectations for slower near-term growth in net sales, net profits, selling prices, and employment in nearly every region of the world. The overall picture has continued to reveal a steady decline in worldwide business expectations since the beginning of 1995. On balance, however, the number of global executives predicting expansion still outnumbered those expecting lower sales and profits, thus suggesting some expansion in the world economy over the months to come.

Executives in nearly every region generally forecast a mature business cycle characterized by slow, steady growth over the near term accompanied by moderate inflationary pressures. Longer-term forecasts from Dun & Bradstreet subsidiary A.C. Nielsen suggest these circumstances are likely to prevail through the end of the decade. These forecasts indicate the world's developed economies are likely to experience modest but gradually accelerating growth over the next few years. The experience of the world's emerging economies will continue to be varied. Pacific Basin economies will continue to post impressive rates of growth. In contrast, Latin American economies are expected to experience only slight near-term growth because of ongoing economic crises in Mexico and Brazil. For the longer term, however, growth is likely to be impressive once these crises are resolved.

Expectations for Growth in Net Sales and Net Profits Decline in All Regions

Global expectations for growth in net sales and net profits over the near term continued the steady decline that marked the first half of the year. Dun & Bradstreet's World Indices for net sales and net profits dropped five and six points to 45 and 33, respectively. These declines were largely the result of marked declines in Pacific Basin and European indices. North American indices exhibited little change largely because results for Mexico were unavailable. The World Index for selling prices also declined, dropping seven points to 26. Here the decline was driven by expectations of reduced inflationary pressures in every region surveyed. The slow pressure to raise prices is an encouraging signal that production is keeping pace with healthy levels of demand. Dun & Bradstreet's World Indices for inventories and employment levels also each dropped two points to 13 and 16, respectively. Executives in every region but North America appear to expect slightly slower growth in finished goods inventories and employment levels.

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North America: Mexico Still Reeling from Devaluation of the Peso

Mexico continues to suffer spiraling inflation and economic instability stemming from devaluation of the peso. These circumstances made it virtually impossible to draw a sharp picture of expectations for the near-term course of the Mexican economy. Fortunately, Mexico and its Latin American trading partner Brazil represent the only exceptions to a basically stable global outlook. Excluding Mexico, North America should experience the strongest near-term growth of all regions. North America's continued strength as a market for exports is one of the main factors buoying optimism in global expectations. Longer-term growth forecasts for North America are as follows.

- Mexico's real gross domestic product (GDP) is now forecast to decline 3.0 percent in 1995, following 3.5 percent growth in 1994. Positive growth of 2.0 percent is expected in 1996. Growth is then anticipated to accelerate through the end of the decade, reaching 5.0 percent by 1999.
- The United States' GDP is now forecast to grow 2.9 percent in 1995, decelerating from 4.1 percent growth in 1994. Growth is expected to be robust through the end of 1995, thus making up for the slow growth observed in the spring. Growth is then anticipated to accelerate somewhat in 1996 to 3.2 percent and to remain at or near that level through the end of the decade.
- Canada's GDP is now forecast to grow 2.3 percent in 1995, decelerating from 4.5 percent growth in 1994. Growth is anticipated to accelerate to 2.7 percent in 1996 and then to average about 2.9 percent through the end of the decade. As in the United States, executives in Canada expressed strong optimism for net sales and net profits over the near term.

Europe: Some Growth Generally Expected in Near Term

In Europe, Dun & Bradstreet's indices for net sales and net profits both declined. The Selling Prices and Employment Level Indices also registered declines. Belgian and Swiss executives expressed the weakest expectations for the future while British and Dutch executives expressed the strongest. Despite marked variation across countries, all European indices remained positive, indicating European executives generally expect some growth over the near term. Longer-term growth forecasts for Europe are as follows:

- Germany's GDP is now forecast to grow 2.8 percent in 1995, decelerating from 2.9 percent growth in 1994. Growth is anticipated to decline somewhat to 2.7 percent in 1996 and then to average about 2.9 percent through 1999.
- France's GDP is now forecast to grow at 3.0 percent in 1995, accelerating from 2.8 percent growth in 1994. Growth is expected to slow somewhat to 2.9 percent in 1996 but then to quicken to 3.1 percent through the end of the decade.

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- Italy's GDP is now forecast to grow 3.0 percent in 1995, accelerating from 2.2 percent in 1994. Growth is anticipated to decline to 2.7 percent in 1996 and then to decelerate further to 2.5 percent by 1999.
- The United Kingdom's GDP is now forecast to grow 2.9 percent in 1995, decelerating from 3.9 percent growth in 1994. Growth is expected to decline somewhat to 2.8 percent in 1996 and to remain about at this level through 1999.

Japan and Pacific Rim: Weak Expectations Persist in Japan

Dun & Bradstreet's Net Sales and Net Profits Indices for Japan and the Pacific Rim both declined. The Selling Prices, Inventories, and Employment Level Indices also declined. All indices continued to remain at markedly low levels, particularly in Japan. The near-term outlook of Japanese executives for selling prices was particularly pessimistic as Japanese businesses continued their struggle to bring prices in line with production and operating costs. Consequently, Japanese executives also expressed weak net profits expectations. New Zealand executives expressed notably optimistic expectations about the near-term future of their economy. Longer-term growth forecasts for Japan and the Pacific Rim are as follows:

- Japan's GDP is now forecast to grow at 0.6 percent in 1995, unchanged from 1994. Growth is expected to increase to 1.5 percent in 1996 and then accelerate robustly to 3.5 percent by 1999.
- New Zealand's GDP is now forecast to grow 3.5 percent in 1995, decelerating from 6.2 percent in 1994. Growth is anticipated to slow to 3.3 percent in 1996 and then to average slightly more than 3.0 percent through the end of the decade.
- China's GDP is now expected to grow 9.5 percent in 1995, decelerating from 11.8 percent in 1994. Growth is expected to continue slowing through the end of the decade as the Chinese economy matures, declining to 7.5 percent by 1999.
- Taiwan's GDP is now forecast to grow 6.9 percent in 1995, accelerating from 6.5 percent growth in 1994. Growth is then anticipated to average 6.5 percent through 1999.
- South Korea's GDP is now forecast to grow 9.0 percent in 1995, accelerating from 8.4 percent growth in 1994. Growth is then expected to average better than 7.0 percent through the end of the decade.

Dun & Bradstreet's quarterly International Survey of Business Expectations is modeled on its quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. Survey participants are asked whether they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven highly accurate, with quarterly forecasts closely paralleling actual performance.

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The current international survey, completed in June 1995, uses similar sampling and interviewing procedures in all countries. Hence the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The Dun & Bradstreet index figures used here represent the net percentage of survey respondents expecting higher sales and profits, among others. The indices are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. GDP growth rates noted here are A.C. Nielsen's most current forecasts from August 1995.

Regional Electronic Equipment Production

North America

North America electronic equipment production is now forecast to grow 7.5 percent to $232.9 billion in 1995. This contrasts with the 5.7 percent growth forecast in spring and marks a deceleration from the 9.4 percent growth experienced in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The continued expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1995 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP) over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- LAN equipment is expected to continue strong growth throughout the forecast period. In addition to new markets in the small/home office area, investment in higher-speed technology such as 100-Mbps and ATM will give renewed growth to the industry.
- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecasts. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market,

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which will increase competition with existing wireless communications services, is expected to fuel even greater growth. However, PCS is a very cost-conscious market, and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, we expect strong growth for mobile equipment in North America and worldwide.

- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets. (Note: Better information on U.S. imports and exports has resulted in a revision to both historical and forecast revenue for North America.)
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets have also continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecom hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecom and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- The North America industrial electronics market will continue to be dominated by economic trends in the United States, principally growth in U.S. capital spending. The United States should remain a significant producer and net exporter of industrial electronics, especially test and measuring equipment. Canada and Mexico will continue to produce some industrial electronics locally, but will remain

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highly dependent on imports from the United States. Likewise, emerging Asian nations will continue to be consumers of U.S. production. (Note: North America industrial production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. capital spending.)

- The North America consumer electronics market will continue to be dominated by economic trends in the United States, chiefly growth in U.S. household income. The United States should remain a net importer of consumer electronics, despite growth in U.S. consumer electronics production. Mexico will remain a significant source of consumer electronics for North America and could well increase its share of U.S. and Canadian markets at the expense of Asia, given a favorable resolution of its current economic crises. (Note: North America consumer production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. household income.)
- U.S. military spending appears likely to increase over the next few years, based on the latest congressional budget proposals. Production of electronic warfare equipment is especially likely to increase in response. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.
- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems.

The most significant downside risk to the forecast continues to be the uncertainty surrounding U.S. economic policy. The growing U.S. trade and budget deficits present policy makers with numerous and challenging choices. Given the current fractious political environment and the uncertain state of economic knowledge concerning the links between the trade and budget deficits, it is not at all clear how policy makers will or even should proceed. The ongoing crisis in Mexico poses additional downside risk to the forecast. A prolonging of Mexico's economic woes accompanied by deepening social instability could well undermine the forecast. The most significant upside risk to the forecast remains a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

Japan

Dollar-based Japanese electronic equipment production is now forecast to grow 16.4 percent to $221.1 billion in 1995. This contrasts to 0.9 percent dollar-based growth forecast in the spring. It also marks an acceleration of growth from the 9.1 percent dollar-based growth experienced in 1994. Virtually all of Japan's dollar-based growth in both

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1995 and 1994 stems from appreciation of the yen against the dollar. The Japan forecast projects the yen to appreciate 15.1 percent against the dollar in 1995. This follows a projected appreciation of 9.2 percent in 1994. When expressed in yen, Japanese electronic equipment production is forecast to increase only 1.1 percent in 1995. This follows a 0.1 percent yen-based contraction experienced in 1994. Overall, Japanese equipment production will continue to be governed by two forces during the forecast period:

- The continuing shift of production offshore. Here, two trends are considered:
  - Electronics production of Japanese companies destined for export is shifting to the export-destination market, particularly for Asia and Europe.
  - Low-end electronics production of Japanese companies is migrating to areas in Asia with lower production costs.
- The strength of the yen against the dollar. Here again, two factors are considered:
  - The marked strengthening of the yen against the dollar has squeezed the margin of profitability on electronics exports, especially to the United States.
  - The strong yen has encouraged the offshore migration of electronics production from Japan: a strong yen over the long term is likely to reinforce and possibly accelerate migration of production.

The following specific factors influence forecast Japanese production:

- Japanese PC unit production is projected to increase but revenue will be held down by declines in average selling prices (ASPs). Revenue from mainframes and midrange computers also will slow as businesses globally turn to distributed/networked processing. The impact of this will be relatively stronger in Japan because of Japan's relatively higher ratio of mainframe production to total computer production.
- Dollar-based revenue from data storage production indicates some growth. This growth, however, stems from appreciation of the yen against the dollar. When expressed in yen, revenue from data storage production is expected to continue declining as production shifts offshore to elsewhere in Asia.
- Input/output device revenue will be buoyed by rising demand for Japanese display devices and high-end page printers.
- Revenue from communications equipment will be driven by strong revenue growth for public telecommunications and mobile communications equipment. Specifically, mobile communications will be spurred by strong demand for cellular phones and related infrastructure. Revenue growth from mobile communications may be stunted if large-volume unit production is accompanied by dramatic declines in ASPs.

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- Industrial equipment revenue will experience robust growth in both the short and long terms. In the short term, revenue will be boosted by the efforts of Kobe-area businesses to overcome the impact of January's earthquake. Revenue will also be buoyed by the rising wave of capital spending now taking place in Japan. Over the longer term, revenue will continue to grow in response to Japan's economic recovery and its commitment to advanced technology.
- Consumer equipment revenue will be impacted by two counterbalancing forces. On the one hand, revenue will continue to decline in response to the offshore migration of consumer production. Audio and video equipment revenue is expected to suffer continued declines on this account. Indeed, offshore migration for these products is expected to accelerate in the years to come. On the other hand, revenue is likely to show growth in response to Japan's growing housing rush. Home appliance revenue in particular is expected to experience robust growth on this account. Appliance revenue for 1995 is projected to be especially robust as Kobe earthquake survivors re-establish their homes and households across Japan and turn to air-conditioning for relief from the summer's unseasonable heat.

Overall, Japan's forecast hinges critically on the interrelated future of the yen against the dollar, the pace of offshore production migration away from Japan, the competitiveness of Japan's exports, and the progress of Japan's economic recovery. Renewed appreciation of the dollar against the yen would accelerate production migration, further handicap exports, and hamper economic recovery, thereby undermining the forecast. Conversely, depreciation would have the opposite effects. A bigger-than-expected PC boom and stronger-than-anticipated economic growth among Japan's trading partners would also lead to better-than-forecast results for Japan.

Europe

European electronic equipment production is now forecast to experience 8.3 percent growth to $171.5 billion in 1995. This contrasts with 3.3 percent growth forecast in the spring. It also marks an acceleration of growth from the 5.9 percent growth experienced in 1994. Europe forecast assumptions are as follows:

- European PC production is now expected to grow substantially through the forecast period, primarily for the consumer market.
- Growth of premise communications equipment will be driven by upgrades of PBX equipment to support both voice and data, with the trend toward voice traffic moving digitally and increasing use of cordless telephones.
- The European public telecom market is experiencing very little growth, but European telecom manufacturing companies' significant presence in the global market is benefiting from the superlative growth occurring in Asia/Pacific.

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- The central office switching market will decline in Europe during the rest of the forecast period, but production will be bolstered by exports to the fast-growing Asia/Pacific market. The European transmission market is set for slow, steady growth, but again there will be significant export opportunities outside western Europe.
- European cellular handset production is now expected to grow much more rapidly than in the spring. GSM continues to penetrate the European market and to enjoy success outside Europe. It now appears much more likely that the U.S. PCS market will adopt the GSM/DCS 1900 standard than in the spring. All of Japan's major producers also have established production facilities in Europe. This should further buoy European production of cellular handsets.
- Broadcast and studio equipment growth will be helped by investment upgrades to digital broadcast equipment.
- Most audio equipment production in Europe is for the high-end specialist market segment. The most important long-term growth opportunity in consumer audio is forecast to come from digital compact cassette equipment and stereo high-fidelity equipment. Volume manufacturers are the major Japanese brand leaders. Overall, the European audio market is supported by imports from Japan and the Far East.
- Color televisions dominate consumer video production. Long-term growth will be attributed to digital transmission, gaining momentum for satellite by 1997 and cable shortly thereafter.
- Wide-screen TV growth is strongest in France and Germany. Emerging digital satellite and cable services are expected to boost sales of wide-screen TVs toward the end of the decade.
- Camcorder production is expected to expand during the forecast period. Sony is the only camcorder manufacturer in Europe with a full assembly plant in France.
- Satellite TV receiver production continues to show strong growth in Europe as the competition from cable TV operators increases. TV sets with built-in analog CATV and DTH satellite receivers also are gaining popularity across Europe.
- Strong market growth and production is forecast for dishwashers and microwave ovens and air-conditioning toward the end of the forecast period. This is largely influenced by changing European demographics affected by changing patterns in marital status and family structures.

Note: Historical and forecast consumer equipment revenue has been revalued and revised to more accurately reflect European production and pricing of set-top boxes.

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The most significant downside risks to the European forecast include:

- In general, there will be slower-than-expected adoption of cellular telephone equipment.
- GSM success outside Europe does not proceed to volume handset use.
- GSM handset production for non-European markets migrates to non-European manufacturing centers.
- The forecast assumes that there will be no changes in tariffs other than those already announced after the General Agreement on Tariffs and Trade negotiations. More restrictive trade could diminish production opportunities.
- Eastern Europe is the volatile area of Europe; political and economic instability is an everyday fact of life. A marked increase of instability, however, could have a detrimental effect on investment in productive capacity.

The most significant upside risks to the European forecast include:

- Cellular handset penetration rates exceed expected future levels at every point in time.
- A strong Japanese economy and currency may accelerate a shift of production from Japan to Europe. (Already some Japanese car manufacturers are exporting their own cars assembled in Europe to Japan.)
- There is a remote possibility that interactive digital services will occur sooner than expected, but this is not very likely.
- Stronger-than-expected economic growth in eastern Europe and CIS markets would boost western European production above forecast levels.

Asia/Pacific-Rest of World

Asia/Pacific-Rest of World electronic equipment production is now forecast to grow 16.0 percent to $165.5 billion in 1995. This contrasts with 15.4 percent growth forecast in the spring. It also marks a deceleration from 20.8 percent growth experienced in 1994. The following factors influence the forecast:

- Generally speaking, prospects for Asia/Pacific remain strong. The region's economies are healthy and expected to experience vigorous and sustained growth over the long term. Foreign investment from Japan (in consumer goods), Europe (in telecommunications equipment), and the United States (in telecommunications and data processing equipment) continues at a robust pace. Moreover, investment from outside the region is being supplemented by intraregional investment from Taiwan. Exports remain strong and the region's economies are benefiting from the combination of internal social stability, regional political stability, and successful economic reform programs.

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- Asia/Pacific continues to benefit greatly from the shift of electronics production away from Japan. The future of this shift will depend heavily on the future course of the Japanese yen relative to the U.S. dollar. Ironically, Asia's "Four Tigers" (Taiwan, Hong Kong, South Korea, and Singapore) themselves may begin to experience a shift of low-value production to other parts of Asia such as Malaysia, Thailand, the Philippines, and Indonesia. In response, the Four Tigers would likely replace lost low-value production with higher-value production commensurate with their rising wages and growing worker skills. Thus, regional equipment production could well exceed forecast levels, given intraregional production shifts.
- The region's economy is increasingly unifying. There is both growing cooperation and interdependence among Asia/Pacific's individual economies. The continued expansion of Association of Southeast Asian Nations (ASEAN), which recently added Vietnam as a member, highlights this trend. An intraregional shift of low-value production from the Four Tigers to other parts of Asia would only reinforce this trend and add additional stimulus to regional growth.
- Production of PCs and related products will continue to be a mainstay of the region. Taiwan and Singapore should continue to be significant PC producers. Malaysia could well become a significant producer of PCs and related products in view of recent investments by several major producers. PC production in the region continues to be constrained by the ongoing DRAM shortage.
- Economic growth and prosperity in the region have generated robust local markets for electronic goods, especially consumer and telecommunications goods. Nonetheless, Asia/Pacific will continue to depend on the outside world both as an outlet for regionally produced data processing and consumer goods and as a source for imported telecommunications equipment. Although PC and consumer good demand is growing in the region, most production will continue to be for export. Regional demand for telecommunications equipment is likewise growing rapidly, especially in China. Although the region can be expected to produce large volumes of telecommunications equipment for local consumption over the long term, Asia/Pacific will continue to import sizable amounts of equipment (largely from Japan), over the near term.
- The region's future is heavily dependent on the future of China. As the world's most populous nation and one of its increasingly more affluent economies, China represents a veritable bonanza for the producers of electronic goods. By the same token, as a rapidly growing and already significant regional producer of electronic goods, China exerts sizable influence on Asia/Pacific equipment production. Two factors bear watching: the progress of the power shift from Deng Xiao Peng to his successor(s), and the path of China's relations with the United States. Although a gradual and smooth transition of power from Deng to a successor appears under way at the moment, the political strife created by a sudden disturbance in this process

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could have far-reaching effects on the region. Likewise, any increase in the already escalated political and economic tensions between China and the United States could have a profound effect on Asia/Pacific equipment production.

Regional Semiconductor Consumption

North America

North American semiconductor device revenue is forecast to grow 33.0 percent in 1995 to $47.8 billion, accelerating from 28.7 percent growth in 1994, and to grow at a 20.9 percent compound annual growth rate (CAGR) from 1994 to 1999, to 92.9 billion in 1999. The North American market forecast is predicated on the following assumptions:

- Data processing will remain the dominant market for semiconductors in North America. PC unit sales in North America will continue along the path of doubling over five years.
- Pentium processors are pushing up MPU revenue strongly. As we expect a long life for the Pentium, revenue growth will seem to slow in 1997 because the Pentium-to-Pentium Pro changeover may not occur as rapidly as 386-to-486-to-Pentium changeovers.
- High-ASP semiconductors, such as the x86 processors and memory SIMMs, will continue to be strongly consumed in North America and added to PCs or motherboards manufactured in the Asia/Pacific region.
- Besides PC consumption, resource-hungry software applications for Windows 95, as well as Windows 95 itself, will continue to drive semiconductor consumption toward higher-performance MPUs and larger DRAM configurations.
- Because of the strong computer market, microcomponent and memory ICs cornered 59 percent of the semiconductors shipped to North America in 1993 and more than 61 percent in 1994. We expect this share to exceed 66 percent in 1995 as microcomponent and memory ICs will lead all other product types in growth at 33 percent and 49 percent, respectively, within the North American market. By 1999, microcomponent and memory ICs will account for more than 71 percent of semiconductor revenue in North America.
- MOS memory will enjoy a third year of stable prices into 1995 with the continuing tight supply of 4Mb and 16Mb DRAM. The DRAM boom will continue well into 1996, but strong capital spending in 1994 by Japanese and Korean DRAM suppliers will show up as excess supply and a decline in ASPs by late 1996. Despite falling ASPs, DRAM revenue will be supported by increasing unit shipments as the PC market moves toward higher levels of DRAM use.

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- The 4Mb DRAM demand is showing continued strength through 1995, a break from past DRAM life cycles. This extended life is the result of limited acceptance of the x1 and x4 configurations of 16Mb DRAMs and the inability of vendors to supply the preferred x16 configuration. This has helped create price stability.
- MPUs will show a declining rate of growth toward the end of the forecast period as increased competition to the x86 family brings ASPs down.
- Discrete device growth (21.9 percent in 1994, 23.2 percent forecast for 1995) increasingly results from the use of power MOS-FETs and IGBTs in switching power supplies and as peripheral drivers and RF devices. MOS-FETs and IGBTs showed 30 percent and 100 percent growth in 1994, respectively, growth rates that are not flagging in 1995.

Japan

Dollar-based Japanese semiconductor device revenue is forecast to grow 34.9 percent in 1995 to $41.8 billion, accelerating from 25.8 percent growth in 1994, and to grow at a 16.0 percent CAGR from 1994 to 1999, to $65.2 billion in 1999. These forecasts have, of course, been influenced by appreciation of the yen against the dollar. When expressed in yen, Japanese semiconductor device revenue is forecast to grow 17.3 percent in 1995, accelerating from 15.2 percent in 1994. Over the longer term, yen-based revenue is forecast to grow at a 12.8 percent CAGR from 1994 to 1999. The Japanese market forecast is predicated on the following assumptions:

- Growth has been accelerating in Japan after the disastrous revenue decline in 1992. We anticipate 35 percent revenue growth in 1995 following the 20 percent and 26 percent growth seen in 1993 and 1994, respectively. Although the past three years have brought dollar revenue enhancements owing to yen-to-dollar depreciation, the Japanese market appears more fundamentally sound than expected previously. The continued migration of electronic equipment manufacturing to Asia/Pacific sites is a factor that will reduce revenue growth over the forecast period, but this migration has been somewhat stunted by constraints in growing Asian infrastructures. The result of this migration is that the Japanese market will drop from 28 percent of worldwide shipments in 1994 to slightly over 23 percent in 1999, a smaller loss of share than our past forecast and a factor in the more optimistic forecast seen here.
- MCU, analog IC, and optical semiconductor growth in Japan will be reduced by the offshore production shift of consumer electronics, the biggest application for these devices in Japan. Improving procurement functions for Japanese manufacturing sites in Asia/Pacific is aiding the slowdown of domestic procurement activities in Japan for these semiconductor devices.

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- As in other regions, MOS memory will enjoy a third year of strong growth in 1995 with the continuing tight supply of 4Mb and 16Mb DRAM. Domestic PC production is exceeding expectations, adding to the strong 78 percent DRAM growth expected in 1995. It is expected that DRAM growth will see a substantial decline in late 1996, as declining ASPs meet slowing demand.
- SRAM had only 7 percent growth in 1994 but will see a growth burst of 17 percent in 1995, as the domestic PC manufacturers consumes fast SRAM for caches.
- Discrete devices will grow at a 13 percent CAGR over the forecast period, starting with a strong 32 percent growth in 1995. Power devices like MOS-FETs and IGBT fuel this growth, but a slowing rate of manufacturing migration has increased the five-year CAGR over past forecasts.
- Optical semiconductors are expected to show a 30 percent growth in 1995, a growth increase over the 21 percent seen in 1994. An explosive increase in the consumption of CD-ROM players has helped fuel this growth. This growth will be blunted beyond 1996 as the multimedia frenzy slows. It is not expected that new growth opportunities in video compact optical storage will affect the forecast in the near term.

Europe

Europe's semiconductor device revenue is forecast to grow 39.3 percent in 1995 to $29.0 billion, accelerating from 34.7 percent growth in 1994, and to grow at a 20.0 percent CAGR from 1994 to 1999, to $51.9 billion in 1999. The European market forecast is predicated on the following assumptions:

- With 39 percent growth expected in 1995 following 35 percent growth in 1994 (and 27 percent growth in 1993), the European market has shown considerably more strength than we anticipated in our recent forecasts. This growth, based on the PC and personal communications booms, is expected to moderate in 1996.
- MCU growth has continued strongly as 1995 brings a second year of greater-than-30 percent revenue growth. ASP erosion, expected as supply catches up with demand in 1996, will limit revenue growth in 1997 and beyond.
- Shortages in discrete products enhanced the market in 1994 as ASPs were kept high. The 19.2 percent growth seen in 1994 was only a preliminary to the 35 percent annual growth expected in 1995. In addition to product shortages, power MOS-FET and IGBT demand has ramped up strongly in the past two years. In the longer term, discretes will return to lower, but more stable, growth.

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Asia/Pacific-ROW

Asia/Pacific-ROW's semiconductor device revenue is forecast to grow 36.5 percent in 1995 to $31.1 billion, accelerating from 30.5 percent growth in 1994, and to grow at a 23.6 percent CAGR from 1994 to 1999, to $65.7 billion in 1999. The Asia/Pacific-ROW market forecast is predicated on the following assumptions:

- The strong yen continues to drive electronic equipment production out of Japan and into the Asia/Pacific region, which offers not only lower production costs but growing markets. Despite this movement, Asia/Pacific will not pass Japan in revenue until 1999.
- China's economy will continue to grow over the forecast period, attracting computer, telecommunications, and consumer equipment manufacturers. High-end telecommunications equipment is being built in China, and shipments of pagers and cellular phones are expected to grow dramatically.
- Most of Asia/Pacific's growth in DRAM demand has come from the PC notebook and desktop sectors. In addition to strong PC shipment growth, incremental DRAM-per-system consumption growth is exacerbating the shortage in 1995 as minimum systems move from 4MB configurations to 8MB. Despite the shortages, DRAM revenue growth will exceed 55 percent in 1995 and 42 percent in 1996. Although ASPs are expected to decline in 1997, DRAM revenue will continue to grow with an increasing Asia/Pacific PC market and higher levels of DRAM usage.
- Even though we expect a 75 percent revenue growth in SRAMs in 1995, this growth has been hampered by severe SRAM shortages and lengthened lead times. Shortages of personal computer cache memories requiring 32Kbx8-configured 256K SRAMs have been increasing since the third quarter of 1994. The transition to 1MB cache RAM from 256KB will gain momentum by the fourth quarter of 1995 because of a strong market for Pentium PCs.
- Asia/Pacific's microprocessor market is dominated by x86 architectures. Although Taiwan produced 16 million PC motherboards in 1994, the number of microprocessors sold in Taiwan was only about 2 million. With ever-shortening PC life cycles, most PC products are shipped without the MPU on-board (92 percent of motherboards, 83 percent of desktop PCs, and 80 percent of notebook computers from Taiwan are shipped this way), a trend that will continue over the forecast period.
- Much of the microprocessor growth in Asia/Pacific results from the rapid growth in local PC consumption. The rising popularity of PCs in Asia/Pacific is being driven by Microsoft's local-language software, such as Chinese Windows, as well as by decreasing prices. In Asia/Pacific's emerging markets, buyers still focus more on the price of the PC system than on any other single factor.

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- The majority of PC motherboards built in Asia/Pacific are shipped with core logic chipsets on-board, making Taiwan one of the largest chipset markets in the world. Since large local chipset companies, such as ALI, SIS, and UMC, compete very aggressively in Taiwan, core logic chipset revenue in Asia/Pacific is not expected to grow as rapidly as microprocessor or memory revenue.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates for 1994 and for 1995 to 1999.

Table 1
Exchange Rates

Country	1994	1995-1999	1994-1995 U.S. Appreciation versus Foreign Currency (%)
Japan (Yen/U.S.$1)	101.81	88.48	-13.09
Europe (ECU/U.S.$1)	0.844	0.76	-9.63
France (Franc/U.S.$1)	5.5367	4.92	-11.07
Germany (Deutsche Mark/U.S.$1)	1.6203	1.41	-12.96
Great Britain (Pound Sterling/U.S.$1)	0.6536	0.63	-4.13
Italy (Lira/U.S.$1)	1,609.34	1,631.23	1.36
Korea (Won/U.S.$1)	802.84	765.58	-4.64
Taiwan (NT$/U.S.$1)	26.45	26.04	-1.55
Hong Kong (HK$/U.S.$1)	7.7276	7.74	0.12
Singapore (S$/U.S.$1)	1.5263	1.41	-7.74
China (Renminbi/U.S.$1)	8.5384	8.35	-2.24

Source: Dataquest (October 1995)

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Table 2
Revenue from Worldwide Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	566,226	598,874	604,655	639,716	707,607
Total Semiconductor	54,545	59,694	65,261	85,518	110,580
Total IC	44,459	48,855	54,418	73,429	95,928
Bipolar Digital	4,173	3,628	3,193	3,079	2,906
MOS Digital	30,152	34,315	39,710	56,374	75,951
MOS Memory	12,128	12,841	15,308	23,306	33,481
MOS Microcomponent	9,584	11,774	14,359	19,947	25,868
MOS Logic	8,440	9,700	10,043	13,121	16,602
Analog (Monolithic + Hybrid)	10,134	10,912	11,515	13,976	17,071
Total Discrete	7,674	8,035	8,155	9,083	10,758
Total Optical Semiconductor	2,412	2,804	2,688	3,006	3,894

Source: Dataquest (November 1995)

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Table 3
Revenue from Worldwide Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	791,001	855,405	921,544	999,861	1,086,294
Total Semiconductor	149,788	182,908	210,361	238,599	275,744
Total IC	130,658	161,283	187,101	212,955	246,810
Bipolar Digital	2,889	2,601	2,336	2,041	1,809
MOS Digital	106,899	134,483	158,239	180,761	210,220
MOS Memory	51,110	66,078	78,578	87,434	101,379
MOS Microcomponent	34,720	43,945	51,959	61,541	72,285
MOS Logic	21,069	24,460	27,702	31,786	36,556
Analog (Monolithic + Hybrid)	20,870	24,199	26,526	30,153	34,781
Total Discrete	14,067	15,927	17,158	19,027	21,514
Total Optical Semiconductor	5,063	5,698	6,102	6,617	7,420

Source: Dataquest (November 1995)

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Table 4
Revenue Growth from Worldwide Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	7.8	5.8	1.0	5.8	10.6
Total Semiconductor	0.4	9.4	9.3	31.0	29.3
Total IC	-0.3	9.9	11.4	34.9	30.6
Bipolar Digital	-3.3	-13.1	-12.0	-3.6	-5.6
MOS Digital	-3.2	13.8	15.7	42.0	34.7
MOS Memory	-21.3	5.9	19.2	52.2	43.7
MOS Microcomponent	22.7	22.9	22.0	38.9	29.7
MOS Logic	6.5	14.9	3.5	30.6	26.5
Analog (Monolithic + Hybrid)	10.6	7.7	5.5	21.4	22.1
Total Discrete	4.8	4.7	1.5	11.4	18.4
Total Optical Semiconductor	0.2	16.3	-4.1	11.8	29.5

Source: Dataquest (November 1995)

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Table 5
Revenue Growth from Worldwide Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	11.8	8.1	7.7	8.5	8.6	9.0
Total Semiconductor	35.5	22.1	15.0	13.4	15.6	20.1
Total IC	36.2	23.4	16.0	13.8	15.9	20.8
Bipolar Digital	-0.6	-10.0	-10.2	-12.6	-11.4	-9.0
MOS Digital	40.7	25.8	17.7	14.2	16.3	22.6
MOS Memory	52.7	29.3	18.9	11.3	15.9	24.8
MOS Microcomponent	34.2	26.6	18.2	18.4	17.5	22.8
MOS Logic	26.9	16.1	13.3	14.7	15.0	17.1
Analog (Monolithic + Hybrid)	22.3	16.0	9.6	13.7	15.3	15.3
Total Discrete	30.8	13.2	7.7	10.9	13.1	14.9
Total Optical Semiconductor	30.0	12.5	7.1	8.4	12.1	13.8

Source: Dataquest (November 1995)

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Table 6
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Data Processing	176,053	184,413	184,087	195,054	225,479
Total Semiconductor	20,389	23,051	26,007	37,850	51,066
Total IC	19,301	21,764	24,687	36,196	48,801
Bipolar Digital	2,267	2,008	1,744	1,719	1,650
MOS Digital	15,408	17,932	20,995	32,108	44,330
MOS Memory	7,761	8,450	9,957	15,663	23,157
MOS Microcomponent	4,434	5,742	7,163	10,971	14,157
MOS Logic	3,214	3,740	3,874	5,474	7,017
Analog (Monolithic + Hybrid)	1,626	1,824	1,948	2,369	2,821
Total Discrete	767	919	932	1,171	1,548
Total Optical Semiconductor	321	367	388	483	717

Source: Dataquest (November 1995)

1990

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Table 7
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Data Processing	254,720	279,201	298,912	321,708	347,466
Total Semiconductor	70,366	86,489	99,255	111,594	129,165
Total IC	67,507	83,277	95,871	107,879	124,990
Bipolar Digital	1,575	1,398	1,220	1,041	905
MOS Digital	62,454	77,949	90,499	102,173	118,683
MOS Memory	35,118	45,001	53,016	58,900	68,167
MOS Microcomponent	18,724	23,277	26,792	31,154	36,583
MOS Logic	8,612	9,671	10,691	12,119	13,932
Analog (Monolithic + Hybrid)	3,479	3,930	4,152	4,664	5,402
Total Discrete	1,946	2,191	2,307	2,553	2,863
Total Optical Semiconductor	912	1,021	1,076	1,163	1,313

Source: Dataquest (November 1995)

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Table 8
Revenue Growth from Worldwide Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Data Processing	9.8	4.7	-0.2	6.0	15.6
Total Semiconductor	-3.8	13.1	12.8	45.5	34.9
Total IC	-4.2	12.8	13.4	46.6	34.8
Bipolar Digital	-2.4	-11.4	-13.2	-1.4	-4.0
MOS Digital	-5.8	16.4	17.1	52.9	38.1
MOS Memory	-22.4	8.9	17.8	57.3	47.8
MOS Microcomponent	29.4	29.5	24.8	53.2	29.0
MOS Logic	9.6	16.4	3.6	41.3	28.2
Analog (Monolithic + Hybrid)	10.7	12.2	6.8	21.6	19.1
Total Discrete	10.3	19.8	1.3	25.7	32.1
Total Optical Semiconductor	-5.4	14.4	5.8	24.3	48.5

Source: Dataquest (November 1995)

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Table 9
Revenue Growth from Worldwide Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Data Processing	13.0	9.6	7.1	7.6	8.0	9.0
Total Semiconductor	37.8	22.9	14.8	12.4	15.7	20.4
Total IC	38.3	23.4	15.1	12.5	15.9	20.7
Bipolar Digital	-4.6	-11.2	-12.7	-14.7	-13.1	-11.3
MOS Digital	40.9	24.8	16.1	12.9	16.2	21.8
MOS Memory	51.7	28.1	17.8	11.1	15.7	24.1
MOS Microcomponent	32.3	24.3	15.1	16.3	17.4	20.9
MOS Logic	22.7	12.3	10.5	13.4	15.0	14.7
Analog (Monolithic + Hybrid)	23.3	13.0	5.6	12.3	15.8	13.9
Total Discrete	25.8	12.6	5.3	10.6	12.1	13.1
Total Optical Semiconductor	27.2	11.9	5.4	8.0	12.9	12.9

Source: Dataquest (November 1995)

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Table 10
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Communications	87,681	94,598	101,189	112,916	127,972
Total Semiconductor	8,495	8,962	10,418	14,054	18,820
Total IC	6,771	7,132	8,541	12,020	16,071
Bipolar Digital	698	559	521	464	425
MOS Digital	4,407	4,784	6,027	8,893	12,217
MOS Memory	1,479	1,457	1,981	3,018	4,411
MOS Microcomponent	1,237	1,447	1,927	2,789	3,673
MOS Logic	1,691	1,880	2,119	3,085	4,133
Analog (Monolithic + Hybrid)	1,667	1,789	1,993	2,663	3,429
Total Discrete	1,264	1,322	1,362	1,489	1,951
Total Optical Semiconductor	460	509	516	544	799

Source: Dataquest (November 1995)

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Table 11
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Communications	148,815	167,831	186,050	207,411	227,688
Total Semiconductor	26,824	34,539	40,845	47,135	54,713
Total IC	22,968	29,906	35,705	41,385	48,180
Bipolar Digital	503	480	454	409	374
MOS Digital	17,875	23,637	28,635	33,227	38,652
MOS Memory	7,040	9,549	11,633	12,959	14,975
MOS Microcomponent	5,269	7,178	8,948	10,883	12,753
MOS Logic	5,565	6,911	8,053	9,385	10,924
Analog (Monolithic + Hybrid)	4,590	5,789	6,617	7,749	9,155
Total Discrete	2,688	3,266	3,636	4,083	4,639
Total Optical Semiconductor	1,168	1,368	1,503	1,666	1,894

Source: Dataquest (November 1995)

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Table 12
Revenue Growth from Worldwide Communications Equipment Production and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Communications	11.1	7.9	7.0	11.6	13.3
Total Semiconductor	6.6	5.5	16.2	34.9	33.9
Total IC	5.0	5.3	19.7	40.7	33.7
Bipolar Digital	-1.2	-19.9	-6.8	-10.9	-8.4
MOS Digital	-0.2	8.6	26.0	47.6	37.4
MOS Memory	-20.7	-1.5	36.0	52.4	46.2
MOS Microcomponent	25.2	17.0	33.1	44.8	31.7
MOS Logic	8.2	11.2	12.7	45.6	33.9
Analog (Monolithic + Hybrid)	25.4	7.3	11.4	33.6	28.8
Total Discrete	15.3	4.6	3.0	9.3	31.0
Total Optical Semiconductor	8.4	10.6	1.4	5.6	46.7

Source: Dataquest (November 1995)

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Table 13
Revenue Growth from Worldwide Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Communications	16.3	12.8	10.9	11.5	9.8	12.2
Total Semiconductor	42.5	28.8	18.3	15.4	16.1	23.8
Total IC	42.9	30.2	19.4	15.9	16.4	24.6
Bipolar Digital	18.2	-4.6	-5.4	-9.9	-8.6	-2.6
MOS Digital	46.3	32.2	21.1	16.0	16.3	25.9
MOS Memory	59.6	35.6	21.8	11.4	15.6	27.7
MOS Microcomponent	43.5	36.2	24.7	21.6	17.2	28.3
MOS Logic	34.7	24.2	16.5	16.5	16.4	21.5
Analog (Monolithic + Hybrid)	33.9	26.1	14.3	17.1	18.1	21.7
Total Discrete	37.8	21.5	11.4	12.3	13.6	18.9
Total Optical Semiconductor	46.3	17.1	9.9	10.8	13.7	18.9

Source: Dataquest (November 1995)

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Table 14
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Industrial	93,682	97,548	97,282	99,920	106,814
Total Semiconductor	6,442	6,607	7,214	8,648	10,396
Total IC	4,247	4,399	5,037	6,267	7,694
Bipolar Digital	490	388	346	298	283
MOS Digital	2,395	2,596	3,207	4,296	5,405
MOS Memory	774	788	976	1,378	1,698
MOS Microcomponent	853	969	1,315	1,669	2,178
MOS Logic	769	840	916	1,250	1,529
Analog (Monolithic + Hybrid)	1,362	1,414	1,485	1,673	2,006
Total Discrete	1,742	1,696	1,683	1,918	2,129
Total Optical Semiconductor	454	513	494	463	573

Source: Dataquest (November 1995)

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Table 15
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Industrial	118,784	126,110	135,572	147,394	161,734
Total Semiconductor	13,808	17,011	19,820	22,930	26,807
Total IC	10,350	13,121	15,646	18,325	21,618
Bipolar Digital	294	277	263	241	221
MOS Digital	7,518	9,791	11,948	14,107	16,760
MOS Memory	2,639	3,488	4,343	4,978	5,919
MOS Microcomponent	2,959	3,996	4,948	6,008	7,160
MOS Logic	1,920	2,307	2,657	3,121	3,681
Analog (Monolithic + Hybrid)	2,538	3,053	3,435	3,976	4,636
Total Discrete	2,728	3,072	3,294	3,645	4,112
Total Optical Semiconductor	730	817	880	960	1,077

Source: Dataquest (November 1995)

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Table 16
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Industrial	9.1	4.1	-0.3	2.7	6.9
Total Semiconductor	4.5	2.6	9.2	19.9	20.2
Total IC	4.4	3.6	14.5	24.4	22.8
Bipolar Digital	-5.4	-20.8	-10.9	-13.9	-4.8
MOS Digital	0.3	8.4	23.5	34.0	25.8
MOS Memory	-18.5	1.8	23.9	41.1	23.3
MOS Microcomponent	15.9	13.7	35.7	26.9	30.5
MOS Logic	9.3	9.2	9.1	36.4	22.3
Analog (Monolithic + Hybrid)	17.3	3.8	5.0	12.7	19.9
Total Discrete	5.8	-2.6	-0.8	13.9	11.0
Total Optical Semiconductor	0.4	13.0	-3.7	-6.2	23.8

Source: Dataquest (November 1995)

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Table 17
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Industrial	11.2	6.2	7.5	8.7	9.7	8.7
Total Semiconductor	32.8	23.2	16.5	15.7	16.9	20.9
Total IC	34.5	26.8	19.2	17.1	18.0	23.0
Bipolar Digital	3.8	-5.6	-5.1	-8.4	-8.1	-4.8
MOS Digital	39.1	30.2	22.0	18.1	18.8	25.4
MOS Memory	55.4	32.1	24.5	14.6	18.9	28.4
MOS Microcomponent	35.8	35.1	23.8	21.4	19.2	26.9
MOS Logic	25.6	20.2	15.2	17.5	17.9	19.2
Analog (Monolithic + Hybrid)	26.6	20.3	12.5	15.8	16.6	18.2
Total Discrete	28.2	12.6	7.2	10.6	12.8	14.1
Total Optical Semiconductor	27.3	12.0	7.6	9.2	12.1	13.4

Source: Dataquest (November 1995)

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Table 18
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Consumer Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Consumer	124,888	137,515	135,788	144,778	158,675
Total Semiconductor	13,211	14,923	15,206	17,727	21,917
Total IC	9,529	10,824	11,175	13,297	16,802
Bipolar Digital	221	243	211	226	210
MOS Digital	5,276	6,158	6,361	7,511	9,755
MOS Memory	1,555	1,587	1,803	2,413	3,188
MOS Microcomponent	1,953	2,368	2,506	2,966	3,976
MOS Logic	1,769	2,202	2,052	2,132	2,591
Analog (Monolithic + Hybrid)	4,031	4,423	4,603	5,560	6,837
Total Discrete	2,755	2,951	3,018	3,213	3,670
Total Optical Semiconductor	927	1,149	1,013	1,218	1,446

Source: Dataquest (November 1995)

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Table 19
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Consumer Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Consumer	175,948	186,359	201,039	218,457	239,061
Total Semiconductor	28,678	33,537	38,018	43,430	50,235
Total IC	21,958	26,078	29,999	34,567	40,153
Bipolar Digital	216	178	146	118	97
MOS Digital	13,685	16,865	20,071	23,418	27,464
MOS Memory	4,858	6,310	7,667	8,611	10,190
MOS Microcomponent	5,400	6,681	8,016	9,788	11,641
MOS Logic	3,427	3,874	4,388	5,020	5,633
Analog (Monolithic + Hybrid)	8,058	9,035	9,782	11,032	12,592
Total Discrete	4,916	5,453	5,886	6,575	7,538
Total Optical Semiconductor	1,804	2,006	2,133	2,287	2,544

Source: Dataquest (November 1995)

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Table 20
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Consumer	5.5	10.1	-1.3	6.6	9.6
Total Semiconductor	0.9	13.0	1.9	16.6	23.6
Total IC	1.2	13.6	3.2	19.0	26.4
Bipolar Digital	-7.5	10.0	-13.5	7.5	-7.1
MOS Digital	-1.6	16.7	3.3	18.1	29.9
MOS Memory	-19.6	2.1	13.6	33.8	32.1
MOS Microcomponent	17.5	21.3	5.8	18.4	34.1
MOS Logic	0.3	24.5	-6.8	3.9	21.5
Analog (Monolithic + Hybrid)	5.7	9.7	4.1	20.8	23.0
Total Discrete	0.4	7.1	2.3	6.5	14.2
Total Optical Semiconductor	-0.9	23.8	-11.8	20.2	18.7

Source: Dataquest (November 1995)

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Table 21
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Consumer	10.9	5.9	7.9	8.7	9.4	8.5
Total Semiconductor	30.8	16.9	13.4	14.2	15.7	18.0
Total IC	30.7	18.8	15.0	15.2	16.2	19.0
Bipolar Digital	2.5	-17.3	-18.0	-19.5	-17.2	-14.3
MOS Digital	40.3	23.2	19.0	16.7	17.3	23.0
MOS Memory	52.4	29.9	21.5	12.3	18.3	26.2
MOS Microcomponent	35.8	23.7	20.0	22.1	18.9	24.0
MOS Logic	32.3	13.1	13.3	14.4	12.2	16.8
Analog (Monolithic + Hybrid)	17.9	12.1	8.3	12.8	14.1	13.0
Total Discrete	34.0	10.9	7.9	11.7	14.6	15.5
Total Optical Semiconductor	24.8	11.2	6.3	7.2	11.2	12.0

Source: Dataquest (November 1995)

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Table 22
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	62,764	62,257	61,701	59,654	58,229
Total Semiconductor	2,806	2,719	2,660	2,679	2,749
Total IC	2,199	2,131	2,087	2,181	2,239
Bipolar Digital	417	354	298	289	260
MOS Digital	1,200	1,224	1,262	1,349	1,427
MOS Memory	388	379	386	471	519
MOS Microcomponent	338	363	393	347	364
MOS Logic	474	482	483	531	543
Analog (Monolithic + Hybrid)	583	553	527	543	552
Total Discrete	501	479	469	407	411
Total Optical Semiconductor	106	108	105	91	99

Source: Dataquest (November 1995)

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Table 23
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Military/Civil Aerospace	58,361	59,275	60,445	61,912	63,508
Total Semiconductor	2,900	3,014	3,153	3,262	3,459
Total IC	2,362	2,492	2,635	2,735	2,904
Bipolar Digital	226	203	192	180	165
MOS Digital	1,602	1,760	1,914	2,012	2,170
MOS Memory	655	763	854	869	933
MOS Microcomponent	406	440	478	519	558
MOS Logic	540	557	581	625	679
Analog (Monolithic + Hybrid)	535	530	529	543	569
Total Discrete	440	423	419	425	443
Total Optical Semiconductor	98	98	99	102	111

Source: Dataquest (November 1995)

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Table 24
Revenue Growth from Worldwide Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	1.7	-0.8	-0.9	-3.3	-2.4
Total Semiconductor	-2.9	-3.1	-2.1	0.7	2.6
Total IC	-2.4	-3.1	-2.1	4.5	2.7
Bipolar Digital	-9.7	-15.1	-15.9	-3.0	-10.0
MOS Digital	-2.9	2.0	3.1	6.9	5.8
MOS Memory	-13.2	-2.3	2.0	21.8	10.3
MOS Microcomponent	4.1	7.4	8.3	-11.7	4.9
MOS Logic	2.1	1.6	0.2	10.0	2.4
Analog (Monolithic + Hybrid)	4.6	-5.0	-4.7	3.0	1.6
Total Discrete	-4.5	-4.4	-2.3	-13.2	1.1
Total Optical Semiconductor	-4.9	2.3	-3.3	-12.8	8.4

Source: Dataquest (November 1995)

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Table 25
Revenue Growth from Worldwide Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Military/Civil Aerospace	0.2	1.6	2.0	2.4	2.6	1.8
Total Semiconductor	5.5	3.9	4.6	3.4	6.0	4.7
Total IC	5.5	5.5	5.7	3.8	6.2	5.3
Bipolar Digital	-13.2	-10.2	-5.3	-6.3	-8.5	-8.7
MOS Digital	12.3	9.9	8.7	5.1	7.9	8.8
MOS Memory	26.2	16.5	11.9	1.7	7.4	12.4
MOS Microcomponent	11.5	8.3	8.7	8.5	7.6	8.9
MOS Logic	-0.6	3.1	4.4	7.4	8.8	4.6
Analog (Monolithic + Hybrid)	-3.1	-1.0	-0.1	2.6	4.8	0.6
Total Discrete	7.0	-3.7	-1.0	1.5	4.3	1.5
Total Optical Semiconductor	-0.9	-0.4	1.6	2.7	8.9	2.3

Source: Dataquest (November 1995)

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Table 26
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Transportation	21,158	22,544	24,607	27,394	30,438
Total Semiconductor	3,201	3,432	3,755	4,560	5,632
Total IC	2,412	2,605	2,891	3,468	4,321
Bipolar Digital	81	75	74	83	77
MOS Digital	1,466	1,622	1,858	2,217	2,817
MOS Memory	172	181	204	364	508
MOS Microcomponent	771	885	1,055	1,204	1,519
MOS Logic	524	557	599	649	789
Analog (Monolithic + Hybrid)	865	908	959	1,168	1,427
Total Discrete	645	668	692	886	1,050
Total Optical Semiconductor	144	159	172	207	261

Source: Dataquest (November 1995)

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Table 27
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Transportation	34,372	36,628	39,525	42,978	46,837
Total Semiconductor	7,213	8,319	9,270	10,249	11,365
Total IC	5,512	6,408	7,245	8,064	8,964
Bipolar Digital	76	65	61	53	47
MOS Digital	3,766	4,481	5,173	5,823	6,491
MOS Memory	800	968	1,065	1,117	1,195
MOS Microcomponent	1,962	2,373	2,777	3,189	3,589
MOS Logic	1,005	1,140	1,331	1,517	1,707
Analog (Monolithic + Hybrid)	1,670	1,862	2,011	2,188	2,426
Total Discrete	1,349	1,522	1,614	1,746	1,919
Total Optical Semiconductor	351	388	411	439	481

Source: Dataquest (November 1995)

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Table 28
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Transportation	6.2	6.6	9.2	11.3	11.1
Total Semiconductor	5.7	7.2	9.4	21.4	23.5
Total IC	6.2	8.0	11.0	20.0	24.6
Bipolar Digital	21.9	-6.6	-2.1	12.2	-6.9
MOS Digital	6.5	10.6	14.6	19.3	27.0
MOS Memory	-16.5	5.1	12.9	78.4	39.7
MOS Microcomponent	15.0	14.8	19.3	14.1	26.2
MOS Logic	4.6	6.2	7.7	8.3	21.6
Analog (Monolithic + Hybrid)	4.4	5.0	5.6	21.8	22.2
Total Discrete	5.0	3.6	3.6	27.9	18.6
Total Optical Semiconductor	0.7	10.1	8.2	20.3	25.9

Source: Dataquest (November 1995)

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Table 29
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Transportation	12.9	6.6	7.9	8.7	9.0	9.0
Total Semiconductor	28.1	15.3	11.4	10.6	10.9	15.1
Total IC	27.6	16.3	13.1	11.3	11.2	15.7
Bipolar Digital	-1.1	-14.6	-7.1	-13.2	-10.5	-9.4
MOS Digital	33.7	19.0	15.5	12.6	11.5	18.2
MOS Memory	57.4	21.1	10.0	4.9	7.0	18.7
MOS Microcomponent	29.1	21.0	17.0	14.8	12.5	18.8
MOS Logic	27.3	13.5	16.8	14.0	12.5	16.7
Analog (Monolithic + Hybrid)	17.0	11.5	8.0	8.8	10.9	11.2
Total Discrete	28.4	12.8	6.1	8.1	10.0	12.8
Total Optical Semiconductor	34.6	10.6	5.7	6.9	9.6	13.0

Source: Dataquest (November 1995)

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Table 30
Revenue from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4,173	3,628	3,193	3,079	2,906
Data Processing	2,267	2,008	1,744	1,719	1,650
Communications	698	559	521	464	425
Industrial	490	388	346	298	283
Consumer	221	243	211	226	210
Military/Civil Aerospace	417	354	298	289	260
Transportation	81	75	74	83	77

Source: Dataquest (November 1995)

Table 31
Revenue from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	2,889	2,601	2,336	2,041	1,809
Data Processing	1,575	1,398	1,220	1,041	905
Communications	503	480	454	409	374
Industrial	294	277	263	241	221
Consumer	216	178	146	118	97
Military/Civil Aerospace	226	203	192	180	165
Transportation	76	65	61	53	47

Source: Dataquest (November 1995)

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Table 32
Revenue Growth from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-3.3	-13.1	-12.0	-3.6	-5.6
Data Processing	-2.4	-11.4	-13.2	-1.4	-4.0
Communications	-1.2	-19.9	-6.8	-10.9	-8.4
Industrial	-5.4	-20.8	-10.9	-13.9	-4.8
Consumer	-7.5	10.0	-13.5	7.5	-7.1
Military/Civil Aerospace	-9.7	-15.1	-15.9	-3.0	-10.0
Transportation	21.9	-6.6	-2.1	12.2	-6.9

Source: Dataquest (November 1995)

Table 33
Revenue Growth from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	-0.6	-10.0	-10.2	-12.6	-11.4	-9.0
Data Processing	-4.6	-11.2	-12.7	-14.7	-13.1	-11.3
Communications	18.2	-4.6	-5.4	-9.9	-8.6	-2.6
Industrial	3.8	-5.6	-5.1	-8.4	-8.1	-4.8
Consumer	2.5	-17.3	-18.0	-19.5	-17.2	-14.3
Military/Civil Aerospace	-13.2	-10.2	-5.3	-6.3	-8.5	-8.7
Transportation	-1.1	-14.6	-7.1	-13.2	-10.5	-9.4

Source: Dataquest (November 1995)

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Table 34
Revenue from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	12,128	12,841	15,308	23,306	33,481
Data Processing	7,761	8,450	9,957	15,663	23,157
Communications	1,479	1,457	1,981	3,018	4,411
Industrial	774	788	976	1,378	1,698
Consumer	1,555	1,587	1,803	2,413	3,188
Military/Civil Aerospace	388	379	386	471	519
Transportation	172	181	204	364	508

Source: Dataquest (November 1995)

Table 35
Revenue from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	51,110	66,078	78,578	87,434	101,379
Data Processing	35,118	45,001	53,016	58,900	68,167
Communications	7,040	9,549	11,633	12,959	14,975
Industrial	2,639	3,488	4,343	4,978	5,919
Consumer	4,858	6,310	7,667	8,611	10,190
Military/Civil Aerospace	655	763	854	869	933
Transportation	800	968	1,065	1,117	1,195

Source: Dataquest (November 1995)

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Table 36
Revenue Growth from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-21.3	5.9	19.2	52.2	43.7
Data Processing	-22.4	8.9	17.8	57.3	47.8
Communications	-20.7	-1.5	36.0	52.4	46.2
Industrial	-18.5	1.8	23.9	41.1	23.3
Consumer	-19.6	2.1	13.6	33.8	32.1
Military/Civil Aerospace	-13.2	-2.3	2.0	21.8	10.3
Transportation	-16.5	5.1	12.9	78.4	39.7

Source: Dataquest (November 1995)

Table 37
Revenue Growth from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	52.7	29.3	18.9	11.3	15.9	24.8
Data Processing	51.7	28.1	17.8	11.1	15.7	24.1
Communications	59.6	35.6	21.8	11.4	15.6	27.7
Industrial	55.4	32.1	24.5	14.6	18.9	28.4
Consumer	52.4	29.9	21.5	12.3	18.3	26.2
Military/Civil Aerospace	26.2	16.5	11.9	1.7	7.4	12.4
Transportation	57.4	21.1	10.0	4.9	7.0	18.7

Source: Dataquest (November 1995)

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Table 38
Revenue from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	9,584	11,774	14,359	19,947	25,868
Data Processing	4,434	5,742	7,163	10,971	14,157
Communications	1,237	1,447	1,927	2,789	3,673
Industrial	853	969	1,315	1,669	2,178
Consumer	1,953	2,368	2,506	2,966	3,976
Military/Civil Aerospace	338	363	393	347	364
Transportation	771	885	1,055	1,204	1,519

Source: Dataquest (November 1995)

Table 39
Revenue from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	34,720	43,945	51,959	61,541	72,285
Data Processing	18,724	23,277	26,792	31,154	36,583
Communications	5,269	7,178	8,948	10,883	12,753
Industrial	2,959	3,996	4,948	6,008	7,160
Consumer	5,400	6,681	8,016	9,788	11,641
Military/Civil Aerospace	406	440	478	519	558
Transportation	1,962	2,373	2,777	3,189	3,589

Source: Dataquest (November 1995)

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Table 40
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	22.7	22.9	22.0	38.9	29.7
Data Processing	29.4	29.5	24.8	53.2	29.0
Communications	25.2	17.0	33.1	44.8	31.7
Industrial	15.9	13.7	35.7	26.9	30.5
Consumer	17.5	21.3	5.8	18.4	34.1
Military/Civil Aerospace	4.1	7.4	8.3	-11.7	4.9
Transportation	15.0	14.8	19.3	14.1	26.2

Source: Dataquest (November 1995)

Table 41
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	34.2	26.6	18.2	18.4	17.5	22.8
Data Processing	32.3	24.3	15.1	16.3	17.4	20.9
Communications	43.5	36.2	24.7	21.6	17.2	28.3
Industrial	35.8	35.1	23.8	21.4	19.2	26.9
Consumer	35.8	23.7	20.0	22.1	18.9	24.0
Military/Civil Aerospace	11.5	8.3	8.7	8.5	7.6	8.9
Transportation	29.1	21.0	17.0	14.8	12.5	18.8

Source: Dataquest (November 1995)

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Table 42
Revenue from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	8,440	9,700	10,043	13,121	16,602
Data Processing	3,214	3,740	3,874	5,474	7,017
Communications	1,691	1,880	2,119	3,085	4,133
Industrial	769	840	916	1,250	1,529
Consumer	1,769	2,202	2,052	2,132	2,591
Military/Civil Aerospace	474	482	483	531	543
Transportation	524	557	599	649	789

Source: Dataquest (November 1995)

Table 43
Revenue from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	21,069	24,460	27,702	31,786	36,556
Data Processing	8,612	9,671	10,691	12,119	13,932
Communications	5,565	6,911	8,053	9,385	10,924
Industrial	1,920	2,307	2,657	3,121	3,681
Consumer	3,427	3,874	4,388	5,020	5,633
Military/Civil Aerospace	540	557	581	625	679
Transportation	1,005	1,140	1,331	1,517	1,707

Source: Dataquest (November 1995)

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Table 44
Revenue Growth from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	6.5	14.9	3.5	30.6	26.5
Data Processing	9.6	16.4	3.6	41.3	28.2
Communications	8.2	11.2	12.7	45.6	33.9
Industrial	9.3	9.2	9.1	36.4	22.3
Consumer	0.3	24.5	-6.8	3.9	21.5
Military/Civil Aerospace	2.1	1.6	0.2	10.0	2.4
Transportation	4.6	6.2	7.7	8.3	21.6

Source: Dataquest (November 1995)

Table 45
Revenue Growth from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	26.9	16.1	13.3	14.7	15.0	17.1
Data Processing	22.7	12.3	10.5	13.4	15.0	14.7
Communications	34.7	24.2	16.5	16.5	16.4	21.5
Industrial	25.6	20.2	15.2	17.5	17.9	19.2
Consumer	32.3	13.1	13.3	14.4	12.2	16.8
Military/Civil Aerospace	-0.6	3.1	4.4	7.4	8.8	4.6
Transportation	27.3	13.5	16.8	14.0	12.5	16.7

Source: Dataquest (November 1995)

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Table 46
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10,134	10,912	11,515	13,976	17,071
Data Processing	1,626	1,824	1,948	2,369	2,821
Communications	1,667	1,789	1,993	2,663	3,429
Industrial	1,362	1,414	1,485	1,673	2,006
Consumer	4,031	4,423	4,603	5,560	6,837
Military/Civil Aerospace	583	553	527	543	552
Transportation	865	908	959	1,168	1,427

Source: Dataquest (November 1995)

Table 47
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	20,870	24,199	26,526	30,153	34,781
Data Processing	3,479	3,930	4,152	4,664	5,402
Communications	4,590	5,789	6,617	7,749	9,155
Industrial	2,538	3,053	3,435	3,976	4,636
Consumer	8,058	9,035	9,782	11,032	12,592
Military/Civil Aerospace	535	530	529	543	569
Transportation	1,670	1,862	2,011	2,188	2,426

Source: Dataquest (November 1995)

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Table 48
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10.6	7.7	5.5	21.4	22.1
Data Processing	10.7	12.2	6.8	21.6	19.1
Communications	25.4	7.3	11.4	33.6	28.8
Industrial	17.3	3.8	5.0	12.7	19.9
Consumer	5.7	9.7	4.1	20.8	23.0
Military/Civil Aerospace	4.6	-5.0	-4.7	3.0	1.6
Transportation	4.4	5.0	5.6	21.8	22.2

Source: Dataquest (November 1995)

Table 49
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	22.3	16.0	9.6	13.7	15.3	15.3
Data Processing	23.3	13.0	5.6	12.3	15.8	13.9
Communications	33.9	26.1	14.3	17.1	18.1	21.7
Industrial	26.6	20.3	12.5	15.8	16.6	18.2
Consumer	17.9	12.1	8.3	12.8	14.1	13.0
Military/Civil Aerospace	-3.1	-1.0	-0.1	2.6	4.8	0.6
Transportation	17.0	11.5	8.0	8.8	10.9	11.2

Source: Dataquest (November 1995)

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Table 50
Revenue from Shipments of Discrete Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	7,674	8,035	8,155	9,083	10,758
Data Processing	767	919	932	1,171	1,548
Communications	1,264	1,322	1,362	1,489	1,951
Industrial	1,742	1,696	1,683	1,918	2,129
Consumer	2,755	2,951	3,018	3,213	3,670
Military/Civil Aerospace	501	479	469	407	411
Transportation	645	668	692	886	1,050

Source: Dataquest (November 1995)

Table 51
Revenue from Shipments of Discrete Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	14,067	15,927	17,158	19,027	21,514
Data Processing	1,946	2,191	2,307	2,553	2,863
Communications	2,688	3,266	3,636	4,083	4,639
Industrial	2,728	3,072	3,294	3,645	4,112
Consumer	4,916	5,453	5,886	6,575	7,538
Military/Civil Aerospace	440	423	419	425	443
Transportation	1,349	1,522	1,614	1,746	1,919

Source: Dataquest (November 1995)

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Table 52
Revenue Growth from Shipments of Discrete Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.8	4.7	1.5	11.4	18.4
Data Processing	10.3	19.8	1.3	25.7	32.1
Communications	15.3	4.6	3.0	9.3	31.0
Industrial	5.8	-2.6	-0.8	13.9	11.0
Consumer	0.4	7.1	2.3	6.5	14.2
Military/Civil Aerospace	-4.5	-4.4	-2.3	-13.2	1.1
Transportation	5.0	3.6	3.6	27.9	18.6

Source: Dataquest (November 1995)

Table 53
Revenue Growth from Shipments of Discrete Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	30.8	13.2	7.7	10.9	13.1	14.9
Data Processing	25.8	12.6	5.3	10.6	12.1	13.1
Communications	37.8	21.5	11.4	12.3	13.6	18.9
Industrial	28.2	12.6	7.2	10.6	12.8	14.1
Consumer	34.0	10.9	7.9	11.7	14.6	15.5
Military/Civil Aerospace	7.0	-3.7	-1.0	1.5	4.3	1.5
Transportation	28.4	12.8	6.1	8.1	10.0	12.8

Source: Dataquest (November 1995)

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Table 54
Revenue from Shipments of Optical Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,412	2,804	2,688	3,006	3,894
Data Processing	321	367	388	483	717
Communications	460	509	516	544	799
Industrial	454	513	494	463	573
Consumer	927	1,149	1,013	1,218	1,446
Military/Civil Aerospace	106	108	105	91	99
Transportation	144	159	172	207	261

Source: Dataquest (November 1995)

Table 55
Revenue from Shipments of Optical Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	5,063	5,698	6,102	6,617	7,420
Data Processing	912	1,021	1,076	1,163	1,313
Communications	1,168	1,368	1,503	1,666	1,894
Industrial	730	817	880	960	1,077
Consumer	1,804	2,006	2,133	2,287	2,544
Military/Civil Aerospace	98	98	99	102	111
Transportation	351	388	411	439	481

Source: Dataquest (November 1995)

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Table 56
Revenue Growth from Shipments of Optical Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	0.2	16.3	-4.1	11.8	29.5
Data Processing	-5.4	14.4	5.8	24.3	48.5
Communications	8.4	10.6	1.4	5.6	46.7
Industrial	0.4	13.0	-3.7	-6.2	23.8
Consumer	-0.9	23.8	-11.8	20.2	18.7
Military/Civil Aerospace	-4.9	2.3	-3.3	-12.8	8.4
Transportation	0.7	10.1	8.2	20.3	25.9

Source: Dataquest (November 1995)

Table 57
Revenue Growth from Shipments of Optical Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	30.0	12.5	7.1	8.4	12.1	13.8
Data Processing	27.2	11.9	5.4	8.0	12.9	12.9
Communications	46.3	17.1	9.9	10.8	13.7	18.9
Industrial	27.3	12.0	7.6	9.2	12.1	13.4
Consumer	24.8	11.2	6.3	7.2	11.2	12.0
Military/Civil Aerospace	-0.9	-0.4	1.6	2.7	8.9	2.3
Transportation	34.6	10.6	5.7	6.9	9.6	13.0

Source: Dataquest (November 1995)

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Table 58
Revenue from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	54,545	59,694	65,261	85,518	110,580
Data Processing	20,389	23,051	26,007	37,850	51,066
Computers	12,106	13,868	16,282	25,243	35,174
Data Storage	2,817	2,683	2,841	3,480	4,727
Input/Output	3,571	4,214	4,493	5,733	6,794
Dedicated System	1,405	1,661	1,633	2,313	2,783
Other Data Processing	490	624	759	1,081	1,588
Communications	8,495	8,962	10,418	14,054	18,820
Premise Telecom	3,348	3,485	4,169	5,808	7,566
Public Telecom	2,134	2,148	2,118	2,606	3,276
Mobile Communications	1,752	2,152	2,847	4,000	5,934
Broadcast and Studio	312	338	388	524	662
Other Communications	949	839	896	1,116	1,381
Industrial	6,442	6,607	7,214	8,648	10,396
Security and Energy Management	585	646	733	888	1,084
Manufacturing System/Instruments	4,222	4,336	4,564	5,676	6,798
Medical Equipment	842	799	945	1,118	1,329
Other Industrial	792	826	972	966	1,185
Consumer	13,211	14,923	15,206	17,727	21,917
Audio	2,343	2,723	2,831	3,069	3,923
Video	6,554	7,417	7,013	7,971	9,627
Personal Electronics	1,972	2,145	2,371	2,755	3,440
Appliances	1,688	1,867	2,170	2,887	3,662
Other Consumer	654	772	821	1,045	1,265
Military/Civil Aerospace	2,806	2,719	2,660	2,679	2,749
Transportation	3,201	3,432	3,755	4,560	5,632

Source: Dataquest (November 1995)

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Table 59
Revenue from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Semiconductor	149,788	182,908	210,361	238,599	275,744
Data Processing	70,366	86,489	99,255	111,594	129,165
Computers	49,258	60,820	70,344	78,550	91,709
Data Storage	6,176	7,566	8,408	9,563	10,844
Input/Output	8,670	10,221	11,497	12,855	14,772
Dedicated System	3,706	4,764	5,395	6,558	7,393
Other Data Processing	2,555	3,117	3,611	4,069	4,448
Communications	26,824	34,539	40,845	47,135	54,713
Premise Telecom	10,387	13,193	15,318	17,578	20,157
Public Telecom	4,439	5,460	6,174	6,943	8,134
Mobile Communications	9,046	12,084	14,743	17,293	20,255
Broadcast and Studio	938	1,155	1,415	1,673	1,967
Other Communications	2,013	2,647	3,195	3,647	4,201
Industrial	13,808	17,011	19,820	22,930	26,807
Security and Energy Management	1,502	1,853	2,204	2,590	3,079
Manufacturing System/Instruments	9,008	11,120	12,935	14,978	17,573
Medical Equipment	1,734	2,149	2,519	2,911	3,380
Other Industrial	1,564	1,888	2,161	2,451	2,774
Consumer	28,678	33,537	38,018	43,430	50,235
Audio	4,908	5,801	6,677	7,594	8,557
Video	12,600	14,839	16,608	18,710	21,338
Personal Electronics	4,360	4,981	5,800	7,331	9,467
Appliances	5,017	5,812	6,570	7,241	8,105
Other Consumer	1,794	2,104	2,363	2,553	2,768
Military/Civil Aerospace	2,900	3,014	3,153	3,262	3,459
Transportation	7,213	8,319	9,270	10,249	11,365

Source: Dataquest (November 1995)

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Table 60
Revenue Growth from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Semiconductor	0.4	9.4	9.3	31.0	29.3
Data Processing	-3.8	13.1	12.8	45.5	34.9
Computers	-8.1	14.5	17.4	55.0	39.3
Data Storage	9.6	-4.8	5.9	22.5	35.8
Input/Output	0.5	18.0	6.6	27.6	18.5
Dedicated System	-4.5	18.3	-1.7	41.7	20.3
Other Data Processing	15.1	27.4	21.5	42.5	46.9
Communications	6.6	5.5	16.2	34.9	33.9
Premise Telecom	-1.7	4.1	19.6	39.3	30.3
Public Telecom	12.3	0.7	-1.4	23.0	25.7
Mobile Communications	15.3	22.8	32.3	40.5	48.4
Broadcast and Studio	12.7	8.2	15.0	35.1	26.3
Other Communications	9.1	-11.5	6.7	24.6	23.8
Industrial	4.5	2.6	9.2	19.9	20.2
Security and Energy Management	5.1	10.3	13.5	21.1	22.1
Manufacturing System/Instruments	5.5	2.7	5.3	24.4	19.8
Medical Equipment	5.6	-5.1	18.3	18.3	18.9
Other Industrial	-1.9	4.3	17.6	-0.6	22.7
Consumer	0.9	13.0	1.9	16.6	23.6
Audio	1.9	16.2	4.0	8.4	27.8
Video	-0.5	13.2	-5.5	13.7	20.8
Personal Electronics	6.4	8.8	10.5	16.2	24.9
Appliances	0.2	10.6	16.3	33.0	26.8
Other Consumer	-1.6	18.1	6.4	27.2	21.1
Military/Civil Aerospace	-2.9	-3.1	-2.1	0.7	2.6
Transportation	5.7	7.2	9.4	21.4	23.5

Source: Dataquest (November 1995)

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Table 61
Revenue Growth from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	35.5	22.1	15.0	13.4	15.6	20.1
Data Processing	37.8	22.9	14.8	12.4	15.7	20.4
Computers	40.0	23.5	15.7	11.7	16.8	21.1
Data Storage	30.7	22.5	11.1	13.7	13.4	18.1
Input/Output	27.6	17.9	12.5	11.8	14.9	16.8
Dedicated System	33.2	28.6	13.2	21.6	12.7	21.6
Other Data Processing	60.9	22.0	15.8	12.7	9.3	22.9
Communications	42.5	28.8	18.3	15.4	16.1	23.8
Premise Telecom	37.3	27.0	16.1	14.8	14.7	21.6
Public Telecom	35.5	23.0	13.1	12.5	17.1	19.9
Mobile Communications	52.4	33.6	22.0	17.3	17.1	27.8
Broadcast and Studio	41.6	23.2	22.5	18.2	17.6	24.3
Other Communications	45.8	31.5	20.7	14.1	15.2	24.9
Industrial	32.8	23.2	16.5	15.7	16.9	20.9
Security and Energy Management	38.6	23.4	18.9	17.5	18.9	23.2
Manufacturing System/Instruments	32.5	23.4	16.3	15.8	17.3	20.9
Medical Equipment	30.5	24.0	17.2	15.6	16.1	20.5
Other Industrial	31.9	20.8	14.4	13.4	13.2	18.5
Consumer	30.8	16.9	13.4	14.2	15.7	18.0
Audio	25.1	18.2	15.1	13.7	12.7	16.9
Video	30.9	17.8	11.9	12.7	14.0	17.3
Personal Electronics	26.7	14.2	16.4	26.4	29.1	22.4
Appliances	37.0	15.9	13.0	10.2	11.9	17.2
Other Consumer	41.8	17.3	12.3	8.0	8.4	16.9
Military/Civil Aerospace	5.5	3.9	4.6	3.4	6.0	4.7
Transportation	28.1	15.3	11.4	10.6	10.9	15.1

Source: Dataquest (November 1995)

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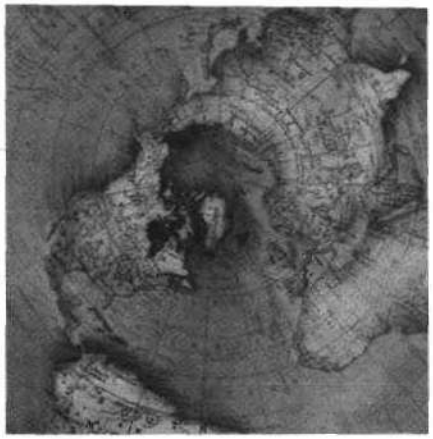
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Worldwide and North American Electronic Equipment Forecast



Market Statistics

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Worldwide and North American Electronic Equipment Forecast



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Worldwide and North American Electronic Equipment Production Forecast

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. This is the second of two forecasts that Dataquest now publishes biannually. The first forecast was published in April. This second forecast reflects changes in worldwide and regional outlooks since spring. It also incorporates data revisions and updates suggested by Dataquest's continuing research of the world's dynamic electronic equipment markets. Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

Worldwide production is segmented into four major geographic regions. The list of tables details the type of production data by region, application market, and unit of measure.

Electronic equipment production is an important determinant of semiconductor market activity because semiconductor demand is derived, in part, from the underlying demand for the systems that use semiconductors. Therefore, the forecast of expected future electronics system production is an essential component to assess expected future semiconductor market activity.

Worldwide electronic equipment production estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. factory revenue are based on the average exchange rate for the given year. The section entitled "Exchange Rates" has more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the

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assumptions of the electronic equipment production forecast are set in the month of July 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through July 1995.
- The July 1995 exchange rate is assumed to hold for all months in the August-December 1995 period, and throughout all future years.

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in the documents located in the binder of the same name.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data Processing
  - Computers
  - Data Storage
  - Input/Output Devices
  - Dedicated Systems
  - Other Data Processing
- Communications
  - Premise Telecom
  - Public Telecom
  - Mobile Communications
  - Broadcast and Studio Equipment
  - Other Communications

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- Industrial
  - Security and Energy Management Systems
  - Manufacturing Systems and Instruments
  - Medical Equipment
  - Other Industrial Equipment
- Consumer
  - Audio
  - Video
  - Personal Electronics
  - Appliances
  - Other Consumer Equipment
- Military/Civilian Aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and PC/motherboard upgrades (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data Storage[2]: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. (See "Line Item Definitions" for more discussion of how revenue is allocated across regions.)

[2]Worldwide mass storage production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of all equipment categories including rigid disk drive, flexible disk drive, optical disk drive, and tape drive, as estimated by the Dataquest Computer Systems and Peripherals Worldwide group. Also, Dataquest now includes solid-state storage such as flash memory cards in this category. Because most production of these cards is in Japan and Asia/Pacific, we do not include this subcategory in the North American forecast.

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- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Note: The category "PC/motherboard upgrades" replaces the category "personal computers" and now includes motherboards offered for sale for use in personal computers.

Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T-carriers/TDM multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, WAN switching systems; premise voice systems, such as premise switching equipment (PBX telephone equipment and key telephone systems) and call processing equipment (voice messaging, interactive voice response systems, and automatic call distributors); and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Note: The category "T-carrier/TDM multiplexers" replaces the category "T1 multiplexers" and includes a slightly broader range of equipment

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now tracked by Dataquest. Similarly, the category "WAN switching systems" replaces the category "packet data switching systems" and includes a slightly broader range of equipment now tracked by Dataquest. The category "premise voice systems" combines the former categories "premise switching equipment" and "call processing equipment."

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing Systems/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, portable/personal stereos, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Note: The category "portable/personal stereos" is a new one and tracks portable stereo systems for personal use.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace[3]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).

[3]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics.

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- Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).

- Asia/Pacific: Includes Asia/Pacific's Newly Industrialized Economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singapore operation (which is factory revenue) and the European distributor or final user.

Personal computers are a particularly challenging example of a product whose production increasingly spans both time and geography. Today, it is not at all uncommon for personal computers to be assembled from components fabricated throughout the world. Moreover, the final assembly of a personal computer often occurs at a place far removed from the

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source of the computer's semiconductors. Dataquest considers a personal computer to be produced in the region where the majority of the computer's semiconductor value is generated. For instance, a personal computer whose electronic components are assembled in Asia/Pacific but whose final assembly into a system is done by a North American distributor in North America is considered produced in Asia/Pacific. This convention guarantees production is located in the region where semiconductor consumption is both the most likely and greatest. The computer is in turn valued at the factory cost of the North American distributor. This convention guarantees the final system is valued at a figure comparable to traditional factory selling price.

Data Sources

The historical information presented in the production data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce estimates of manufacturers' shipments
- Japanese production statistics compiled and published by the Ministry of International Trade and Industry
- Various European and Asian nations' government agency statistics
- Trade associations
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here represent the most accurate and meaningful generally available today.

Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the Dataquest Research Methodology document.

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This

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establishes a five-year trend growth path or "envelope" for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general is composed of annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Forecast Assumptions

Economics

Slower Growth Expected in Major European, North American, and Asian Markets
Dun & Bradstreet's most recent quarterly survey of more than 11,000 global executives in 16 countries revealed expectations for slower near-term growth in net sales, net profits, selling prices, and employment in nearly every region of the world. The overall picture has continued to reveal a steady decline in worldwide business expectations since the beginning of 1995. On balance, however, the number of global executives predicting expansion still outnumbered those expecting lower sales and profits, thus suggesting some expansion in the world economy over the months to come.

Executives in nearly every region generally forecast a mature business cycle characterized by slow, steady growth over the near term accompanied by moderate inflationary pressures. Longer-term forecasts from Dun & Bradstreet subsidiary A.C. Nielsen suggest these circumstances are likely to prevail through the end of the decade. These forecasts indicate the world's developed economies are likely to experience modest but gradually accelerating growth over the next few years. The experience of the world's emerging economies will continue to be varied. Pacific Basin economies will continue to post impressive rates of growth. In contrast, Latin American economies are expected to experience only slight near-term growth because of ongoing economic crises in Mexico and Brazil. For the longer term, however, growth is likely to be impressive once these crises are resolved.

Expectations for Growth in Net Sales and Net Profits Decline in All Regions
Global expectations for growth in net sales and net profits over the near term continued the steady decline that marked the first half of the year. Dun & Bradstreet's World Indices for net sales and net profits dropped five and six points to 45 and 33, respectively. These declines were largely the result of marked declines in Pacific Basin and European indices.

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North American indices exhibited little change largely because results for Mexico were unavailable. The World Index for selling prices also declined, dropping seven points to 26. Here the decline was driven by expectations of reduced inflationary pressures in every region surveyed. The slow pressure to raise prices is an encouraging signal that production is keeping pace with healthy levels of demand. Dun & Bradstreet's World Indices for inventories and employment levels also each dropped two points to 13 and 16, respectively. Executives in every region but North America appear to expect slightly slower growth in finished goods inventories and employment levels.

North America: Mexico Still Reeling from Devaluation of the Peso

Mexico continues to suffer spiraling inflation and economic instability stemming from devaluation of the peso. These circumstances made it virtually impossible to draw a sharp picture of expectations for the near-term course of the Mexican economy. Fortunately, Mexico and its Latin American trading partner Brazil represent the only exceptions to a basically stable global outlook. Excluding Mexico, North America should experience the strongest near-term growth of all regions. North America's continued strength as a market for exports is one of the main factors buoying optimism in global expectations. Longer-term growth forecasts for North America are as follows.

- Mexico's real gross domestic product (GDP) is now forecast to decline 3.0 percent in 1995, following 3.5 percent growth in 1994. Positive growth of 2.0 percent is expected in 1996. Growth is then anticipated to accelerate through the end of the decade, reaching 5.0 percent by 1999.
- The United States' GDP is now forecast to grow 2.9 percent in 1995, decelerating from 4.1 percent growth in 1994. Growth is expected to be robust through the end of 1995, thus making up for the slow growth observed in the spring. Growth is then anticipated to accelerate somewhat in 1996 to 3.2 percent and to remain at or near that level through the end of the decade.
- Canada's GDP is now forecast to grow 2.3 percent in 1995, decelerating from 4.5 percent growth in 1994. Growth is anticipated to accelerate to 2.7 percent in 1996 and then to average about 2.9 percent through the end of the decade. As in the United States, executives in Canada expressed strong optimism for net sales and net profits over the near term.

Europe: Some Growth Generally Expected in Near Term

In Europe, Dun & Bradstreet's indices for net sales and net profits both declined. The Selling Prices and Employment Level Indices also registered declines. Belgian and Swiss executives expressed the weakest expectations for the future while British and Dutch executives expressed the strongest. Despite marked variation across countries, all European indices remained positive, indicating European executives generally

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expect some growth over the near term. Longer-term growth forecasts for Europe are as follows:

- Germany's GDP is now forecast to grow 2.8 percent in 1995, decelerating from 2.9 percent growth in 1994. Growth is anticipated to decline somewhat to 2.7 percent in 1996 and then to average about 2.9 percent through 1999.
- France's GDP is now forecast to grow at 3.0 percent in 1995, accelerating from 2.8 percent growth in 1994. Growth is expected to slow somewhat to 2.9 percent in 1996 but then to quicken to 3.1 percent through the end of the decade.
- Italy's GDP is now forecast to grow 3.0 percent in 1995, accelerating from 2.2 percent in 1994. Growth is anticipated to decline to 2.7 percent in 1996 and then to decelerate further to 2.5 percent by 1999.
- The United Kingdom's GDP is now forecast to grow 2.9 percent in 1995, decelerating from 3.9 percent growth in 1994. Growth is expected to decline somewhat to 2.8 percent in 1996 and to remain about at this level through 1999.

Japan and Pacific Rim: Weak Expectations Persist in Japan

Dun & Bradstreet's Net Sales and Net Profits Indices for Japan and the Pacific Rim both declined. The Selling Prices, Inventories, and Employment Level Indices also declined. All indices continued to remain at markedly low levels, particularly in Japan. The near-term outlook of Japanese executives for selling prices was particularly pessimistic as Japanese businesses continued their struggle to bring prices in line with production and operating costs. Consequently, Japanese executives also expressed weak net profits expectations. New Zealand executives expressed notably optimistic expectations about the near-term future of their economy. Longer-term growth forecasts for Japan and the Pacific Rim are as follows:

- Japan's GDP is now forecast to grow at 0.6 percent in 1995, unchanged from 1994. Growth is expected to increase to 1.5 percent in 1996 and then accelerate robustly to 3.5 percent by 1999.
- New Zealand's GDP is now forecast to grow 3.5 percent in 1995, decelerating from 6.2 percent in 1994. Growth is anticipated to slow to 3.3 percent in 1996 and then to average slightly more than 3.0 percent through the end of the decade.
- China's GDP is now expected to grow 9.5 percent in 1995, decelerating from 11.8 percent in 1994. Growth is expected to continue slowing through the end of the decade as the Chinese economy matures, declining to 7.5 percent by 1999.
- Taiwan's GDP is now forecast to grow 6.9 percent in 1995, accelerating from 6.5 percent growth in 1994. Growth is then anticipated to average 6.5 percent through 1999.
- South Korea's GDP is now forecast to grow 9.0 percent in 1995, accelerating from 8.4 percent growth in 1994. Growth is then expected to average better than 7.0 percent through the end of the decade.

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Dun & Bradstreet's quarterly International Survey of Business Expectations is modeled on its quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. Survey participants are asked whether they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven highly accurate, with quarterly forecasts closely paralleling actual performance.

The current international survey, completed in June 1995, uses similar sampling and interviewing procedures in all countries. Hence the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The Dun & Bradstreet index figures used here represent the net percentage of survey respondents expecting higher sales and profits, among others. The indices are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. GDP growth rates noted here are A.C. Nielsen's most current forecasts from August 1995.

Regional Electronic Equipment Production

North America

North America electronic equipment production is now forecast to grow 7.5 percent to $232.9 billion in 1995. This contrasts with the 5.7 percent growth forecast in spring and marks a deceleration from the 9.4 percent growth experienced in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The continued expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1995 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP) over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- LAN equipment is expected to continue strong growth throughout the forecast period. In addition to new markets in the small/home office area, investment in higher-speed technology such as 100-Mbps and ATM will give renewed growth to the industry.

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- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecasts. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market, which will increase competition with existing wireless communications services is expected to fuel even greater growth. However, PCS is a very cost-conscious market, and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, we expect strong growth for mobile equipment in North America and worldwide.
- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets. (Note: Better information in U.S. imports and exports has resulted in a revision to both historical and forecast revenue for North America.)
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets have also continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecom hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecom and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.

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- The North America industrial electronics market will continue to be dominated by economic trends in the United States, principally growth in U.S. capital spending. The United States should remain a significant producer and net exporter of industrial electronics, especially test and measuring equipment. Canada and Mexico will continue to produce some industrial electronics locally, but will remain highly dependent on imports from the United States. Likewise, emerging Asian nations will continue to be consumers of U.S. production. (Note: North America industrial production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. capital spending.
- The North America consumer electronics market will continue to be dominated by economic trends in the United States, chiefly growth in U.S. household income. The United States should remain a net importer of consumer electronics, despite growth in U.S. consumer electronics production. Mexico will remain a significant source of consumer electronics for North America and could well increase its share of U.S. and Canadian markets at the expense of Asia, given a favorable resolution of its current economic crises. (Note: North America consumer production has been re-estimated and revalued to better reflect Mexican and Canadian production as well as trends in U.S. household income.)
- U.S. military spending appears likely to increase over the next few years, based on the latest congressional budget proposals. Production of electronic warfare equipment is especially likely to increase in response. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.
- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems.

The most significant downside risk to the forecast continues to be the uncertainty surrounding U.S. economic policy. The growing U.S. trade and budget deficits present policy makers with numerous and challenging choices. Given the current fractious political environment and the uncertain state of economic knowledge concerning the links between the trade and budget deficits, it is not at all clear how policy makers will or even should proceed. The ongoing crisis in Mexico poses additional downside risk to the forecast. A prolonging of Mexico's economic woes accompanied by deepening social instability could well undermine the forecast. The most significant upside risk to the forecast remains a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

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Japan

Dollar-based Japanese electronic equipment production is now forecast to grow 16.4 percent to $221.1 billion in 1995. This contrasts to 0.9 percent dollar-based growth forecast in the spring. It also marks an acceleration of growth from the 9.1 percent dollar-based growth experienced in 1994. Virtually all of Japan's dollar-based growth in both 1995 and 1994 stems from appreciation of the yen against the dollar. The Japan forecast projects the yen to appreciate 15.1 percent against the dollar in 1995. This follows a projected appreciation of 9.2 percent in 1994. When expressed in yen, Japanese electronic equipment production is forecast to increase only 1.1 percent in 1995. This follows a 0.1 percent yen-based contraction experienced in 1994. Overall, Japanese equipment production will continue to be governed by two forces during the forecast period:

- The continuing shift of production offshore. Here, two trends are considered:
  - Electronics production of Japanese companies destined for export is shifting to the export-destination market, particularly for Asia and Europe.
  - Low-end electronics production of Japanese companies is migrating to areas in Asia with lower production costs.
- The strength of the yen against the dollar. Here again, two factors are considered:
  - The marked strengthening of the yen against the dollar has squeezed the margin of profitability on electronics exports, especially to the United States.
  - The strong yen has encouraged the offshore migration of electronics production from Japan: a strong yen over the long term is likely to reinforce and possibly accelerate migration of production.

The following specific factors influence forecast Japanese production:

- Japanese PC unit production is projected to increase but revenue will be held down by declines in average selling prices (ASPs). Revenue from mainframes and midrange computers also will slow as businesses globally turn to distributed/networked processing. The impact of this will be relatively stronger in Japan because of Japan's relatively higher ratio of mainframe production to total computer production.
- Dollar-based revenue from data storage production indicates some growth. This growth, however, stems from appreciation of the yen against the dollar. When expressed in yen, revenue from data storage production is expected to continue declining as production shifts offshore to elsewhere in Asia.
- Input/output device revenue will be buoyed by rising demand for Japanese display devices and high-end page printers.
- Revenue from communications equipment will be driven by strong

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revenue growth for public telecommunications and mobile communications equipment. Specifically, mobile communications will be spurred by strong demand for cellular phones and related infrastructure. Revenue growth from mobile communications may be stunted if large-volume unit production is accompanied by dramatic declines in ASPs.

- Industrial equipment revenue will experience robust growth in the both the short and long terms. In the short term, revenue will be boosted by the efforts of Kobe-area businesses to overcome the impact of January's earthquake. Revenue will also be buoyed by the rising wave of capital spending now taking place in Japan. Over the longer term, revenue will continue to grow in response to Japan's economic recovery and its commitment to advanced technology.
- Consumer equipment revenue will be impacted by two counterbalancing forces. On the one hand, revenue will continue to decline in response to the offshore migration of consumer production. Audio and video equipment revenue is expected to suffer continued declines on this account. Indeed, offshore migration for these products is expected to accelerate in the years to come. On the other hand, revenue is likely to show growth in response to Japan's growing housing rush. Home appliance revenue in particular is expected to experience robust growth on this account. Appliance revenue for 1995 is projected to be especially robust as Kobe earthquake survivors reestablish their homes and households across Japan and turn to air-conditioning for relief from the summer's unseasonable heat.

Overall, Japan's forecast hinges critically on the interrelated future of the yen against the dollar, the pace of offshore production migration away from Japan, the competitiveness of Japan's exports, and the progress of Japan's economic recovery. Renewed appreciation of the dollar against the yen would accelerate production migration, further handicap exports, and hamper economic recovery, thereby undermining the forecast. Conversely, depreciation would have the opposite effects. A bigger-than-expected PC boom and stronger-than-anticipated economic growth among Japan's trading partners would also lead to better-than-forecast results for Japan.

Europe

European electronic equipment production is now forecast to experience 8.3 percent growth to $171.5 billion in 1995. This contrasts with 3.3 percent growth forecast in the spring. It also marks an aceleration of growth from the 5.9 percent growth experienced in 1994. Europe forecast assumptions are as follows:

- European PC production is now expected to grow substantially through the forecast period, primarily for the consumer market.
- Growth of premise communications equipment will be driven by upgrades of PBX equipment to support both voice and data, with the trend toward voice traffic moving digitally and increasing use of cordless telephones.

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- The European public telecom market is experiencing very little growth, but European telecom manufacturing companies' significant presence in the global market is benefiting from the superlative growth occurring in Asia/Pacific.
- The central office switching market will decline in Europe during the rest of the forecast period, but production will be bolstered by exports to the fast-growing Asia/Pacific market. The European transmission market is set for slow, steady growth, but again there will be significant export opportunities outside western Europe.
- European cellular handset production is now expected to grow much more rapidly than in the spring. GSM continues to penetrate the European market and to enjoy success outside Europe. It now appears much more likely that the U.S. PCS market will adopt the GSM/DCS 1900 standard than in the spring. All of Japan's major producers also have established production facilities in Europe. This should further buoy European production of cellular handsets.
- Broadcast and studio equipment growth will be helped by investment upgrades to digital broadcast equipment.
- Most audio equipment production in Europe is for the high-end specialist market segment. The most important long-term growth opportunity in consumer audio is forecast to come from digital compact cassette equipment and stereo high-fidelity equipment. Volume manufacturers are the major Japanese brand leaders. Overall, the European audio market is supported by imports from Japan and the Far East.
- Color televisions dominate consumer video production. Long-term growth will be attributed to digital transmission, gaining momentum for satellite by 1997 and cable shortly thereafter.
- Wide-screen TV growth is strongest in France and Germany. Emerging digital satellite and cable services are expected to boost sales of wide-screen TVs toward the end of the decade.
- Camcorder production is expected to expand during the forecast period. Sony is the only camcorder manufacturer in Europe with a full assembly plant in France.
- Satellite TV receiver production continues to show strong growth in Europe as the competition from cable TV operators increases. TV sets with built-in analog CATV and DTH satellite receivers also are gaining popularity across Europe.
- Strong market growth and production is forecast for dishwashers and microwave ovens and air-conditioning toward the end of the forecast period. This is largely influenced by changing European demographics affected by changing patterns in marital status and family structures.

Note: Historical and forecast consumer revenue has been revalued and revised to more accurately reflect European production and pricing of set-top boxes.

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The most significant downside risks to the European forecast include:

- In general, there will be slower-than-expected adoption of cellular telephone equipment.
- GSM success outside Europe does not proceed to volume handset use.
- GSM handset production for non-European markets migrates to non-European manufacturing centers.
- The forecast assumes that there will be no changes in tariffs other than those already announced after the General Agreement on Tariffs and Trade negotiations. More restrictive trade could diminish production opportunities.
- Eastern Europe is the volatile area of Europe; political and economic instability is an everyday fact of life. A marked increase of instability, however, could have a detrimental effect on investment in productive capacity.

The most significant upside risks to the European forecast include:

- Cellular handset penetration rates exceed expected future levels at every point in time.
- A strong Japanese economy and currency may accelerate a shift of production from Japan to Europe. (Already some Japanese car manufacturers are exporting their own cars assembled in Europe to Japan.)
- There is a remote possibility that interactive digital services will occur sooner than expected, but this is not very likely.
- Stronger-than-expected economic growth in eastern Europe and CIS markets would boost western European production above forecast levels.

Asia/Pacific-Rest of World

Asia/Pacific-Rest of World electronic equipment production is now forecast to grow 16.0 percent to $165.5 billion in 1995. This contrasts with 15.4 percent growth forecast in the spring. It also marks a deceleration from 20.8 percent growth experienced in 1994. The following factors influence the forecast:

- Generally speaking, prospects for Asia/Pacific remain strong. The region's economies are healthy and expected to experience vigorous and sustained growth over the long term. Foreign investment from Japan (in consumer goods), Europe (in telecommunications equipment), and the United States (in telecommunications and data processing equipment) continues at a robust pace. Moreover, investment from outside the region is being supplemented by intraregional investment from Taiwan. Exports remain strong and the region's economies are benefiting from the combination of internal social stability, regional political stability, and successful economic reform programs.

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- Asia/Pacific continues to benefit greatly from the shift of electronics production away from Japan. The future of this shift will depend heavily on the future course of the Japanese yen relative to the U.S. dollar. Ironically, Asia's "Four Tigers" (Taiwan, Hong Kong, South Korea, and Singapore) themselves may begin to experience a shift of low-value production to other parts of Asia such as Malaysia, Thailand, the Philippines, and Indonesia. In response, the Four Tigers would likely replace lost low-value production with higher-value production commensurate with their rising wages and growing worker skills. Thus, regional equipment production could well exceed forecast levels, given intraregional production shifts.
- The region's economy is increasingly unifying. There is both growing cooperation and interdependence among Asia/Pacific's individual economies. The continued expansion of Association of Southeast Asian Nations (ASEAN), which recently added Vietnam as a member, highlights this trend. An intraregional shift of low-value production from the Four Tigers to other parts of Asia would only reinforce this trend and add additional stimulus to regional growth.
- Production of PCs and related products will continue to be a mainstay of the region. Taiwan and Singapore should continue to be significant PC producers. Malaysia could well become a significant producer of PCs and related products in view of recent investments by several major producers. PC production in the region continues to be constrained by the ongoing DRAM shortage.
- Economic growth and prosperity in the region have generated robust local markets for electronic goods, especially consumer and telecommunications goods. Nonetheless, Asia/Pacific will continue to depend on the outside world both as an outlet for regionally produced data processing and consumer goods and as a source for imported telecommunications equipment. Although PC and consumer good demand is growing in the region, most production will continue to be for export. Regional demand for telecommunications equipment is likewise growing rapidly, especially in China. Although the region can be expected to produce large volumes of telecommunications equipment for local consumption over the long term, Asia/Pacific will continue to import sizable amounts of equipment (largely from Japan), over the near term.
- The region's future is heavily dependent on the future of China. As the world's most populous nation and one of its increasingly more affluent economies, China represents a veritable bonanza for the producers of electronic goods. By the same token, as a rapidly growing and already significant regional producer of electronic goods, China exerts sizable influence on Asia/Pacific equipment production. Two factors bear watching: the progress of the power shift from Deng Xiao Peng to his successor(s), and the path of China's relations with the United States. Although a gradual and smooth transition of power from Deng to a successor appears under way at the moment, the political strife created by a sudden disturbance in this process could have

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far-reaching effects on the region. Likewise, any increase in the already escalated political and economic tensions between China and the United States could have a profound effect on Asia/Pacific equipment production.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates for 1994 and 1995 to 1999.

Table 1
Exchange Rates

Country	1994	1995-1999	1994-1995 U.S.$ Appreciation versus Foreign Currency (%)
Japan (Yen/U.S.$1)	101.81	88.48	-13.09
Europe (ECU/U.S.$1)	0.844	0.76	-9.63
France (Franc/U.S.$1)	5.5367	4.92	-11.07
Germany (Deutsche Mark/U.S.$1)	1.6203	1.41	-12.96
Great Britain (Pound Sterling/U.S.$1)	0.6536	0.63	-4.13
Italy (Lira/U.S.$1)	1,609.34	1,631.23	1.36
Korea (Won/U.S.$1)	802.84	765.58	-4.64
Taiwan (NT$/U.S.$1)	26.45	26.04	-1.55
Hong Kong (HK$/U.S.$1)	7.7276	7.74	0.12
Singapore (S$/U.S.$1)	1.5263	1.41	-7.74
China (Renminbi/U.S.$1)	8.5384	8.35	-2.24

Source: Dataquest (October 1995)

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Table 2
Worldwide Revenue from Production of Each Electronic Equipment Group, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	566,226	598,874	604,655	639,716	707,607
Data Processing	176,053	184,413	184,087	195,054	225,479
Computers[1]	103,335	106,953	103,499	109,524	130,002
Data Storage	21,170	22,323	23,906	24,587	28,840
Input/Output	31,199	33,551	34,004	35,835	38,914
Dedicated System	17,501	18,640	19,521	21,472	23,075
Other Data Processing	2,848	2,945	3,157	3,636	4,647
Communications	87,681	94,598	101,189	112,916	127,972
Premise Telecom	26,339	28,398	31,499	36,689	41,999
Public Telecom	26,588	28,591	28,634	31,186	34,167
Mobile Communications	16,803	18,931	22,493	27,901	34,116
Broadcast and Studio	3,873	3,920	4,218	4,518	4,837
Other Communications	14,079	14,758	14,345	12,622	12,854
Industrial	93,682	97,548	97,282	99,920	106,814
Security and Energy Management	10,116	11,529	11,655	11,897	12,834
Manufacturing Systems/Instruments	55,942	57,615	55,692	56,862	60,338
Medical Equipment	12,097	13,356	14,158	15,057	15,782
Other Industrial	15,528	15,048	15,778	16,103	17,860
Consumer	124,888	137,515	135,788	144,778	158,675
Audio	16,296	19,011	19,479	20,543	22,904
Video	43,488	48,295	45,698	47,876	51,299
Personal Electronics	15,190	16,011	16,625	17,433	19,286
Appliances	40,350	43,689	43,495	46,616	51,564
Other Consumer	9,563	10,509	10,492	12,310	13,623
Military/Civil Aerospace	62,764	62,257	61,701	59,654	58,229
Transportation	21,158	22,544	24,607	27,394	30,438
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81
ECU/U.S.$ Exchange Rate	0.788	0.811	0.770	0.858	0.844

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 3
Worldwide Revenue from Production of Each Electronic Equipment Group, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	791,001	855,405	921,544	999,861	1,086,294
Data Processing	254,720	279,201	298,912	321,708	347,466
Computers[1]	151,361	169,429	183,411	198,427	216,109
Data Storage	29,802	31,897	32,524	34,279	35,932
Input/Output	43,224	46,355	50,008	53,923	58,915
Dedicated System	24,802	25,622	26,534	28,164	29,210
Other Data Processing	5,530	5,898	6,435	6,915	7,300
Communications	148,815	167,831	186,050	207,411	227,688
Premise Telecom	47,639	53,874	60,261	68,164	76,315
Public Telecom	37,255	39,809	42,195	45,565	50,926
Mobile Communications	44,473	53,578	61,355	69,322	74,271
Broadcast and Studio	5,645	5,990	6,658	7,503	8,354
Other Communications	13,802	14,581	15,581	16,858	17,821
Industrial	118,784	126,110	135,572	147,394	161,734
Security and Energy Management	14,698	15,621	17,068	18,798	20,837
Manufacturing Systems/Instruments	67,096	71,273	76,508	83,371	92,042
Medical Equipment	17,087	18,058	19,115	20,302	21,628
Other Industrial	19,904	21,159	22,880	24,923	27,226
Consumer	175,948	186,359	201,039	218,457	239,061
Audio	25,556	27,974	31,020	34,537	38,329
Video	55,771	59,892	64,812	71,488	79,533
Personal Electronics	21,110	21,669	23,203	25,698	28,617
Appliances	57,250	59,608	63,486	67,136	72,039
Other Consumer	16,262	17,215	18,518	19,598	20,543
Military/Civil Aerospace	58,361	59,275	60,445	61,912	63,508
Transportation	34,372	36,628	39,525	42,978	46,837
Yen/U.S.$ Exchange Rate	88.48	88.48	88.48	88.48	88.48
ECU/U.S.$ Exchange Rate	0.762	0.762	0.762	0.762	0.762

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 4
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1990-1994
(Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	7.8	5.8	1.0	5.8	10.6
Data Processing	9.8	4.7	-0.2	6.0	15.6
Computers[1]	9.9	3.5	-3.2	5.8	18.7
Data Storage	26.3	5.4	7.1	2.9	17.3
Input/Output	1.9	7.5	1.4	5.4	8.6
Dedicated System	-1.5	6.5	4.7	10.0	7.5
Other Data Processing	141.3	3.4	7.2	15.2	27.8
Communications	11.1	7.9	7.0	11.6	13.3
Premise Telecom	7.7	7.8	10.9	16.5	14.5
Public Telecom	11.1	7.5	0.1	8.9	9.6
Mobile Communications	16.0	12.7	18.8	24.0	22.3
Broadcast and Studio	11.5	1.2	7.6	7.1	7.1
Other Communications	12.1	4.8	-2.8	-12.0	1.8
Industrial	9.1	4.1	-0.3	2.7	6.9
Security and Energy Management	1.3	14.0	1.1	2.1	7.9
Manufacturing Systems/Instruments	14.2	3.0	-3.3	2.1	6.1
Medical Equipment	8.0	10.4	6.0	6.4	4.8
Other Industrial	-1.1	-3.1	4.9	2.1	10.9
Consumer	5.5	10.1	-1.3	6.6	9.6
Audio	6.5	16.7	2.5	5.5	11.5
Video	5.6	11.1	-5.4	4.8	7.1
Personal Electronics	5.1	5.4	3.8	4.9	10.6
Appliances	6.0	8.3	-0.4	7.2	10.6
Other Consumer	2.2	9.9	-0.2	17.3	10.7
Military/Civil Aerospace	1.7	-0.8	-0.9	-3.3	-2.4
Transportation	6.2	6.6	9.2	11.3	11.1
U.S.$ Appreciation versus Yen	4.3	-5.6	-7.0	-12.1	-8.4
U.S.$ Appreciation versus Ecu	-13.2	2.9	-5.1	11.4	-1.6

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 5
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1995-1999
(Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	11.8	8.1	7.7	8.5	8.6	9.0
Data Processing	13.0	9.6	7.1	7.6	8.0	9.0
Computers[1]	16.4	11.9	8.3	8.2	8.9	10.7
Data Storage	3.3	7.0	2.0	5.4	4.8	4.5
Input/Output	11.1	7.2	7.9	7.8	9.3	8.6
Dedicated System	7.5	3.3	3.6	6.1	3.7	4.8
Other Data Processing	19.0	6.7	9.1	7.5	5.6	9.5
Communications	16.3	12.8	10.9	11.5	9.8	12.2
Premise Telecom	13.4	13.1	11.9	13.1	12.0	12.7
Public Telecom	9.0	6.9	6.0	8.0	11.8	8.3
Mobile Communications	30.4	20.5	14.5	13.0	7.1	16.8
Broadcast and Studio	16.7	6.1	11.2	12.7	11.3	11.5
Other Communications	7.4	5.6	6.9	8.2	5.7	6.8
Industrial	11.2	6.2	7.5	8.7	9.7	8.7
Security and Energy Management	14.5	6.3	9.3	10.1	10.8	10.2
Manufacturing Systems/Instruments	11.2	6.2	7.3	9.0	10.4	8.8
Medical Equipment	8.3	5.7	5.9	6.2	6.5	6.5
Other Industrial	11.4	6.3	8.1	8.9	9.2	8.8
Consumer	10.9	5.9	7.9	8.7	9.4	8.5
Audio	11.6	9.5	10.9	11.3	11.0	10.8
Video	8.7	7.4	8.2	10.3	11.3	9.2
Personal Electronics	9.5	2.7	7.1	10.8	11.4	8.2
Appliances	11.0	4.1	6.5	5.7	7.3	6.9
Other Consumer	19.4	5.9	7.6	5.8	4.8	8.6
Military/Civil Aerospace	0.2	1.6	2.0	2.4	2.6	1.8
Transportation	12.9	6.6	7.9	8.7	9.0	9.0
U.S.$ Appreciation versus Yen	-13.1	0	0	0	0	NM
U.S.$ Appreciation versus Ecu	-9.7	0	0	0	0	NM

NM = Not meaningful

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 6
Regional Revenue from Production of Each Electronic Equipment Group, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Worldwide Total	566,226	598,874	604,655	639,716	707,607
Data Processing	176,053	184,413	184,087	195,054	225,479
Communications	87,681	94,598	101,189	112,916	127,972
Industrial	93,682	97,548	97,282	99,920	106,814
Consumer	124,888	137,515	135,788	144,778	158,675
Military/Civil Aerospace	62,764	62,257	61,701	59,654	58,229
Transportation	21,158	22,544	24,607	27,394	30,438
North American Total	194,625	194,843	193,914	198,037	216,696
Data Processing	67,032	65,588	59,477	57,374	64,317
Communications	27,230	29,174	32,563	37,014	43,997
Industrial	38,751	39,892	41,581	43,687	46,856
Consumer	21,471	21,046	21,650	23,659	25,821
Military/Civil Aerospace	36,603	35,588	34,732	31,662	30,169
Transportation	3,537	3,554	3,911	4,641	5,537
Japanese Total	160,930	177,790	167,296	174,131	189,980
Data Processing	45,901	50,464	49,083	50,766	56,503
Communications	21,298	22,857	22,375	25,216	28,389
Industrial	26,585	28,870	25,228	26,517	28,959
Consumer	56,038	63,960	58,420	58,248	62,112
Military/Civil Aerospace	1,601	1,590	1,675	1,865	1,992
Transportation	9,507	10,048	10,516	11,519	12,025
European Total	139,089	142,435	143,402	149,454	158,331
Data Processing	37,469	36,859	34,899	38,002	41,482
Communications	28,698	31,087	32,899	35,116	37,983
Industrial	26,078	26,196	27,491	26,295	27,217
Consumer	19,606	20,304	19,249	20,036	20,845
Military/Civil Aerospace	20,976	21,171	21,055	21,447	20,851
Transportation	6,262	6,818	7,809	8,558	9,953
Asia/Pacific-ROW Total	71,582	83,807	100,042	118,094	142,600
Data Processing	25,651	31,502	40,629	48,911	63,177
Communications	10,455	11,480	13,353	15,570	17,604
Industrial	2,268	2,590	2,982	3,421	3,782
Consumer	27,773	32,204	36,469	42,835	49,897
Military/Civil Aerospace	3,583	3,907	4,239	4,680	5,218
Transportation	1,852	2,124	2,371	2,676	2,922
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81
ECU/U.S.$ Exchange Rate	0.788	0.811	0.770	0.858	0.844

Source: Dataquest (October 1995)

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Table 7
Regional Revenue from Production of Each Electronic Equipment Group, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Worldwide Total	791,001	855,405	921,544	999,861	1,086,294
Data Processing	254,720	279,201	298,912	321,708	347,466
Communications	148,815	167,831	186,050	207,411	227,688
Industrial	118,784	126,110	135,572	147,394	161,734
Consumer	175,948	186,359	201,039	218,457	239,061
Military/Civil Aerospace	58,361	59,275	60,445	61,912	63,508
Transportation	34,372	36,628	39,525	42,978	46,837
North American Total	232,947	246,005	260,245	272,536	288,551
Data Processing	71,334	75,062	79,597	80,981	84,154
Communications	49,235	54,651	59,407	65,255	72,043
Industrial	49,835	52,785	55,339	58,206	61,880
Consumer	26,805	27,203	28,626	29,689	30,911
Military/Civil Aerospace	29,621	29,920	30,397	31,016	31,714
Transportation	6,117	6,384	6,879	7,389	7,849
Japanese Total	221,074	225,957	237,840	251,620	268,925
Data Processing	61,983	61,815	63,729	65,540	68,735
Communications	36,818	39,699	42,683	45,110	47,537
Industrial	36,076	38,160	42,275	48,139	55,097
Consumer	70,267	70,243	72,795	75,926	79,943
Military/Civil Aerospace	2,257	2,232	2,204	2,177	2,152
Transportation	13,673	13,808	14,153	14,730	15,460
European Total	171,520	186,644	200,194	217,511	231,389
Data Processing	46,595	52,102	56,925	63,940	69,035
Communications	42,417	47,369	51,499	56,283	58,939
Industrial	28,525	30,196	32,202	34,539	37,359
Consumer	22,124	23,880	25,219	26,910	28,799
Military/Civil Aerospace	20,628	20,489	20,275	20,075	19,719
Transportation	11,231	12,606	14,075	15,763	17,538
Asia/Pacific-ROW Total	165,460	196,798	223,265	258,193	297,430
Data Processing	74,809	90,221	98,661	111,247	125,543
Communications	20,344	26,111	32,462	40,764	49,168
Industrial	4,349	4,969	5,756	6,510	7,398
Consumer	56,753	65,033	74,400	85,932	99,408
Military/Civil Aerospace	5,855	6,633	7,569	8,644	9,923
Transportation	3,350	3,831	4,418	5,096	5,990
Yen/U.S.$ Exchange Rate	88.48	88.48	88.48	88.48	88.48
ECU/U.S.$ Exchange Rate	0.762	0.762	0.762	0.762	0.762

Source: Dataquest (October 1995)

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Table 8
Regional Revenue Growth from Production of Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Worldwide Total	7.8	5.8	1.0	5.8	10.6
Data Processing	9.8	4.7	-0.2	6.0	15.6
Communications	11.1	7.9	7.0	11.6	13.3
Industrial	9.1	4.1	-0.3	2.7	6.9
Consumer	5.5	10.1	-1.3	6.6	9.6
Military/Civil Aerospace	1.7	-0.8	-0.9	-3.3	-2.4
Transportation	6.2	6.6	9.2	11.3	11.1
North American Total	4.8	0.1	-0.5	2.1	9.4
Data Processing	6.1	-2.2	-9.3	-3.5	12.1
Communications	8.1	7.1	11.6	13.7	18.9
Industrial	4.8	2.9	4.2	5.1	7.3
Consumer	-0.3	-2.0	2.9	9.3	9.1
Military/Civil Aerospace	4.9	-2.8	-2.4	-8.8	-4.7
Transportation	-9.3	0.5	10.0	18.7	19.3
Japanese Total	4.8	10.5	-5.9	4.1	9.1
Data Processing	4.6	9.9	-2.7	3.4	11.3
Communications	7.8	7.3	-2.1	12.7	12.6
Industrial	6.5	8.6	-12.6	5.1	9.2
Consumer	3.9	14.1	-8.7	-0.3	6.6
Military/Civil Aerospace	-12.2	-0.7	5.3	11.4	6.8
Transportation	3.4	5.7	4.7	9.5	4.4
European Total	12.2	2.4	0.7	4.2	5.9
Data Processing	17.9	-1.6	-5.3	8.9	9.2
Communications	14.7	8.3	5.8	6.7	8.2
Industrial	22.8	0.5	4.9	-4.4	3.5
Consumer	3.4	3.6	-5.2	4.1	4.0
Military/Civil Aerospace	-3.6	0.9	-0.5	1.9	-2.8
Transportation	20.6	8.9	14.5	9.6	16.3
Asia/Pacific-ROW Total	15.6	17.1	19.4	18.0	20.8
Data Processing	19.4	22.8	29.0	20.4	29.2
Communications	16.9	9.8	16.3	16.6	13.1
Industrial	-14.9	14.2	15.1	14.7	10.6
Consumer	16.2	16.0	13.2	17.5	16.5
Military/Civil Aerospace	9.2	9.0	8.5	10.4	11.5
Transportation	14.0	14.7	11.6	12.9	9.2
U.S.$ Appreciation versus Yen	4.3	-5.6	-7.0	-12.1	-8.4
U.S.$ Appreciation versus ECU	-13.2	2.9	-5.1	11.4	-1.6

Source: Dataquest (October 1995)

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Table 9
Regional Revenue Growth from Production of Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Worldwide Total	11.8	8.1	7.7	8.5	8.6	9.0
Data Processing	13.0	9.6	7.1	7.6	8.0	9.0
Communications	16.3	12.8	10.9	11.5	9.8	12.2
Industrial	11.2	6.2	7.5	8.7	9.7	8.7
Consumer	10.9	5.9	7.9	8.7	9.4	8.5
Military/Civil Aerospace	0.2	1.6	2.0	2.4	2.6	1.8
Transportation	12.9	6.6	7.9	8.7	9.0	9.0
North American Total	7.5	5.6	5.8	4.7	5.9	5.9
Data Processing	10.9	5.2	6.0	1.7	3.9	5.5
Communications	11.9	11.0	8.7	9.8	10.4	10.4
Industrial	6.4	5.9	4.8	5.2	6.3	5.7
Consumer	3.8	1.5	5.2	3.7	4.1	3.7
Military/Civil Aerospace	-1.8	1.0	1.6	2.0	2.3	1.0
Transportation	10.5	4.4	7.8	7.4	6.2	7.2
Japanese Total	16.4	2.2	5.3	5.8	6.9	7.2
Data Processing	9.7	-0.3	3.1	2.8	4.9	4.0
Communications	29.7	7.8	7.5	5.7	5.4	10.9
Industrial	24.6	5.8	10.8	13.9	14.5	13.7
Consumer	13.1	0	3.6	4.3	5.3	5.2
Military/Civil Aerospace	13.3	-1.1	-1.3	-1.2	-1.1	1.6
Transportation	13.7	1.0	2.5	4.1	5.0	5.2
European Total	8.3	8.8	7.3	8.7	6.4	7.9
Data Processing	12.3	11.8	9.3	12.3	8.0	10.7
Communications	11.7	11.7	8.7	9.3	4.7	9.2
Industrial	4.8	5.9	6.6	7.3	8.2	6.5
Consumer	6.1	7.9	5.6	6.7	7.0	6.7
Military/Civil Aerospace	-1.1	-0.7	-1.0	-1.0	-1.8	-1.1
Transportation	12.8	12.2	11.7	12.0	11.3	12.0
Asia/Pacific-ROW Total	16.0	18.9	13.4	15.6	15.2	15.8
Data Processing	18.4	20.6	9.4	12.8	12.9	14.7
Communications	15.6	28.3	24.3	25.6	20.6	22.8
Industrial	15.0	14.2	15.8	13.1	13.6	14.4
Consumer	13.7	14.6	14.4	15.5	15.7	14.8
Military/Civil Aerospace	12.2	13.3	14.1	14.2	14.8	13.7
Transportation	14.6	14.3	15.3	15.4	17.5	15.4
U.S.$ Appreciation versus Yen	-13.1	0	0	0	0	NM
U.S.$ Appreciation versus ECU	-9.7	0	0	0	0	NM

NM = Not meaningful
Source: Dataquest (October 1995)

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Table 10
Revenue from North American Data Processing Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	194,625	194,843	193,914	198,037	216,696
Data Processing	67,032	65,588	59,477	57,374	64,317
Computer[1]	47,133	46,124	40,491	38,766	45,048
Supercomputer	1,476	1,542	1,441	1,510	1,565
Mainframe	13,326	11,327	8,479	5,703	6,080
Midrange	16,820	16,712	12,192	9,073	8,825
Workstation	5,589	5,936	5,912	6,124	7,693
PC/Motherboard Upgrade	9,922	10,607	12,467	16,357	20,885
Data Storage Device	5,972	5,715	4,494	3,455	3,103
Rigid Disk Drive	5,027	4,619	3,392	2,480	1,938
14-Inch	1,093	681	279	0	0
8-10-Inch	2,373	2,938	2,481	1,514	802
5.25-Inch	551	301	175	85	54
3.5-Inch	1,010	699	458	847	1,032
2.5-Inch	0	0	0	32	46
1.8-Inch	0	0	0	2	5
Optical Disk Drive	33	38	40	30	37
Rewrite Optical Disk Drive	15	18	20	11	13
WORM Optical Disk Drive	17	19	19	11	7
CD-ROM	1	1	2	9	17
Tape Drive	911	1,058	1,062	945	1,128
Input/Output Device	8,230	8,335	8,728	8,785	9,057
Terminal	1,317	1,100	975	805	642
Graphics Terminal	113	138	228	297	293
X-Terminal	87	130	226	296	292
Other Graphics Terminal	26	8	2	2	1
Alphanumeric Terminal	1,204	962	747	508	349
Printer	3,196	3,277	3,459	3,334	3,420
Serial Printer	670	690	735	834	802
Line Printer	1,012	967	983	593	597
Page Printer	1,514	1,620	1,741	1,907	2,021
Other Input/Output Device	3,717	3,958	4,294	4,645	4,995
Dedicated System	4,795	4,596	4,945	5,503	5,969
Copier and Duplicator	1,425	1,421	1,580	1,935	2,178
Personal Copier	79	88	107	170	291
Segments 1-3	863	803	815	894	925
Segments 4-6	483	530	658	871	962

(Continued)

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Table 10 (Continued)
Revenue from North American Data Processing Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Personal Organizer	0	0	0	0	0
Smart Card (IC Card)	0	0	0	0	10
Other Dedicated System	3,370	3,175	3,366	3,567	3,781
Other Data Processing	903	817	818	865	1,139
Sound/Audio Board	0	3	12	22	44
Digital Video Board	76	92	113	140	188
Accelerator Board	501	379	332	307	470
Embedded CPU Board	326	343	361	397	437

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 11
Revenue from North American Data Processing Equipment Production, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	232,947	246,005	260,245	272,536	288,551
Data Processing	71,334	75,062	79,597	80,981	84,154
Computer[1]	50,985	53,581	57,428	58,174	60,417
Supercomputer	1,600	1,665	1,788	1,928	2,081
Mainframe	5,828	5,112	5,416	5,047	5,111
Midrange	8,859	8,424	9,480	9,303	9,909
Workstation	8,780	9,145	9,938	9,691	9,323
PC/Motherboard Upgrade	25,918	29,235	30,806	32,205	33,994
Data Storage Device	3,108	3,153	2,739	2,415	2,149
Rigid Disk Drive	1,677	1,524	1,160	1,028	936
14-Inch	0	0	0	0	0
8-10-Inch	461	40	0	0	0
5.25-Inch	47	41	7	0	0
3.5-Inch	1,121	1,382	1,099	984	893
2.5-Inch	38	31	16	6	2
1.8-Inch	10	30	38	38	42
Optical Disk Drive	67	81	93	108	108
Rewrite Optical Disk Drive	24	29	26	21	15
WORM Optical Disk Drive	9	10	10	9	8
CD-ROM	34	43	58	78	85
Tape Drive	1,364	1,548	1,486	1,279	1,105
Input/Output Device	9,543	10,093	10,598	11,140	11,885
Terminal	571	556	558	562	570
Graphics Terminal	310	349	384	413	440
X-Terminal	310	349	384	413	440
Other Graphics Terminal	0	0	0	0	0
Alphanumeric Terminal	261	207	174	149	130
Printer	3,577	3,711	3,748	3,781	3,975
Serial Printer	798	800	816	830	858
Line Printer	596	595	572	553	538
Page Printer	2,183	2,316	2,360	2,398	2,579
Other Input/Output Device	5,395	5,826	6,292	6,796	7,340
Dedicated System	6,449	6,919	7,462	7,857	8,273
Copier and Duplicator	2,411	2,615	2,828	2,913	2,983
Personal Copier	367	444	529	505	486
Segments 1-3	915	899	913	891	878
Segments 4-6	1,129	1,271	1,386	1,517	1,620

(Continued)

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Table 11 (Continued)
Revenue from North American Data Processing Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Personal Organizer	0	0	0	0	0
Smart Card (IC Card)	30	55	130	170	230
Other Dedicated System	4,008	4,249	4,504	4,774	5,060
Other Data Processing	1,249	1,316	1,370	1,395	1,430
Sound/Audio Board	36	33	31	29	29
Digital Video Board	318	368	387	369	360
Accelerator Board	415	388	372	361	346
Embedded CPU Board	480	527	580	637	695

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 12
Revenue Growth from North American Data Processing Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.8	0.1	-0.5	2.1	9.4
Data Processing	6.1	-2.2	-9.3	-3.5	12.1
Computer[1]	6.3	-2.1	-12.2	-4.3	16.2
Supercomputer	8.5	4.5	-6.5	4.8	3.6
Mainframe	-3.6	-15.0	-25.1	-32.7	6.6
Midrange	-5.5	-0.6	-27.0	-25.6	-2.7
Workstation	51.6	6.2	-0.4	3.6	25.6
PC/Motherboard Upgrade	29.6	6.9	17.5	31.2	27.7
Data Storage Device	29.0	-4.3	-21.4	-23.1	-10.2
Rigid Disk Drive	27.4	-8.1	-26.6	-26.9	-21.9
14-Inch	-22.6	-37.7	-59.1	NM	NM
8-10-Inch	125.6	23.8	-15.6	-39.0	-47.0
5.25-Inch	-9.7	-45.5	-41.9	-51.2	-36.7
3.5-Inch	16.1	-30.8	-34.5	85.0	21.9
2.5-Inch	NM	NM	NM	NM	43.5
1.8-Inch	NM	NM	NM	NM	112.0
Optical Disk Drive	70.1	15.1	6.0	-25.8	23.3
Rewrite Optical Disk Drive	102.8	16.0	9.6	-46.4	27.0
WORM Optical Disk Drive	50.5	15.1	-2.6	-43.3	-32.8
CD-ROM	30.4	1.5	94.8	307.9	85.4
Tape Drive	37.0	16.1	0.4	-10.9	19.4
Input/Output Device	-3.0	1.3	4.7	0.6	3.1
Terminal	-34.2	-16.5	-11.4	-17.4	-20.3
Graphics Terminal	8.7	22.1	65.2	30.5	-1.4
X-Terminal	278.3	49.4	73.8	30.9	-1.3
Other Graphics Terminal	-67.9	-69.2	-75.0	-16.6	-28.1
Alphanumeric Terminal	-36.5	-20.1	-22.3	-32.0	-31.3
Printer	8.7	2.5	5.6	-3.6	2.6
Serial Printer	-11.4	3.0	6.5	13.5	-3.8
Line Printer	2.3	-4.4	1.7	-39.6	0.6
Page Printer	26.6	7.0	7.5	9.5	6.0
Other Input/Output Device	5.0	6.5	8.5	8.2	7.5
Dedicated System	-1.4	-4.1	7.6	11.3	8.5
Copier and Duplicator	7.8	-0.3	11.1	22.5	12.5
Personal Copier	51.9	11.0	21.6	59.1	70.9
Segments 1-3	2.7	-6.9	1.5	9.7	3.4
Segments 4-6	12.5	9.7	24.1	32.5	10.4

(Continued)

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Table 12 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Personal Organizer	NM	NM	NM	NM	NM
Smart Card (IC Card)	NM	NM	NM	NM	NM
Other Dedicated System	-4.8	-5.8	6.0	6.0	6.0
Other Data Processing	1.1	-9.5	0.1	5.8	31.7
Sound/Audio Board	NM	NM	290.2	84.9	100.7
Digital Video Board	38.2	21.1	22.8	23.5	34.5
Accelerator Board	-4.6	-24.3	-12.5	-7.7	53.4
Embedded CPU Board	4.2	5.2	5.2	10.0	10.1

NM = Not meaningful

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 13
Revenue Growth from North American Data Processing Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	7.5	5.6	5.8	4.7	5.9	5.9
Data Processing	10.9	5.2	6.0	1.7	3.9	5.5
Computer[1]	13.2	5.1	7.2	1.3	3.9	6.0
Supercomputer	2.2	4.1	7.4	7.8	7.9	5.9
Mainframe	-4.1	-12.3	5.9	-6.8	1.3	-3.4
Midrange	0.4	-4.9	12.5	-1.9	6.5	2.3
Workstation	14.1	4.2	8.7	-2.5	-3.8	3.9
PC/Motherboard Upgrade	24.1	12.8	5.4	4.5	5.6	10.2
Data Storage Device	0.1	1.5	-13.1	-11.8	-11.0	-7.1
Rigid Disk Drive	-13.5	-9.1	-23.9	-11.4	-8.9	-13.5
14-Inch	NM	NM	NM	NM	NM	NM
8-10-Inch	-42.5	-91.3	NM	NM	NM	-100.0
5.25-Inch	-13.1	-12.7	-82.7	NM	NM	-100.0
3.5-Inch	8.6	23.3	-20.5	-10.5	-9.3	-2.9
2.5-Inch	-17.2	-17.2	-49.8	-59.7	-71.6	-47.6
1.8-Inch	119.2	191.4	28.5	-1.0	10.0	55.0
Optical Disk Drive	81.1	20.9	14.8	16.1	0	23.9
Rewrite Optical Disk Drive	76.5	21.8	-9.9	-19.1	-26.7	2.8
WORM Optical Disk Drive	30.5	3.8	-0.1	-1.5	-16.7	2.1
CD-ROM	106.5	24.9	34.9	34.9	9.2	38.7
Tape Drive	20.9	13.5	-4.0	-13.9	-13.6	-0.4
Input/Output Device	5.4	5.8	5.0	5.1	6.7	5.6
Terminal	-11.1	-2.6	0.4	0.8	1.4	-2.3
Graphics Terminal	5.7	12.6	10.0	7.7	6.5	8.5
X-Terminal	6.2	12.6	10.0	7.6	6.5	8.5
Other Graphics Terminal	NM	NM	NM	NM	-26.6	-24.5
Alphanumeric Terminal	-25.2	-20.7	-15.9	-14.4	-12.8	-17.9
Printer	4.6	3.8	1.0	0.9	5.1	3.1
Serial Printer	-0.5	0.3	2.0	1.7	3.4	1.4
Line Printer	-0.2	-0.1	-3.8	-3.4	-2.8	-2.1
Page Printer	8.0	6.1	1.9	1.6	7.5	5.0
Other Input/Output Device	8.0	8.0	8.0	8.0	8.0	8.0
Dedicated System	8.0	7.3	7.8	5.3	5.3	6.7
Copier and Duplicator	10.7	8.5	8.1	3.0	2.4	6.5
Personal Copier	25.9	21.2	19.0	-4.6	-3.7	10.8
Segments 1-3	-1.0	-1.7	1.5	-2.3	-1.5	-1.0
Segments 4-6	17.3	12.6	9.0	9.4	6.8	11.0

(Continued)

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Table 13 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Personal Organizer	NM	NM	NM	NM	NM	NM
Smart Card (IC Card)	200.0	83.3	136.4	30.8	35.3	87.2
Other Dedicated System	6.0	6.0	6.0	6.0	6.0	6.0
Other Data Processing	9.7	5.3	4.1	1.9	2.4	4.6
Sound/Audio Board	-18.6	-8.1	-7.4	-6.0	-0.3	-8.3
Digital Video Board	69.4	15.7	5.3	-4.6	-2.5	13.9
Accelerator Board	-11.7	-6.6	-4.1	-3.2	-4.1	-6.0
Embedded CPU Board	9.8	9.8	10.1	9.8	9.1	9.7

NM = Not meaningful

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (October 1995)

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Table 14
Revenue from North American Communications Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Communication	27,230	29,174	32,563	37,014	43,997
Premise Telecom	10,008	10,730	12,290	14,546	17,303
Image and Text Communication	322	432	540	621	654
Facsimile (Card See Modem)	207	228	230	199	226
Video Teleconferencing	115	204	310	422	428
Data Communications Equipment	4,376	5,044	6,465	8,424	10,440
Modem (Modem Card)	804	673	490	588	735
Statistical Multiplexer	163	146	144	150	139
T-Carrier/TDM Multiplexer	433	416	667	1,357	1,693
Front-End Processor	479	466	462	460	440
DSU/CSU	213	254	302	476	531
Protocol Converter	153	141	137	133	130
LAN Cards	1,140	1,173	1,274	1,430	1,529
LAN hubs/Internetworking	685	1,455	2,647	3,465	4,751
WAN Switching	306	320	342	365	493
Premise Voice Systems	4,733	4,699	4,832	5,043	5,765
Premise Switching	3,066	2,866	2,828	2,768	2,950
Voice Messaging	861	945	1,024	1,217	1,544
Interactive Voice Response	404	480	529	556	670
Automatic Call Distributor	402	408	451	502	601
Desktop Terminal	577	555	452	458	443
Telephone Sets/Answerers	387	385	367	393	408
Teleprinter	190	170	85	65	35
Public Telecom	5,064	5,559	5,823	6,593	8,170
Transmission	2,990	3,184	3,046	3,588	5,215
Central Office Switching	2,074	2,375	2,777	3,005	2,955
Mobile Communication	6,935	7,459	8,754	9,960	12,168
Mobile Radio	6,738	7,151	8,378	9,561	11,742
Cellular/PCS Terminal	2,828	3,017	3,265	3,514	4,888
Other Portable Radio	2,037	2,041	2,180	1,900	1,824
Mobile Radio Base Station	1,568	1,797	2,508	3,559	4,169
Pager (One- and Two-Way)	305	296	425	588	861
Radio Checkout	197	308	376	398	426
Broadcast and Studio	1,838	1,813	1,949	2,052	2,141
Audio	367	414	499	482	492
Video	466	472	486	466	489
Transmitter, RF Power Amp	124	222	257	317	301
Studio Transmitter Link	25	43	49	54	55

(Continued)

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Table 14 (Continued)
Revenue from North American Communications Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Cable TV (Headend)	554	292	227	275	330
CCTV	165	214	230	254	265
Other (Including Studio, Theater)	137	156	201	204	208
Other Telecom	3,385	3,613	3,747	3,863	4,215
Intercomm., Elec. Amp.	346	304	289	249	360
Communication Equipment, nec*	3,039	3,309	3,458	3,614	3,855

*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 15
Revenue from North American Communications Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Communication	49,235	54,651	59,407	65,255	72,043
Premise Telecom	20,026	22,198	24,291	26,398	29,166
Image and Text Communication	787	839	968	1,227	1,864
Facsimile (Card See Modem)	252	270	272	267	261
Video Teleconferencing	535	569	696	960	1,603
Data Communications Equipment	12,097	13,044	13,848	14,406	15,081
Modem (Modem Card)	961	1,043	1,004	976	916
Statistical Multiplexer	131	118	110	104	98
T-Carrier/TDM Multiplexer	1,964	2,200	2,420	2,661	2,928
Front-End Processor	415	400	380	360	341
DSU/CSU	584	625	669	716	766
Protocol Converter	120	115	109	105	101
LAN Cards	1,643	1,438	1,399	1,300	1,254
LAN hubs/Internetworking	5,639	6,305	6,757	6,933	7,114
WAN Switching	641	801	1,001	1,251	1,564
Premise Voice Systems	6,704	7,862	9,023	10,290	11,723
Premise Switching	3,032	3,126	3,220	3,343	3,627
Voice Messaging	2,107	2,846	3,507	4,195	4,783
Interactive Voice Response	783	952	1,188	1,498	1,889
Automatic Call Distributor	782	938	1,108	1,254	1,424
Desktop Terminal	438	453	452	474	498
Telephone Sets/Answerers	423	453	452	474	498
Teleprinter	15	0	0	0	0
Public Telecom	8,454	9,394	10,189	11,139	14,006
Transmission	5,643	6,754	7,632	8,643	11,505
Central Office Switching	2,811	2,640	2,557	2,496	2,501
Mobile Communication	14,045	15,963	17,413	19,749	20,536
Mobile Radio	13,589	15,334	16,684	18,911	19,672
Cellular/PCS Terminal	5,723	6,644	6,907	8,166	8,334
Other Portable Radio	2,024	2,330	2,677	3,079	3,540
Mobile Radio Base Station	5,023	5,436	5,879	6,002	6,038
Pager (One- and Two-Way)	819	924	1,221	1,664	1,760
Radio Checkout	456	629	729	838	864
Broadcast and Studio	2,283	2,443	2,622	2,825	2,924
Audio	513	536	559	584	610
Video	521	555	591	629	670
Transmitter, RF Power Amp	307	313	320	326	332
Studio Transmitter Link	56	57	58	60	61

(Continued)

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Table 15 (Continued)
Revenue from North American Communications Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Cable TV (Headend)	396	475	570	684	698
CCTV	277	290	303	317	323
Other (Including Studio, Theater)	212	216	221	225	230
Other Telecom	4,427	4,653	4,891	5,144	5,410
Intercomm., Elec. Amp.	360	362	364	368	372
Communication Equipment, nec*	4,067	4,291	4,527	4,776	5,038

*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 16
Revenue Growth from North American Communications Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Communication	8.1	7.1	11.6	13.7	18.9
Premise Telecom	7.7	7.2	14.5	18.4	18.9
Image and Text Communication	25.8	34.2	25.0	15.0	5.3
Facsimile (Card See Modem)	5.6	10.1	0.9	-13.5	13.6
Video Teleconferencing	91.7	77.4	52.0	36.1	1.4
Data Communications Equipment	7.7	15.3	28.2	30.3	23.9
Modem (Modem Card)	-16.8	-16.3	-27.2	20.0	25.0
Statistical Multiplexer	-7.9	-10.4	-1.4	4.2	-7.3
T-Carrier/TDM Multiplexer	-2.9	-3.9	60.3	103.4	24.8
Front-End Processor	-0.6	-2.7	-0.9	-0.4	-4.3
DSU/CSU	52.1	19.2	18.9	57.6	11.6
Protocol Converter	-6.7	-7.8	-2.8	-2.9	-2.3
LAN Cards	14.2	2.9	8.6	12.2	6.9
LAN hubs/Internetworking	71.3	112.4	81.9	30.9	37.1
WAN Switching	5.2	4.6	6.9	6.7	35.0
Premise Voice Systems	8.3	-0.7	2.8	4.4	14.3
Premise Switching	-4.4	-6.5	-1.3	-2.1	6.6
Voice Messaging	52.9	9.8	8.4	18.8	26.9
Interactive Voice Response	97.1	18.8	10.2	5.1	20.5
Automatic Call Distributor	1.0	1.5	10.5	11.3	19.7
Desktop Terminal	-3.8	-3.8	-18.5	1.4	-3.3
Telephone Sets/Answerers	-2.0	-0.5	-4.6	7.1	3.8
Teleprinter	-7.3	-10.5	-50.0	-23.5	-46.2
Public Telecom	7.0	9.8	4.7	13.2	23.9
Transmission	15.5	6.5	-4.3	17.8	45.3
Central Office Switching	-3.2	14.5	16.9	8.2	-1.7
Mobile Communication	22.6	7.6	17.4	13.8	22.2
Mobile Radio	23.7	6.1	17.2	14.1	22.8
Cellular/PCS Terminal	20.9	6.7	8.2	7.6	39.1
Other Portable Radio	38.5	0.2	6.8	-12.8	-4.0
Mobile Radio Base Station	7.2	14.6	39.5	41.9	17.1
Pager (One- and Two-Way)	76.3	-3.0	43.6	38.4	46.4
Radio Checkout	-6.6	56.3	22.1	6.0	6.9
Broadcast and Studio	2.1	-1.4	7.5	5.3	4.3
Audio	-11.1	12.8	20.5	-3.4	2.0
Video	-2.9	1.3	3.0	-4.1	5.0
Transmitter, RF Power Amp	18.1	79.0	15.8	23.3	-5.0
Studio Transmitter Link	19.0	72.0	14.0	10.2	2.0

(Continued)

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Table 16 (Continued)
Revenue Growth from North American Communications Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Cable TV (Headend)	2.4	-47.3	-22.3	21.1	20.0
CCTV	13.8	29.7	7.5	10.4	4.5
Other (Including Studio, Theater)	44.2	13.9	28.8	1.5	2.0
Other Telecom	-8.8	6.7	3.7	3.1	9.1
Intercomm., Elec. Amp.	-6.0	-12.1	-4.9	-13.8	44.6
Communication Equipment, nec*	-9.1	8.9	4.5	4.5	6.7

*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 17
Revenue Growth from North American Communications Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communication	11.9	11.0	8.7	9.8	10.4	10.4
Premise Telecom	15.7	10.8	9.4	8.7	10.5	11.0
Image and Text Communication	20.3	6.6	15.4	26.8	51.9	23.3
Facsimile (Card See Modem)	11.5	7.1	0.7	-1.8	-2.2	2.9
Video Teleconferencing	25.0	6.4	22.3	37.9	67.0	30.2
Data Communications Equipment	15.9	7.8	6.2	4.0	4.7	7.6
Modem (Modem Card)	30.7	8.5	-3.7	-2.8	-6.1	4.5
Statistical Multiplexer	-5.8	-9.9	-6.8	-5.5	-5.8	-6.8
T-Carrier/TDM Multiplexer	16.0	12.0	10.0	10.0	10.0	11.6
Front-End Processor	-5.7	-3.6	-5.0	-5.3	-5.3	-5.0
DSU/CSU	10.0	7.0	7.0	7.0	7.0	7.6
Protocol Converter	-7.7	-4.2	-5.2	-3.7	-3.7	-4.9
LAN Cards	7.5	-12.5	-2.7	-7.1	-3.5	-3.9
LAN hubs/Internetworking	18.7	11.8	7.2	2.6	2.6	8.4
WAN Switching	30.0	25.0	25.0	25.0	25.0	26.0
Premise Voice Systems	16.3	17.3	14.8	14.0	13.9	15.3
Premise Switching	2.8	3.1	3.0	3.8	8.5	4.2
Voice Messaging	36.5	35.1	23.2	19.6	14.0	25.4
Interactive Voice Response	16.9	21.6	24.8	26.1	26.1	23.0
Automatic Call Distributor	30.1	19.9	18.1	13.2	13.6	18.8
Desktop Terminal	-1.1	3.3	-0.2	5.0	5.0	2.4
Telephone Sets/Answerers	3.7	6.9	-0.2	5.0	5.0	4.1
Teleprinter	-57.1	NM	NM	NM	NM	-100.0
Public Telecom	3.5	11.1	8.5	9.3	25.7	11.4
Transmission	8.2	19.7	13.0	13.2	33.1	17.1
Central Office Switching	-4.9	-6.1	-3.1	-2.4	0.2	-3.3
Mobile Communication	15.4	13.7	9.1	13.4	4.0	11.0
Mobile Radio	15.7	12.8	8.8	13.3	4.0	10.9
Cellular/PCS Terminal	17.1	16.1	4.0	18.2	2.1	11.3
Other Portable Radio	11.0	15.1	14.9	15.0	15.0	14.2
Mobile Radio Base Station	20.5	8.2	8.1	2.1	0.6	7.7
Pager (One- and Two-Way)	-4.9	12.8	32.1	36.3	5.8	15.4
Radio Checkout	7.0	37.9	15.9	15.0	3.1	15.2
Broadcast and Studio	6.7	7.0	7.3	7.7	3.5	6.4
Audio	4.4	4.4	4.4	4.4	4.4	4.4
Video	6.5	6.5	6.5	6.5	6.5	6.5
Transmitter, RF Power Amp	2.0	2.0	2.0	2.0	2.0	2.0

(Continued)

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Table 17 (Continued)
Revenue Growth from North American Communications Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Studio Transmitter Link	2.0	2.0	2.0	2.0	2.0	2.0
Cable TV (Headend)	20.0	20.0	20.0	20.0	2.0	16.2
CCTV	4.5	4.5	4.5	4.5	2.0	4.0
Other (Including Studio, Theater)	2.0	2.0	2.0	2.0	2.0	2.0
Other Telecom	5.0	5.1	5.1	5.2	5.2	5.1
Intercomm., Elec. Amp.	0	0.6	0.6	1.1	1.1	0.7
Communication Equipment, nec*	5.5	5.5	5.5	5.5	5.5	5.5

NM = Not meaningful
*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 18
Revenue from North American Industrial Equipment Production, 1990-1994
(Millions of Dollars)

	1990	1991	1992	1993	1994
Industrial	38,751	39,892	41,581	43,687	46,856
Security/Energy Management	3,388	3,558	3,712	3,871	4,087
Alarm System	1,104	1,231	1,473	1,619	1,696
Intrusion Detection	653	715	841	908	934
Fire Detection	452	516	632	711	762
Energy Management	2,284	2,327	2,239	2,252	2,391
Manufacturing System	15,547	15,398	15,710	17,558	19,494
Semiconductor Production	1,589	1,524	1,570	2,129	3,141
Controls	6,274	6,097	5,528	5,985	6,226
Process Controls	2,584	2,581	2,621	3,386	3,737
Control and Processing Displays	4,824	4,902	5,697	5,763	6,093
Robots	275	294	295	295	297
Test and Measuring Equipment	7,769	8,426	8,434	8,272	8,511
ATE-Semiconductor Equipment	865	897	471	563	591
Other Test and Measurement	6,337	6,959	7,429	7,188	7,398
Nuclear Electronics	567	571	533	520	522
Medical Equipment	5,760	6,884	7,199	7,741	8,194
Diagnostic	1,981	2,043	2,477	2,264	2,335
Therapeutic	1,279	1,873	1,505	1,752	1,889
Patient Monitoring	857	990	1,129	1,190	1,259
Surgical Support	406	613	865	787	942
Irradiation Equipment	1,237	1,365	1,223	1,749	1,769
Other Industrial System	6,288	5,625	6,526	6,245	6,570

Source: Dataquest (October 1995)

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Table 19
Revenue from North American Industrial Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Industrial	49,835	52,785	55,339	58,206	61,880
Security/Energy Management	4,259	4,485	4,737	4,989	5,245
Alarm System	1,753	1,832	1,919	2,005	2,091
Intrusion Detection	949	973	1,000	1,025	1,048
Fire Detection	805	859	919	981	1,043
Energy Management	2,506	2,653	2,818	2,984	3,154
Manufacturing System	21,530	23,163	24,214	25,558	27,653
Semiconductor Production	4,409	5,040	4,966	5,160	6,065
Controls	6,393	6,634	6,904	7,165	7,420
Process Controls	4,073	4,484	4,950	5,449	5,988
Control and Processing Displays	6,359	6,707	7,094	7,482	7,876
Robots	296	298	300	302	304
Test and Measuring Equipment	8,641	8,869	9,131	9,373	9,604
ATE-Semiconductor Equipment	611	639	671	702	732
Other Test and Measurement	7,514	7,714	7,943	8,154	8,355
Nuclear Electronics	516	516	517	517	516
Medical Equipment	8,582	9,108	9,721	10,378	11,095
Diagnostic	2,375	2,442	2,519	2,590	2,658
Therapeutic	2,011	2,163	2,333	2,510	2,695
Patient Monitoring	1,316	1,389	1,471	1,553	1,636
Surgical Support	1,115	1,332	1,596	1,907	2,274
Irradiation Equipment	1,765	1,781	1,802	1,818	1,831
Other Industrial System	6,823	7,160	7,535	7,908	8,283

Source: Dataquest (October 1995)

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Table 20
Revenue Growth from North American Industrial Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Industrial	4.8	2.9	4.2	5.1	7.3
Security/Energy Management	-1.1	5.0	4.3	4.3	5.6
Alarm System	-9.3	11.5	19.7	9.9	4.7
Intrusion Detection	-10.8	9.6	17.6	8.0	2.9
Fire Detection	-7.0	14.2	22.5	12.5	7.1
Energy Management	3.4	1.9	-3.8	0.6	6.2
Manufacturing System	5.0	-1.0	2.0	11.8	11.0
Semiconductor Production	-4.1	-4.1	3.0	35.6	47.5
Controls	7.2	-2.8	-9.3	8.3	4.0
Process Controls	8.0	-0.1	1.6	29.2	10.4
Control and Processing Displays	3.8	1.6	16.2	1.2	5.7
Robots	7.4	7.1	0.2	-0.2	0.9
Test and Measuring Equipment	13.3	8.5	0.1	-1.9	2.9
ATE-Semiconductor Equipment	44.5	3.7	-47.5	19.5	4.9
Other Test and Measurement	12.1	9.8	6.8	-3.2	2.9
Nuclear Electronics	-6.5	0.7	-6.5	-2.5	0.3
Medical Equipment	7.5	19.5	4.6	7.5	5.8
Diagnostic	5.4	3.2	21.2	-8.6	3.1
Therapeutic	17.2	46.4	-19.6	16.4	7.8
Patient Monitoring	3.0	15.5	14.0	5.4	5.8
Surgical Support	-3.7	50.9	41.2	-9.1	19.7
Irradiation Equipment	9.3	10.3	-10.4	43.0	1.2
Other Industrial System	-3.9	-10.5	16.0	-4.3	5.2

Source: Dataquest (October 1995)

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Table 21
Revenue Growth from North American Industrial Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	6.4	5.9	4.8	5.2	6.3	5.7
Security/Energy Management	4.2	5.3	5.6	5.3	5.1	5.1
Alarm System	3.4	4.5	4.8	4.5	4.3	4.3
Intrusion Detection	1.5	2.5	2.8	2.5	2.2	2.3
Fire Detection	5.7	6.8	7.0	6.7	6.4	6.5
Energy Management	4.8	5.9	6.2	5.9	5.7	5.7
Manufacturing System	10.4	7.6	4.5	5.5	8.2	7.2
Semiconductor Production	40.4	14.3	-1.5	3.9	17.5	14.1
Controls	2.7	3.8	4.1	3.8	3.6	3.6
Process Controls	9.0	10.1	10.4	10.1	9.9	9.9
Control and Processing Displays	4.4	5.5	5.8	5.5	5.3	5.3
Robots	-0.5	0.6	0.9	0.6	0.4	0.4
Test and Measuring Equipment	1.5	2.6	2.9	2.7	2.5	2.4
ATE-Semiconductor Equipment	3.5	4.6	4.9	4.6	4.4	4.4
Other Test and Measurement	1.6	2.7	3.0	2.7	2.5	2.5
Nuclear Electronics	-1.1	0	0.3	0	-0.2	-0.2
Medical Equipment	4.7	6.1	6.7	6.8	6.9	6.2
Diagnostic	1.7	2.8	3.1	2.8	2.6	2.6
Therapeutic	6.5	7.6	7.9	7.6	7.4	7.4
Patient Monitoring	4.5	5.6	5.9	5.6	5.4	5.4
Surgical Support	18.4	19.5	19.8	19.5	19.3	19.3
Irradiation Equipment	-0.2	0.9	1.2	0.9	0.7	0.7
Other Industrial System	3.8	4.9	5.2	4.9	4.7	4.7

Source: Dataquest (October 1995)

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Table 22
Revenue from North American Consumer Equipment Production, 1990-1994 (Millions of Dollars)

	1990	1991	1992	1993	1994
Consumer	21,471	21,046	21,650	23,659	25,821
Audio	802	719	693	716	766
Compact Disc Player	16	21	27	33	41
Radio	287	213	165	165	184
Personal/Portable Stereo	24	26	32	33	35
Stereo Component	217	214	222	226	239
Musical Instrument	240	230	232	242	250
Tape Recorder	19	15	15	17	17
Video	7,428	7,414	7,420	7,775	8,508
VCR, VTR	67	67	69	70	107
Camcorder	35	32	29	31	44
Video Disk Player	1	1	0	0	0
Color Televisions	6,618	6,628	6,687	6,966	7,508
Cable/Satellite Set-Top Decoder	707	686	635	708	849
Personal Electronics	207	195	199	203	210
Games (Systems and cartridges)	9	9	9	9	8
Camera	25	24	24	24	25
Watches	105	105	108	110	115
Clocks	68	58	58	60	62
Appliances	11,926	11,585	12,116	13,669	14,942
Air Conditioner	2,032	1,767	1,847	2,027	2,463
Microwave Oven	558	502	525	574	627
Washer and Dryer	3,184	3,122	3,264	3,518	3,724
Refrigerator	4,119	4,160	4,352	5,228	5,606
Dishwasher	1,030	1,020	1,067	1,168	1,284
Range and Oven	1,004	1,014	1,060	1,154	1,239
Other Consumer	1,108	1,133	1,223	1,296	1,395
Automatic Garage Door Opener	257	267	318	352	411
Other Consumer Equipment, nec*	851	866	905	944	983

*nec = not elsewhere classified

Source: Dataquest (October 1995)

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Table 23
Revenue from North American Consumer Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Consumer	26,805	27,203	28,626	29,689	30,911
Audio	811	864	908	960	1,019
Compact Disc Player	50	62	76	94	115
Radio	194	204	212	221	231
Personal/Portable Stereo	36	39	42	45	47
Stereo Component	252	266	276	288	302
Musical Instrument	261	274	282	292	302
Tape Recorder	18	19	20	20	21
Video	8,840	9,216	9,968	10,638	10,858
VCR, VTR	74	155	203	265	306
Camcorder	62	88	126	180	193
Video Disk Player	0	0	0	0	0
Color Televisions	7,630	7,681	8,242	8,845	9,131
Cable/Satellite Set-Top Decoder	1,074	1,292	1,397	1,348	1,228
Personal Electronics	223	233	241	250	264
Games (Systems and cartridges)	10	9	9	9	13
Camera	27	28	29	29	30
Watches	120	127	131	136	142
Clocks	66	69	72	75	78
Appliances	15,470	15,351	15,917	16,186	17,047
Air Conditioner	2,515	2,428	2,528	2,559	2,689
Microwave Oven	657	688	713	734	764
Washer and Dryer	3,879	3,842	3,997	4,036	4,233
Refrigerator	5,792	5,693	5,872	6,018	6,357
Dishwasher	1,341	1,376	1,434	1,439	1,538
Range and Oven	1,286	1,324	1,372	1,400	1,466
Other Consumer	1,461	1,539	1,593	1,655	1,724
Automatic Garage Door Opener	435	464	485	510	537
Other Consumer Equipment, nec*	1,026	1,075	1,107	1,145	1,186

*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 24
Revenue Growth from North American Consumer Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Consumer	-0.3	-2.0	2.9	9.3	9.1
Audio	-0.5	-10.4	-3.7	3.3	7.0
Compact Disc Player	87.5	33.3	28.7	22.5	22.6
Radio	-5.0	-25.6	-22.7	0	11.5
Personal/Portable Stereo	3.2	8.9	21.6	4.5	6.1
Stereo Component	-0.5	-1.4	3.8	1.9	5.7
Musical Instrument	2.1	-4.2	0.7	4.3	3.5
Tape Recorder	-5.3	-22.2	3.0	9.3	3.7
Video	0.2	-0.2	0.1	4.8	9.4
VCR, VTR	8.9	0.4	1.8	2.1	52.9
Camcorder	14.4	-9.9	-7.9	6.8	41.9
Video Disk Player	0	0	NM	NM	NM
Color Televisions	-1.6	0.2	0.9	4.2	7.8
Cable/Satellite Set-Top Decoder	18.1	-3.0	-7.5	11.5	19.9
Personal Electronics	5.4	-5.6	2.0	1.9	3.5
Games (Systems and cartridges)	-18.2	-0.7	1.3	3.7	-11.1
Camera	0	-4.0	0.1	1.1	4.7
Watches	0	0	3.0	2.0	4.0
Clocks	22.6	-15.4	1.1	2.0	4.4
Appliances	-0.6	-2.9	4.6	12.8	9.3
Air Conditioner	4.8	-13.0	4.5	9.7	21.5
Microwave Oven	-14.2	-10.0	4.7	9.3	9.1
Washer and Dryer	1.7	-1.9	4.6	7.8	5.8
Refrigerator	-2.5	1.0	4.6	20.1	7.2
Dishwasher	0.2	-1.0	4.6	9.5	10.0
Range and Oven	-2.6	1.0	4.5	8.9	7.3
Other Consumer	0.2	2.3	7.9	6.0	7.6
Automatic Garage Door Opener	2.0	3.7	19.2	10.6	16.9
Other Consumer Equipment, nec*	-0.4	1.9	4.5	4.3	4.1

NM = Not meaningful

*nec = not elsewhere classified

Source: Dataquest (October 1995)

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Table 25
Revenue Growth from North American Consumer Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	3.8	1.5	5.2	3.7	4.1	3.7
Audio	5.9	6.6	5.0	5.7	6.1	5.9
Compact Disc Player	23.8	24.2	22.3	22.8	23.0	23.2
Radio	5.3	5.6	3.8	4.2	4.4	4.7
Personal/Portable Stereo	2.9	8.3	7.7	7.1	4.4	6.1
Stereo Component	5.1	5.6	3.8	4.5	4.8	4.8
Musical Instrument	4.5	4.8	3.0	3.4	3.6	3.9
Tape Recorder	5.5	5.0	3.2	3.7	3.8	4.2
Video	3.9	4.3	8.2	6.7	2.1	5.0
VCR, VTR	-30.8	109.5	31.0	30.5	15.5	23.4
Camcorder	40.9	41.9	43.2	42.9	7.2	34.4
Video Disk Player	NM	NM	NM	NM	NM	NM
Color Televisions	1.6	0.7	7.3	7.3	3.2	4.0
Cable/Satellite Set-Top Decoder	26.5	20.3	8.1	-3.5	-8.9	7.7
Personal Electronics	5.8	4.6	3.3	3.8	5.6	4.6
Games (Systems and cartridges)	25.0	-10.0	0	0	44.4	10.2
Camera	4.8	4.4	2.5	3.2	3.6	3.7
Watches	5.0	5.3	3.5	3.9	4.1	4.3
Clocks	5.4	5.7	3.9	4.3	4.5	4.7
Appliances	3.5	-0.8	3.7	1.7	5.3	2.7
Air Conditioner	2.1	-3.5	4.2	1.2	5.1	1.8
Microwave Oven	4.9	4.6	3.7	2.9	4.1	4.0
Washer and Dryer	4.2	-1.0	4.0	1.0	4.9	2.6
Refrigerator	3.3	-1.7	3.1	2.5	5.6	2.5
Dishwasher	4.4	2.6	4.2	0.4	6.9	3.7
Range and Oven	3.8	3.0	3.6	2.0	4.7	3.4
Other Consumer	4.8	5.3	3.5	3.9	4.1	4.3
Automatic Garage Door Opener	5.8	6.5	4.7	5.1	5.3	5.5
Other Consumer Equipment, nec*	4.3	4.8	3.0	3.4	3.6	3.8

NM = Not meaningful
*nec = not elsewhere classified
Source: Dataquest (October 1995)

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Table 26
Revenue from North American Military/Civil Aerospace Equipment Production, 1990-1994 (Millions of Dollars)

	1990	1991	1992	1993	1994
Military/Civil Aerospace	36,603	35,588	34,732	31,662	30,169
Radar/Sonar/Reconnaissance	15,032	14,835	14,774	13,195	12,601
Missile/Space	5,903	5,865	5,731	5,192	4,880
Navigation	5,669	4,798	4,936	4,771	4,628
Electronic Warfare	4,533	4,733	4,789	4,430	4,164
Aircraft Flight Systems	4,183	3,814	3,451	2,985	2,806
Command, Control	1,284	1,543	1,051	1,089	1,089

Source: Dataquest (October 1995)

Table 27
Revenue from North American Military/Civil Aerospace Equipment Production, 1995-1999 (Millions of Dollars)

	1995	1996	1997	1998	1999
Military/Civil Aerospace	29,621	29,920	30,397	31,016	31,714
Radar/Sonar/Reconnaissance	12,349	12,534	12,722	12,977	13,301
Missile/Space	4,734	4,687	4,710	4,734	4,757
Navigation	4,674	4,768	4,863	4,960	5,059
Electronic Warfare	3,998	3,958	4,017	4,117	4,220
Aircraft Flight Systems	2,750	2,819	2,889	2,990	3,095
Command, Control	1,116	1,155	1,196	1,238	1,281

Source: Dataquest (October 1995)

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Table 28
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Military/Civil Aerospace	4.9	-2.8	-2.4	-8.8	-4.7
Radar/Sonar/Reconnaissance	3.8	-1.3	-0.4	-10.7	-4.5
Missile/Space	7.4	-0.6	-2.3	-9.4	-6.0
Navigation	24.2	-15.4	2.9	-3.3	-3.0
Electronic Warfare	-10.0	4.4	1.2	-7.5	-6.0
Aircraft Flight Systems	3.5	-8.8	-9.5	-13.5	-6.0
Command, Control	1.1	20.2	-31.9	3.6	0

Source: Dataquest (October 1995)

Table 29
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	-1.8	1.0	1.6	2.0	2.3	1.0
Radar/Sonar/Reconnaissance	-2.0	1.5	1.5	2.0	2.5	1.1
Missile/Space	-3.0	-1.0	0.5	0.5	0.5	-0.5
Navigation	1.0	2.0	2.0	2.0	2.0	1.8
Electronic Warfare	-4.0	-1.0	1.5	2.5	2.5	0.3
Aircraft Flight Systems	-2.0	2.5	2.5	3.5	3.5	2.0
Command, Control	2.5	3.5	3.5	3.5	3.5	3.3

Source: Dataquest (October 1995)

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Table 30
Revenue from North American Transportation Equipment Production, 1990-1994
(Millions of Dollars)

	1990	1991	1992	1993	1994
Transportation	3,537	3,554	3,911	4,641	5,537
Entertainment	457	407	422	478	526
Vehicle/Body Control	329	303	337	378	433
Driver Information	649	649	681	771	881
Powertrain	1,646	1,590	1,722	1,964	2,259
Safety and Convenience	455	606	749	1,050	1,438

Source: Dataquest (October 1995)

Table 31
Revenue from North American Transportation Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Transportation	6,117	6,384	6,879	7,389	7,849
Entertainment	560	555	580	603	624
Vehicle/Body Control	459	475	502	545	591
Driver Information	948	978	1,050	1,142	1,252
Powertrain	2,440	2,486	2,612	2,748	2,884
Safety and Convenience	1,710	1,890	2,135	2,351	2,498

Source: Dataquest (October 1995)

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Table 32
Revenue Growth from North American Transportation Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Transportation	-9.3	0.5	10.0	18.7	19.3
Entertainment	-6.8	-11.0	3.8	13.3	10.0
Vehicle/Body Control	-8.5	-8.1	11.4	12.2	14.6
Driver Information	-8.6	0	5.0	13.2	14.3
Powertrain	-14.0	-3.4	8.3	14.1	15.0
Safety and Convenience	6.8	33.3	23.6	40.2	37.0

Source: Dataquest (October 1995)

Table 33
Revenue Growth from North American Transportation Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	10.5	4.4	7.8	7.4	6.2	7.2
Entertainment	6.5	-0.9	4.5	4.0	3.5	3.5
Vehicle/Body Control	6.0	3.5	5.7	8.6	8.4	6.4
Driver Information	7.6	3.2	7.4	8.8	9.6	7.3
Powertrain	8.0	1.9	5.1	5.2	4.9	5.0
Safety and Convenience	18.9	10.5	13.0	10.1	6.3	11.7

Source: Dataquest (October 1995)

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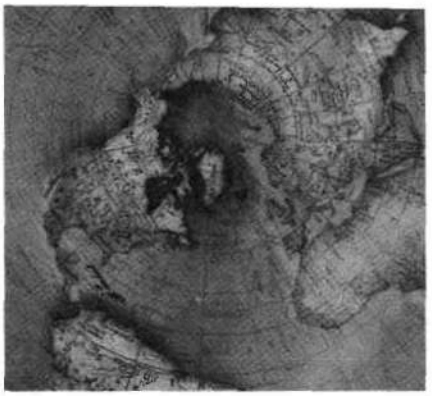
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Dataquest

Data Processing Application Markets



Market Trends

Program: Semiconductor Application Markets Worldwide
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Publication Date: September 25, 1995
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Chapter 1
Introduction and Methodology

This document is the third in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, communications (two), consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

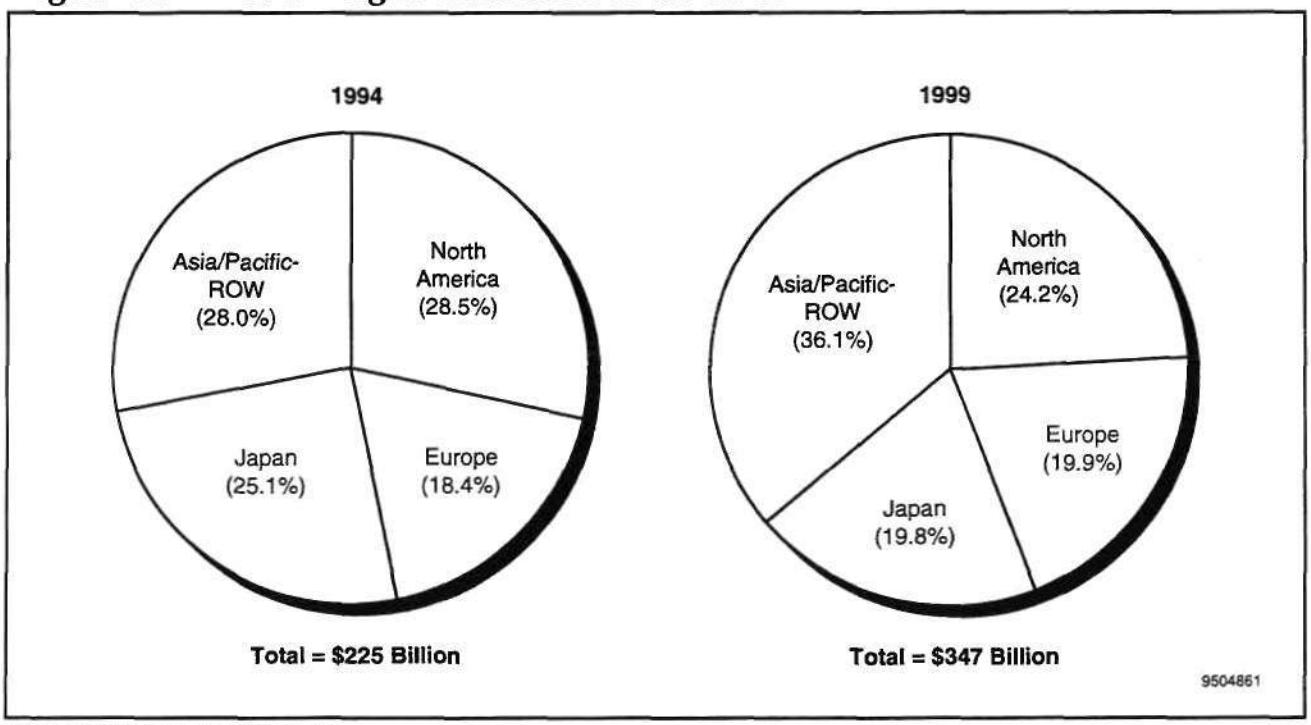
Project Analysts: Dale Ford and Greg Sheppard

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Chapter 2
The Worldwide Computer Market

Figure 2-1 shows the regional production of data processing equipment including: computers; peripherals such as rigid disk drives, CD-ROM drives, floppy disk drives, and add-in cards; printers; monitors and terminals; copiers; scanners; and smart cards. Figure 2-2 shows the global geographic markets for computer systems. North America is the largest producer of data processing equipment. However, moving toward 1999, the Asia/Pacific region will continue its explosive growth as it provides products for export markets and local regional consumption. The region will become the largest revenue producer of data processing equipment in 1995. Growth in computer market revenue in the Asia/Pacific-ROW region will parallel this growth as the region increases its consumption from almost 18 percent of the worldwide market to over 23 percent by 1999. The North American region will continue its strong consumption patterns, but will shrink in its share of the worldwide market from 42 percent to 36 percent.

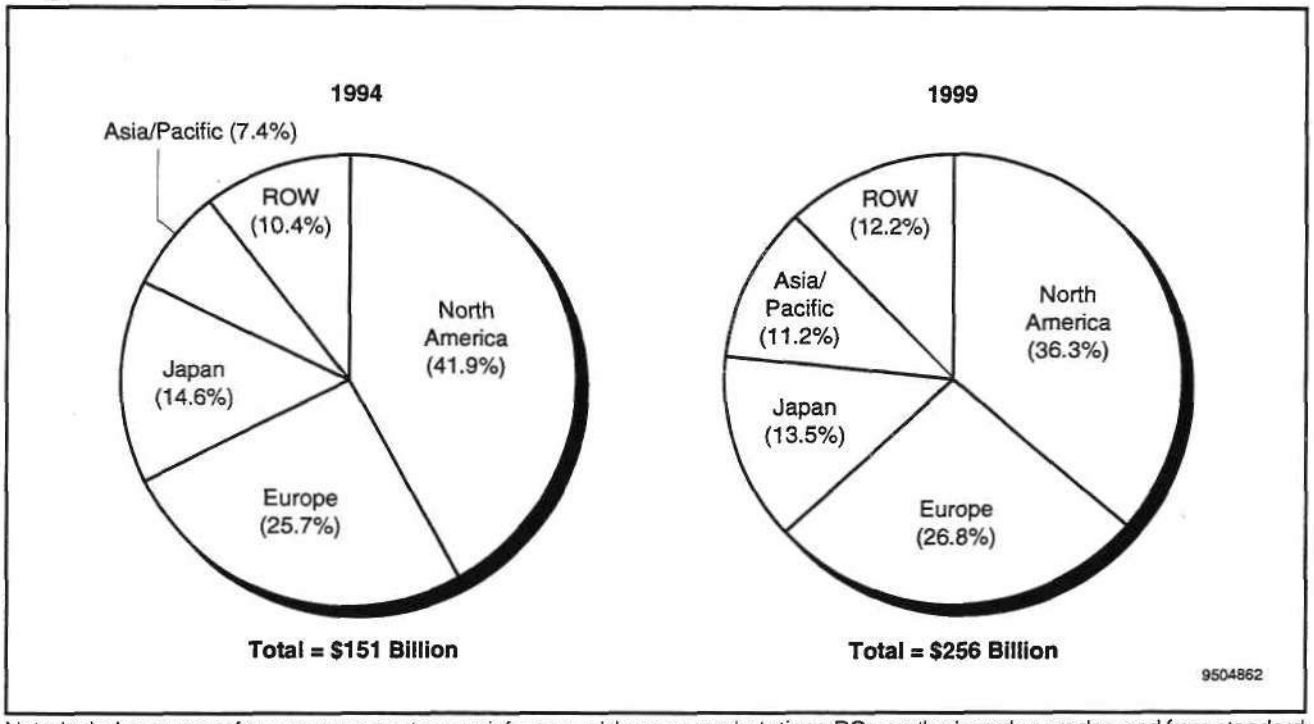
Figure 2-1
Regional Data Processing Production Revenue Share



Source: Dataquest (August 1995)

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Figure 2-2
Regional Computer Markets

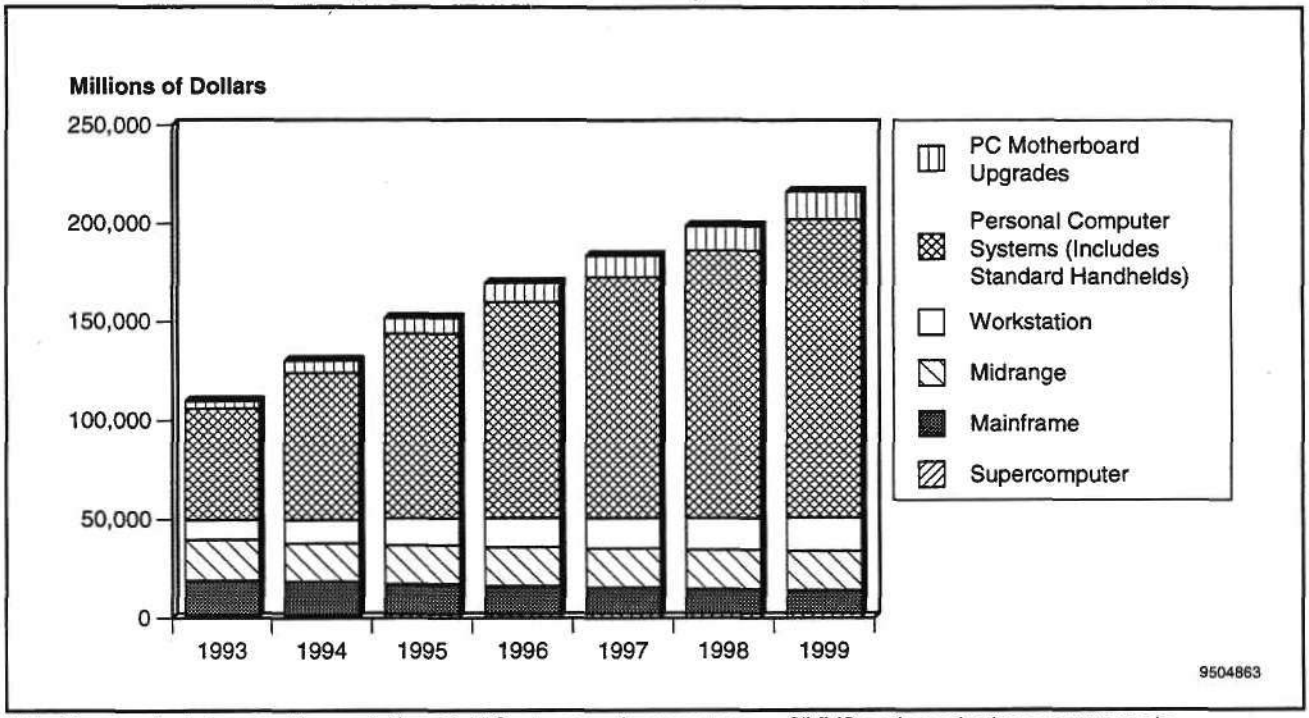


Note: Includes revenue from supercomputers, mainframes, midranges, workstations, PCs, motherboard upgrades, and from standard peripherals and memory upgrades installed up to the point of sale
Source: Dataquest (August 1995)

Figure 2-3 and Tables 2-1 through 2-3 present Dataquest's forecast for the worldwide computer systems markets. The overall market is predicted to grow at a healthy rate, with unit shipments growing at an 18.3 percent compound annual growth rate (CAGR) from 1994 to 1995 and revenue increasing by 10.7 percent in the same period. The downsizing trend will continue with personal computers and workstations exhibiting strong growth while mainframe and midrange revenue will remain flat or contract. Revenue growth for the new standard handheld devices such as personal digital assistants (PDAs) is expected to accelerate during 1998 and 1999 driving a 42 percent CAGR from 1994 to 1999.

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Figure 2-3
Worldwide Computer Systems Forecast, Factory Revenue (Millions of Dollars)



Note: Revenue includes graphics, serial/parallel I/O, storage adapters, memory SIMMS, and standard memory upgrade.
Excludes standard peripherals.
*Includes standard handhelds
Source: Dataquest (August 1995)

Table 2-1
Worldwide Computer Systems Forecast, Unit Shipments (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1998
Supercomputer	0.8	1.2	1.2	1.4	1.6	1.8	2.1	12.4
Mainframe	8.8	9.5	8.9	8.4	8.0	7.8	7.5	-4.6
Midrange	500.1	500.5	530.2	546.4	573.7	590.0	606.6	3.9
Workstation	623.0	772.0	857.0	902.0	945.0	1,033.0	1,085.0	7.0
Personal Computer Systems (Includes Standard Handhelds)	39,087.0	48,266.0	58,106.0	69,487.0	80,538.0	94,955.0	112,245.0	18.4
PC Motherboard Upgrades	2,759.0	4,404.0	5,476.0	6,738.0	7,992.0	9,582.0	11,190.0	20.5
Total	42,978.8	53,953.2	64,979.3	77,683.2	90,058.3	106,169.6	125,136.2	18.3

Source: Dataquest (September 1995)

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Table 2-2
Worldwide Computer Systems Forecast, Factory Revenue* (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1998
Supercomputer	1,855	1,930	2,005	2,087	2,181	2,268	2,339	3.9
Mainframe	17,310	16,606	15,360	14,270	13,342	12,508	11,758	-6.7
Midrange	20,591	19,329	19,523	19,659	19,777	19,856	19,956	0.6
Workstation	9,996	11,945	13,736	14,732	15,469	16,165	16,811	7.1
Personal Computer Systems (Includes Standard Handhelds)	56,323	74,379	93,253	109,323	121,989	135,493	151,359	15.3
PC Motherboard Upgrades	3,449	5,813	7,672	9,359	10,653	12,236	13,887	19.0
Total	109,524	130,002	151,549	169,429	183,411	198,527	216,109	10.7

Includes graphics, serial/parallel I/O, storage adapters, memory SIMMS, and standard memory upgrade; excludes standard peripherals
Source: Dataquest (August 1995)

Table 2-3
Worldwide Computer Systems Forecast, Average Selling Price* (U.S. Dollars)

Product Type	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1998
Supercomputer ($K)	2,199	1,677	1,617	1,518	1,388	1,251	1,132	-7.6
Mainframe ($K)	1,964	1,746	1,730	1,694	1,666	1,611	1,566	-2.2
Midrange ($)	40,560	38,045	36,273	35,443	33,959	33,153	32,407	-3.2
Workstation ($)	16,045	15,473	16,028	16,333	16,369	15,649	15,494	0.0
Personal Computer Systems (Includes Standard Handhelds) ($)	1,441	1,541	1,605	1,573	1,515	1,427	1,348	-2.6
PC Motherboard Upgrades ($)	1,250	1,320	1,401	1,389	1,333	1,277	1,241	-1.2

Includes graphics, serial/parallel I/O, storage adapters, memory SIMMS, and standard memory upgrade; excludes standard peripherals
Source: Dataquest (August 1995)

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Chapter 3
Personal Computer and Workstation Application Markets

Market and Production Trends

Personal Computers

Market and production trends in PCs are as follows:

- Although notebook and subnotebook computers have enjoyed strong growth, desktop systems will continue to dominate the computing platform because of their lower manufacturing costs, the ability to handle robust configurations with large amounts of storage, and their role in offering the fastest and latest computing technologies.
- Notebooks have enjoyed solid unit and revenue growth because of their ability to replicate desktop environments with features such as Windows applications, the introduction of more powerful microprocessors such as the Pentium, and larger hard drive capacities.
- Ultraportable and Notepad shipments continue to surge with popular offerings from Apple, Olivetti, Gateway 2000, Hewlett-Packard, and others. This market is expected to exceed notebook shipments worldwide by the end of 1998.
- Shipments of laptops and transportable units continue to dwindle as smaller notebook systems cause them to phase out.
- In the world of mobile computing, handheld devices such as PDAs have commanded incredible attention as they have captured the imagination of consumers and manufacturers alike. Dataquest has defined two categories for these handheld devices:
  - Expandable organizers: These are computers that typically measure 3.0 x 6.0 x 0.75 inches and weigh less than a pound. They are distinguished by the capability to have the user add applications and memory, and the fact that expansion is proprietary to a particular device or family. The operating systems typically are proprietary. The market for these devices is expected to peak at more than 0.5 million unit shipments in 1995 and then slowly shrink to fewer than 0.4 million by 1999.
  - Standard handheld computers: These devices typically measure 4 x 7 x 1 inches and weigh about a pound. They are distinguished from expandable organizers by their adherence to hardware and software compatibility standards. The operating systems are open and licensed, and application development and memory expansion are open to third-party developers and may be distributed in a standard format (such as PCMCIA). PDAs fall into this category.

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- Strong growth in the worldwide home PC market will continue across all regions. This sector is projected to account for nearly half of all PC shipments in 1998 in the United States, the most mature market.
- Microsoft's new mainstream operating system "Windows 95" was launched in the second half of 1995 with actual product sales beginning on August 24. Its multitasking nature will have an impact on hardware such as SCSI controllers. It also will raise the demand for memory, forcing users to upgrade to 12MB or more.
- Emerging markets and regions will account for a sharply increased proportion of shipments by 1998.
- The multimedia-ready PC market continued its torrid growth in 1994. Shipments of complete multimedia systems grew fourfold from 1993 to 1994, reaching 10.3 million shipments. Dataquest expects sales of complete multimedia systems to continue to boom during the next five years.
- Major PC manufacturers will continue to place a strong emphasis on the branding of PCs.
- Manufacturing strategies are dictated by economies of scale with strong influence from free trade zones, the availability of components, and the quality and price of labor. The trend is toward producing close to the end market or at least final configuration being executed on demand close to the end market.
- There is a clear trend toward using turnkey or contracted manufacturing sources such as Intel, SCI, and Solectron.

Workstations

Market and production trends in workstations are as follows:

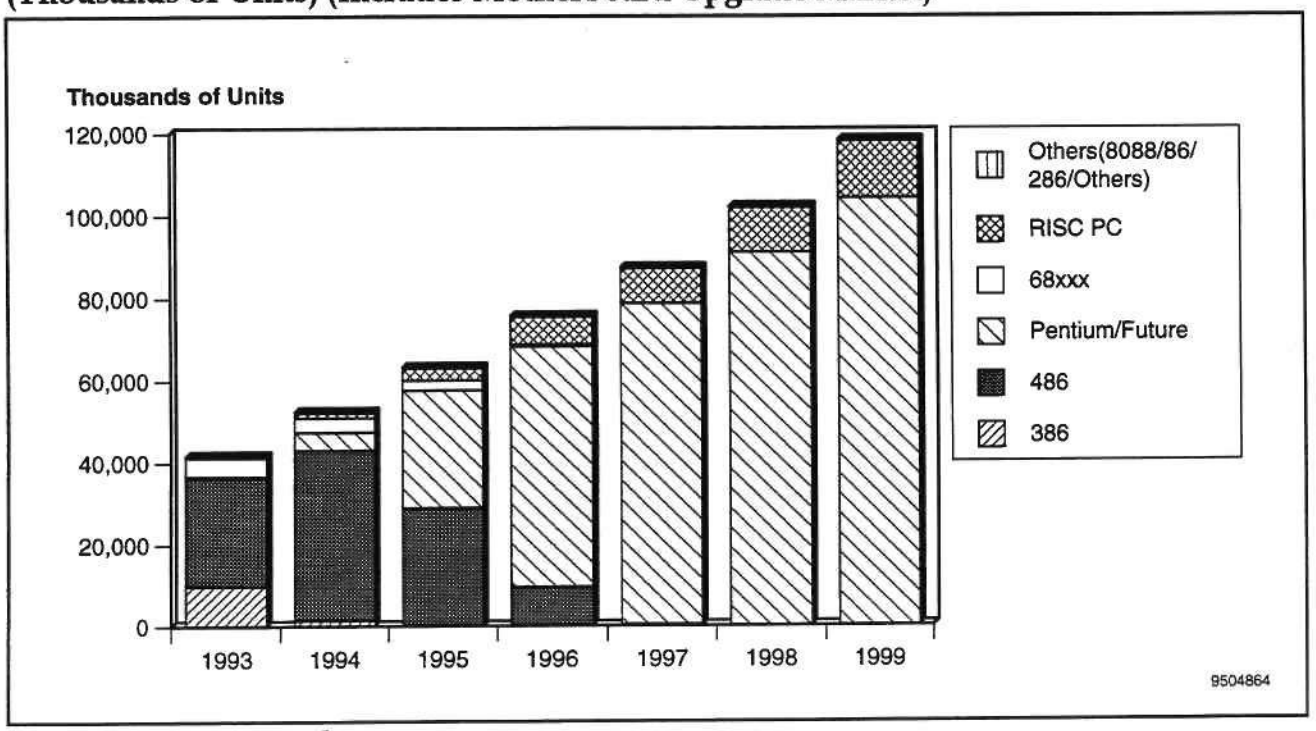
- Entry-level workstation growth will be limited by the emergence of RISC PCs and Pentium-class PC workstations with traditional workstation features and performance but at a lower cost structure. Entry-level workstations will advance in features and performance to differentiate from and compete with PC workstations.
- Early RISC PCs primarily will run the same UNIX operating systems as the full custom-designed workstations from the same microprocessor architecture.
- Windows NT is increasing penetration in 1995 particularly and continue to grow through 1998.
- Among the traditional workstations (entry-level, midrange, and super), superworkstations will grow at the fastest rate because of the increasing demand for sophisticated 3-D graphics, downsizing computational tasks from supercomputers, and continuing deployment as servers. These systems will continue to be heavily loaded with memory and disk capacity to match their price point in the market.

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- Average sales prices of traditional workstations will stay fairly constant because of two factors: the demand for lower prices will be satisfied by PC workstations, and the ratio of higher-priced superworkstations will increase.

Figure 3-1 and Tables 3-1 to 3-3 present Dataquest's worldwide PC and workstation market forecasts. Figures 3-2 through 3-4 show the regional variation in markets and production from 1994 to 1999. Figure 3-5 illustrates the North American PC and workstation motherboard production forecast given in Table 3-4.

Figure 3-1
Worldwide Personal Computer Shipments by Microprocessor Type (Thousands of Units) (Includes Motherboard Upgrade Market)



Source: Dataquest (August 1995)

Table 3-1
Worldwide Personal Computer Market by Product Type*

Product Type	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Desktop/Deskside								
Units (K)	32,712	39,219	46,623	54,056	60,865	70,221	81,419	15.7
ASP ($K)	1.80	1.87	1.95	1.90	1.84	1.79	1.74	-1.4
Factory Revenue ($M)	59,039	73,297	91,012	102,579	112,204	125,847	141,916	14.1
Transportable								
Units (K)	76	122	39	32	18	16	15	-34.2
ASP ($K)	4.11	6.72	6.69	6.07	5.38	4.92	4.51	-7.7
Factory Revenue ($M)	312	817	262	194	97	79	68	-39.2

(Continued)

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Table 3-1 (Continued)
Worldwide Personal Computer Market by Product Type*

Product Type	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Laptop								
Units (K)	170	47	13	0	0	0	0	-100.0
ASP ($K)	3.90	5.04	4.98	0	0	0	0	-100.0
Factory Revenue ($M)	662	237	63	0	0	0	0	-100.0
Notebook/Tablet								
Units (K)	5,477	7,489	9,414	11,559	12,379	13,077	12,780	11.3
ASP ($K)	2.35	2.49	2.52	2.36	2.32	2.18	2.06	-3.7
Factory Revenue ($M)	12,851	18,638	23,746	27,256	28,696	28,554	26,369	7.2
Ultraportable/Notepad								
Units (K)	417	1,007	1,479	3,065	6,051	9,041	12,786	66.3
ASP ($K)	1.67	1.83	1.78	1.79	1.77	1.70	1.64	-2.3
Factory Revenue ($M)	697	1,846	2,639	5,473	10,727	15,337	20,922	62.5
Standard Handheld (Palmtop)								
Units (K)	237	390	542	775	1,225	2,600	5,245	68.2
ASP ($K)	0.57	0.82	0.48	0.46	0.41	0.35	0.35	-15.7
Factory Revenue ($M)	135	318	258	357	502	913	1,842	42.1
Motherboard Upgrades								
Units (K)	2,759	4,404	5,476	6,738	7,992	9,582	11,190	20.5
ASP ($K)	1.25	1.32	1.40	1.39	1.33	1.28	1.24	-1.2
Factory Revenue ($M)	3,449	5,814	7,673	9,362	10,655	12,238	13,887	19.0
Total PC (Including Handheld and Motherboard Upgrade)								
Units (K)	41,847	52,677	63,586	76,225	88,530	104,537	123,435	18.6
ASP ($K)	1.9	2.0	2.0	2.0	1.9	1.8	1.8	-2.2
Factory Revenue ($M)	77,144	100,968	125,653	145,222	162,881	182,969	205,004	15.2

*ASP and factory revenue include standard peripherals and memory upgrades installed up to the point of sale.
Source: Dataquest (September 1995)

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Table 3-2
Worldwide Personal Computer Shipments by Microprocessor Type (Thousands of Units) (Includes Motherboard Upgrade Market)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1998
386	9,873	1,432	47	0	0	0	0	-100.0
486	26,619	41,693	28,923	9,667	416	0	0	-100.0
Pentium/Future	227	4,451	28,746	58,681	78,342	91,183	104,279	87.9
68xxx	4,609	3,503	2,461	471	158	0	0	-100.0
RISC PC	76	1,161	2,863	6,631	8,389	10,754	13,911	64.3
Others (8088/86/286/Others)	205	40	0	0	0	0	0	-100.0
Total	41,609	52,280	63,040	75,450	87,305	101,937	118,190	17.7

*Does not include standard handhelds (palmtops)
Source: Dataquest (September 1995)

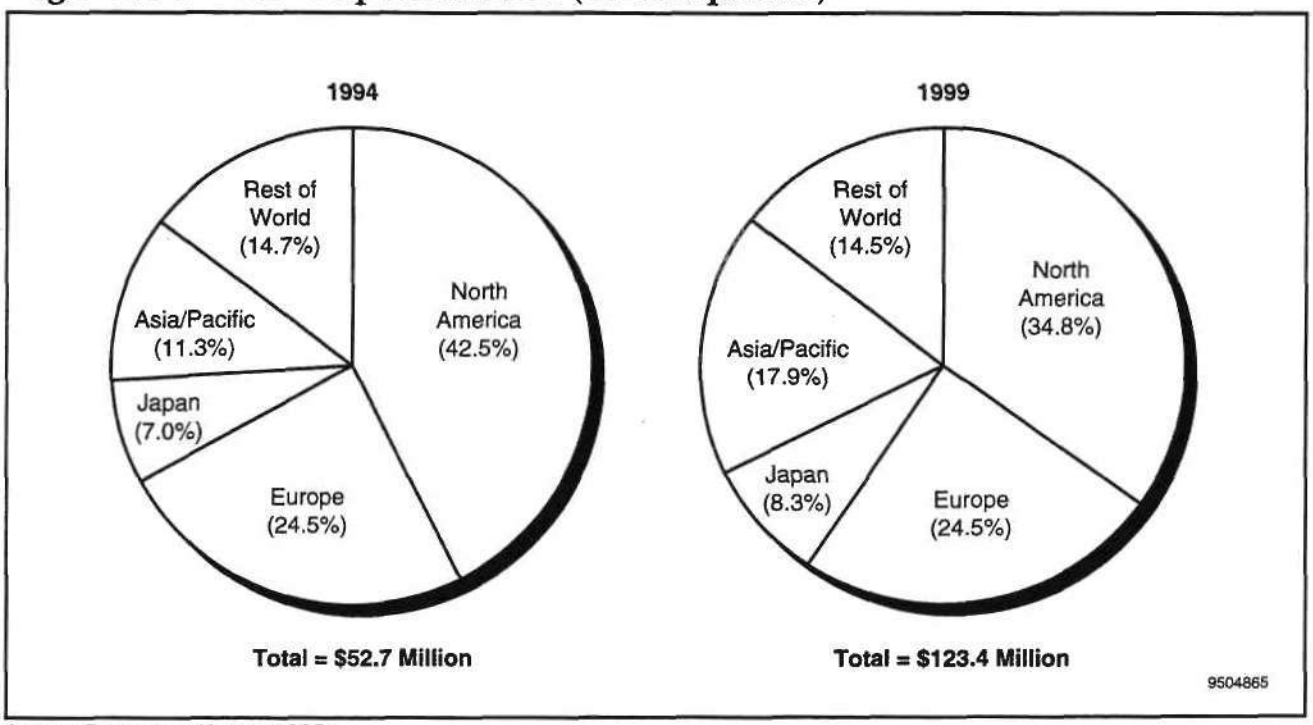
Table 3-3
Worldwide Personal Computer Revenue by Microprocessor Type (Millions of Dollars) (Includes Motherboard Upgrade Market, Excludes Standard Handhelds)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
386	13,617	1,453	40	0	0	0	0	-100.0
486	54,022	76,429	53,261	14,388	564	0	0	-100.0
Pentium/Future	1,075	13,913	62,747	118,429	148,015	164,845	181,489	67.1
68xxx	8,081	5,872	3,736	592	181	0	0	-100.0
RISC PC	74	2,938	5,604	11,458	13,620	17,210	21,671	49.1
Others (8088/86/286/Others)	140	22	0	0	0	0	0	-100.0
Total	77,009	100,627	125,388	144,866	162,380	182,055	203,160	15.1

*Factory revenue includes standard peripherals and memory upgrades installed up to the point of sale. Excludes standard handhelds (palmtops).
Source: Dataquest (September 1995)

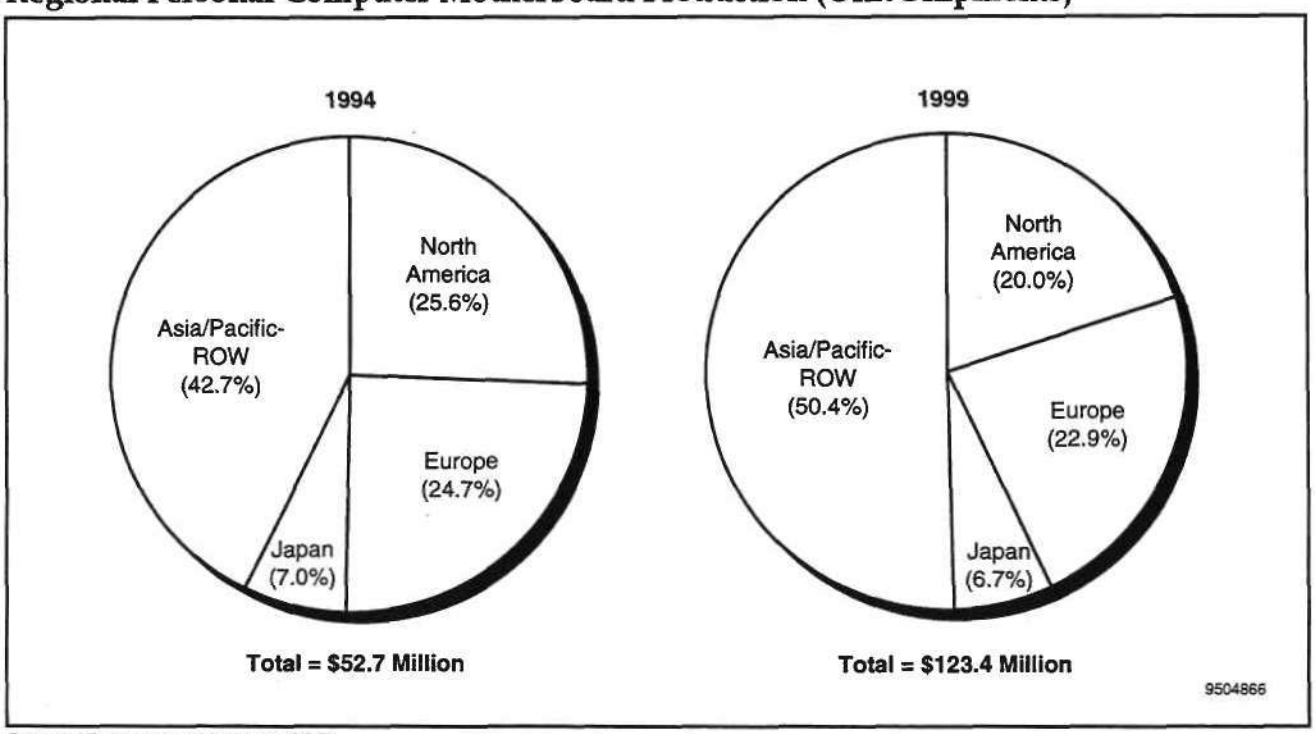
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Figure 3-2
Regional Personal Computer Markets (Unit Shipments)



Source: Dataquest (August 1995)

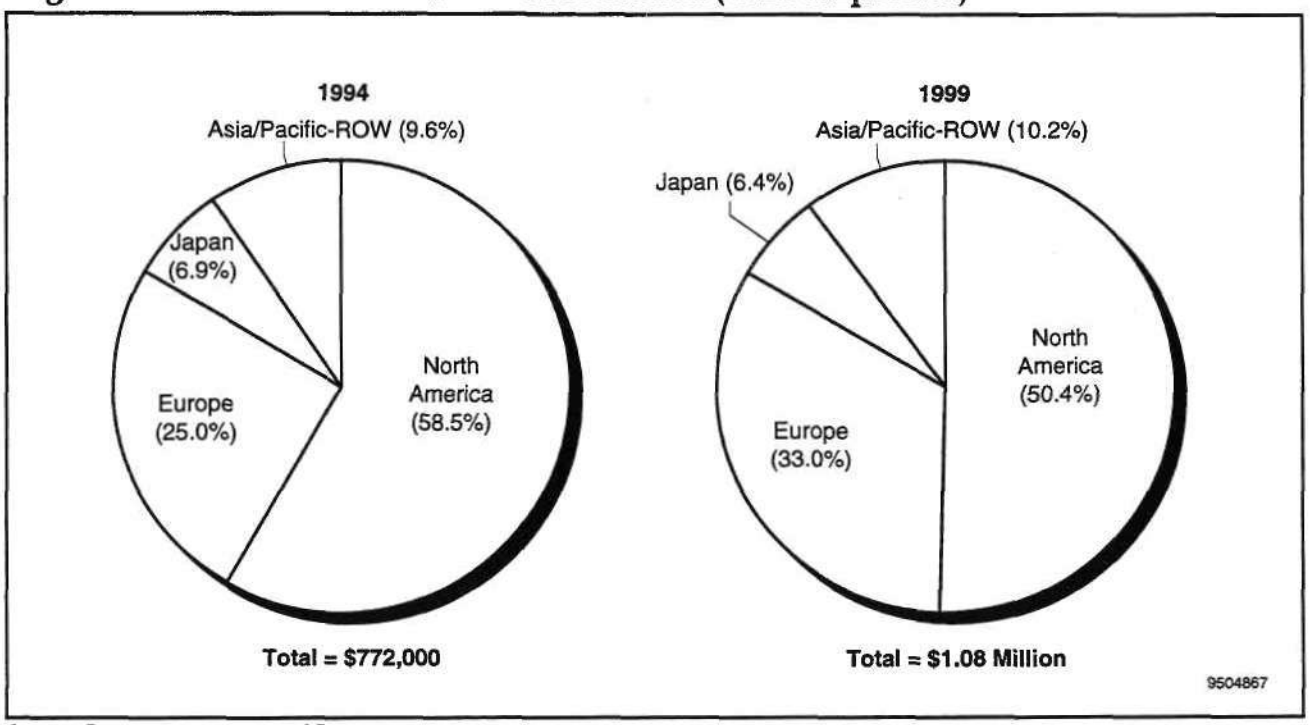
Figure 3-3
Regional Personal Computer Motherboard Production (Unit Shipments)



Source: Dataquest (August 1995)

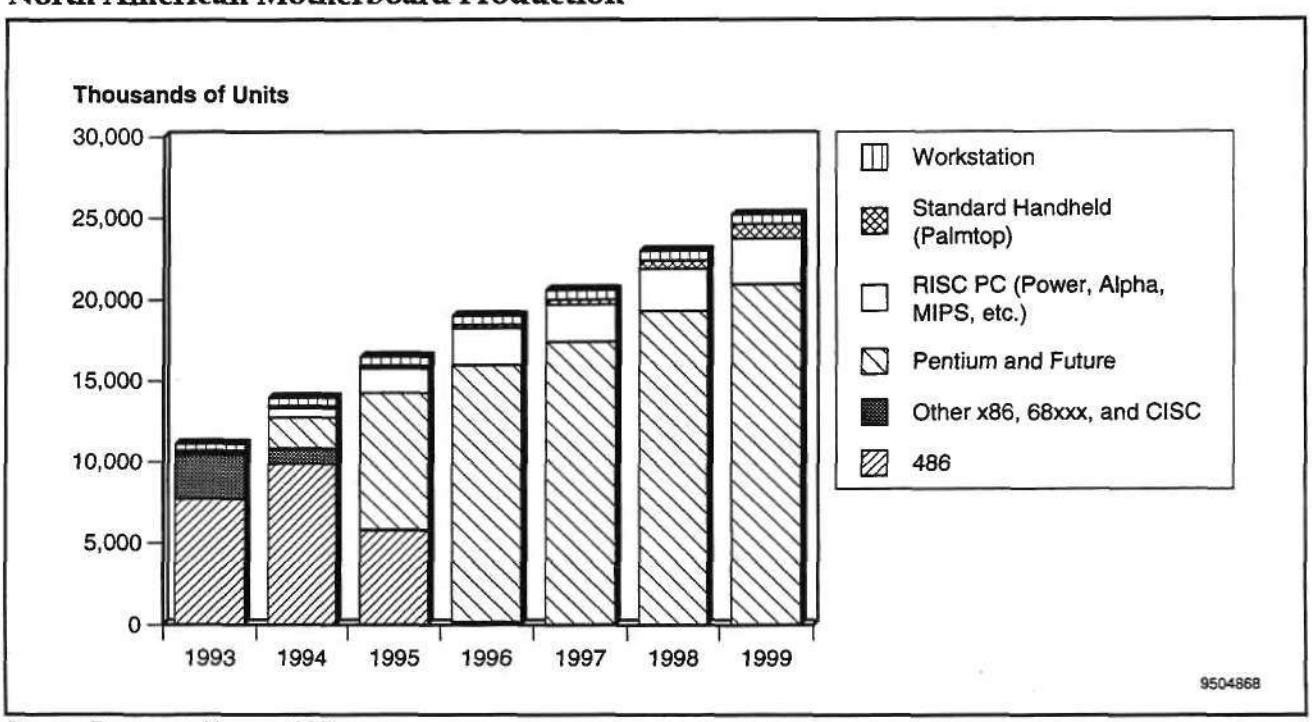
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Figure 3-4
Regional Workstation Motherboard Production (Unit Shipments)



Source: Dataquest (August 1995)

Figure 3-5
North American Motherboard Production



Source: Dataquest (August 1995)

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Table 3-4
North American Motherboard Production by Microprocessor Type (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
486	7,725	9,883	5,767	199	0	0	0	-100.0
Other x86, 68xxx, and CISC	2,765	984	74	0	0	0	0	-100.0
Pentium/Future	127	1,905	8,443	15,813	17,441	19,348	20,994	61.7
RISC PC (Power, Alpha, MIPS, Etc.)	0	568	1,510	2,261	2,300	2,568	2,788	37.5
Standard Handheld (Palmtop)	130	160	184	229	303	511	888	40.9
Workstation	347	452	498	509	552	563	547	3.9
Total	11,090	13,948	16,474	19,010	20,593	22,988	25,214	12.6

Source: Dataquest (September 1995)

OEMs

Tables 3-5 through 3-8 list the key OEMs ranked by revenue and unit shipment market share. For the first time in more than a decade, a company other than IBM or Apple Computer leads the world in PC shipments in 1994. Compaq Computer not only leapfrogged the perennial PC shipment leaders, but did so in dramatic fashion by shipping 847,000 more PCs than any other manufacturer. Unable to continue grabbing market share away from the clone makers in 1994, the large PC suppliers were forced to turn their guns on each other, with Compaq and Packard Bell winning the battle. They were the only companys in the top five to increase their share of the market in 1994. In the workstation market, Sun Microsystems lost market share to Hewlett-Packard and IBM, which experienced shipment growth rates of 30 to 47 percent, respectively.

Table 3-5
Personal Computers Worldwide Revenue Market Share (Percentage)*

	1993	1994
Compaq	9.2	10.5
IBM	11.8	8.8
Apple	10.1	8.5
NEC	5.3	5.5
Packard Bell	1.7	3.9
Toshiba	2.3	3.7
Dell	3.6	3.3
Gateway 2000	2.2	2.7
Hewlett-Packard	1.9	2.7
Acer	1.2	2.3
Other Vendors	50.7	48.2

*Does not include motherboard upgrade revenue
Source: Dataquest (September 1995)

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Table 3-6
Personal Computers Worldwide Unit Market Share (Percentage)*

	1993	1994
Compaq	8.05	10.03
IBM	10.84	8.26
Apple	9.43	8.26
Packard Bell	2.94	5.16
NEC	4.16	4.05
AST Research	2.68	2.72
Dell	3.02	2.68
Hewlett-Packard	1.75	2.66
Acer	1.41	2.63
Toshiba	1.73	2.53
Other Vendors	53.99	51.02

*Does not include motherboard upgrade shipments
Source: Dataquest (September 1995)

Table 3-7
Workstations Worldwide Revenue Market Share (Percentage)

	1993	1994
Sun Microsystems	30.66	28.01
Hewlett-Packard	22.66	21.49
IBM	15.39	18.03
Silicon Graphics	9.37	10.48
Digital Equipment	9.49	9.91
Other Vendors	12.43	12.08

Source: Dataquest (August 1995)

Table 3-8
Workstations Worldwide Unit Market Share (Percentage)

	1993	1994
Sun Microsystems	37.98	36.51
Hewlett-Packard	19.03	19.97
IBM	10.99	11.95
Digital Equipment	10.81	10.8
Silicon Graphics	5.95	6.01
Other Vendors	15.24	14.76

Source: Dataquest (August 1995)

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Systems Technology and Architecture Trends

The technology road maps of PCs and workstations principally are driven by the twin factors of economy and improved end-user features. PC makers typically try to give the buyer more features with each new product generation while maintaining price points. Workstation makers are known more for emphasizing performance and other features, although the low end of the workstation market is attempting to be competitive with the high end of the PC range. Some specific trends are listed in the following sections.

Personal Computers

Trends in PCs are as follows:

- Desktop power demand will come from servicing graphical user interface (GUI) and WYSIWYG-oriented applications including processing (compressing and decompressing); store, forward, and read multimedia (OLE enabled); and real-time multimedia such as desktop videoconferencing. Networking support increasingly will require faster servicing as transfer rates soar (for example, toward 100 Mbps over Ethernet) and the size and frequency of transferred files and e-mail soar as well.
- Expect continued proliferation of variations on the Pentium theme as Intel, Advanced Micro Devices, Cyrix, and NexGen cover the entire price/performance/power consumption spectrum.
- The Power PC alliance will continue to be a major element in Apple, IBM, and other units.
- The backplane bus, long pointed out as one of the bottlenecks limiting PC performance, will be supplemented by the local bus with eventual domination by the PCI standard. ISA, EISA, and other buses will remain on most systems for some time because of the vast bulk of add-in cards based on these buses.
- Plug-and-play PCs, with support from major players such as Microsoft, Intel, Compaq, AMD, and others, will be a significant feature in the drive to make PCs more user-friendly.
- The "green" PC as stimulated by the Energy Star program and similar requirements coming out of Europe should become a viable selling point for future PCs.
- The SCSI interface has had a short-term upswing in use for accessing larger disk capacities, disk arrays, CD-ROM drives, and other peripherals such as scanners. Because SCSI is more expensive to implement, IDE and its enhanced upgrade most likely will remain the dominant RDD interface.
- Serial and parallel I/O have remained fairly constant, but now new technologies such as 1394/Firewire and Access.bus are vying to displace those trusted standbys.

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- The universal serial bus (USB) standard was rolled out with strong support from Intel, Microsoft, and Compaq at the Windows Hardware Engineering Conference '95 (WINHEC '95). This local bus for the PC will provide a common standard for communicating among PCs, modems, scanners, joysticks, keyboards, mice, monitors, and printers.
- The worldwide PC Card market started to take off in 1994 with 3.4 million unit shipments. Customers and vendors have started to realize how PC Cards can help mobile workers be more productive by enabling them to simply and quickly add new capabilities to their mobile devices. While modem cards were by far the largest market in terms of unit shipments in 1994, vendors will need to incorporate multiple functions in PC Card technology in order to stay viable in the long term.
- A key trend in mobile technology will be the purchase of skeleton systems by users that are then enhanced with shrink-wrapped PCMCIA RDDs, memory cards, and communications features.
- Other key trends in mobile computing will include commercialized low-power-consuming components, standardization of operating voltage for circuits and components at 3V/3.3V, development of a highly efficient and high-capacity battery, and effective handwriting/voice recognition.

Table 3-9 highlights projected trends in PC technology. Figure 3-6 shows areas that offer opportunities for enhancement.

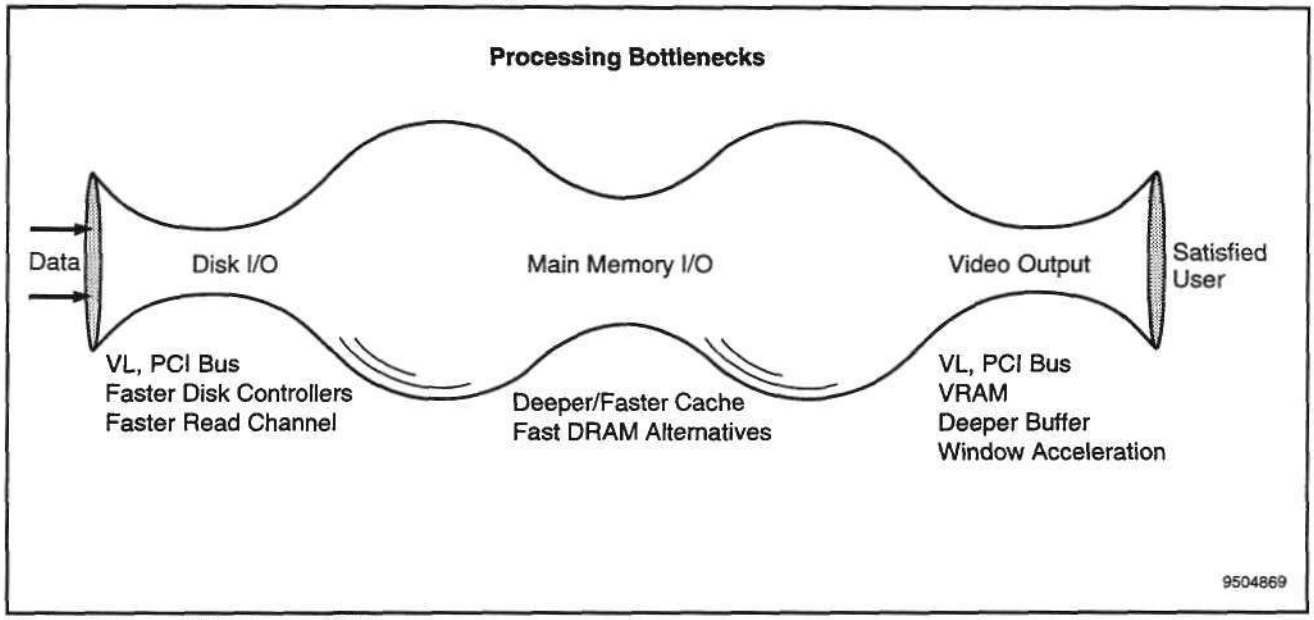
Table 3-9
The Evolving PC

Standard Features	1993	1995	1997	Trend
Main Memory (MB)	4-6	8-12	16-20	To wider organizations, sub-70ns, and cache replacement. Toward EDO Architecture
CPU*	386 and 486 (SX/DX)/68K	486DXx/Pentium PowerPC	Pentium/PowerPC/P6	Toward more power and higher price/performance ratio
Cache (K)	64/128	128/256	256	Possible integration with MPU or Core Logic
Bus*	ISA et al.	ISA with VL/PCI	ISA with PCI	PCI dominant and higher-speed versions of PCI
Video	VGA/Mac (1/4MB buffer)	32/64-bit Accelerated GUI (1MB buffer)	64-bit Accelerated GUI (1MB buffer)	Addition of digital video and 3-D features
		Accelerated/Mac	Motion Video Acceleration	
Storage	IDE/SCSI	EIDE/SCSI	EIDE/SCSI	IDE/enhanced IDE will dominate
Local I/O	RS-232/422	RS-232/422	RS-232/422/USB	Toward USB, possible entrance of 1394/Access.bus

*And corresponding core logic
Source: Dataquest (September 1995)

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Figure 3-6
PC Performance Enhancement Opportunities



Source: Dataquest (September 1995)

Workstations

Trends in workstations are as follows:

- Workstations are much like other desktop computers and contain a cached CPU, most often a high-performance RISC design, a large DRAM main memory, a hard disk drive, various I/O (networking, keyboard, SCSI, and serial ports), and high-resolution video. The major differences from a PC are the performance of the CPU, the quality of the graphics interface, the size of main memory and hard disk, and the use of the UNIX operating system.
- There is an increasing trend by manufacturers to offer higher-capacity external storage subsystems with gigabytes capacities becoming more common. The expanded capacity enhances the workstation's capability to be used as a server on the network.
- There is an increasing shift toward RISC CPUs, wider use of cache SRAMs, and possibly lower use of dedicated graphics hardware.
- CPUs that are continually getting less expensive and newer 64-bit architectures that are well-suited for migrating existing 64-bit applications are likely to accelerate the advent of greater parallelism, either through symmetric multiprocessing, shared memory clusters of workstation farms, or massively parallel architectures.
- Tables 3-10 through 3-14 provide forecasts for key PC and workstation technologies. Figures 3-7 through 3-11 provide block diagrams for generic Pentium, Power Macintosh, generic Notebook, Apple Newton, and Indigo Workstation systems.

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Table 3-10
Worldwide PC Bus Requirements (Percentage of Total or Category)

	1993	1994	1995	1996	1997	1998	1999
AT/ISA Total	68	70	70	67	65	64	64
ISA Only	18	6	1	0	0	0	0
With VL	81	75	50	23	5	1	1
With PCI	1	19	49	77	95	99	99
EISA Total	3	3	3	3	3	2	2
EISA Only	79	23	8	4	2	0	0
With PCI	21	77	92	96	98	100	100
MCA Total	3	2	1	1	1	0	0
Proprietary/Specialty	10	8	7	8	8	9	10
Proprietary/Specialty Only	100	100	95	92	90	85	85
With PCI	0	0	5	8	10	15	15
No Bus (Notebook, Etc.)	16	18	19	21	23	24	24
Total	100	100	100	100	100	100	100

Source: Dataquest (August 1995)

Table 3-11
Worldwide Penetration of PCMCIA/PC Card Slot Forecast (Thousands of Slots)

	1993	1994	1995	1996	1997	1998	1999
With One or More Type II Slots	4,869	10,389	14,545	16,751	19,173	21,571	23,813
With One or More Type III Slots	1,889	4,040	5,333	5,973	6,272	5,958	5,482

Source: Dataquest (August 1995)

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Table 3-12
Worldwide PC and Workstation (Host) Storage Interface Requirement (Percentage of Category)

	1993	1994	1995	1996	1997	1998	1999
x86/68xxx/Others							
IDE/AT	84	85	86	88	90	92	94
SCSI (I/II/III)	16	15	14	12	10	8	6
FC-AL/SSA/1394	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100
Pentium and Future PC							
IDE/AT	10	76	85	86	85	83	80
SCSI (I/II/III)	90	24	15	13	13	12	10
FC-AL/SSA/1394	0	0	0	1	2	5	10
Total	100	100	100	100	100	100	100
RISC PC							
IDE/AT	2	10	14	16	17	17	17
SCSI (I/II/III)	98	90	86	82	79	75	69
FC-AL/SSA/1394	0	0	0	2	4	8	14
Total	100	100	100	100	100	100	100
Workstation							
IDE/AT	0	0	0	0	0	0	0
SCSI (I/II/III)	95	97	98	94	89	75	65
FC-AL/SSA/1394	0	0	0	5	11	25	35
Others	5	3	2	1	0	0	0
Total	100	100	100	100	100	100	100

Source: Dataquest (August 1995)

Table 3-13
Worldwide PC Graphics Standard Penetration (Motherboard-Based or Add-In)

	1993	1994	1995	1996	1997	1998	1999
VGA (Percentage of Total)	56	28	5	1	0	0	0
Accelerated VGA (Percentage of Total)	41	66	77	45	14	2	0
Accelerated VGA + Motion Video and Future Features (Percentage of Total)	0	3	18	54	86	98	100
Others (XGA, pre-VGA)	3	3	0	0	0	0	0

Source: Dataquest (August 1995)

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Table 3-14
Worldwide Embedded Communications and Multimedia PCs and Workstations

	1993	1994	1995	1996	1997	1998	1999
PC							
Modem (Percentage of Total)	1.5	1.6	1.8	2.0	2.3	2.5	2.8
LAN (Percentage of Total)	1	2	3	6	10	17	26
USB (Percentage of Total)	-	-	-	8	35	94	100
Sound I/O (Percentage of Total)	14	16	19	25	34	45	56
Graphics (Percentage of Total)	44	46	50	55	57	60	63
MPEG Decoder (%)	-	-	-	4.3	3.5	2.8	
General-Purpose DSP (%)	0.1	0.5	1.0	2.0	3.0	4.0	
Workstation							
Modem (Percentage of Total)	NA	NA	NA	NA	NA	NA	NA
LAN (Percentage of Total)	100	100	100	100	100	100	100
Sound I/O (Percentage of Total)	55	75	95	100	100	100	100
Graphics (Percentage of Total)	85	85	85	85	85	85	85
General-Purpose DSP (%)	4	5	5	5	5	5	5

NA = Not applicable
Source: Dataquest (August 1995)

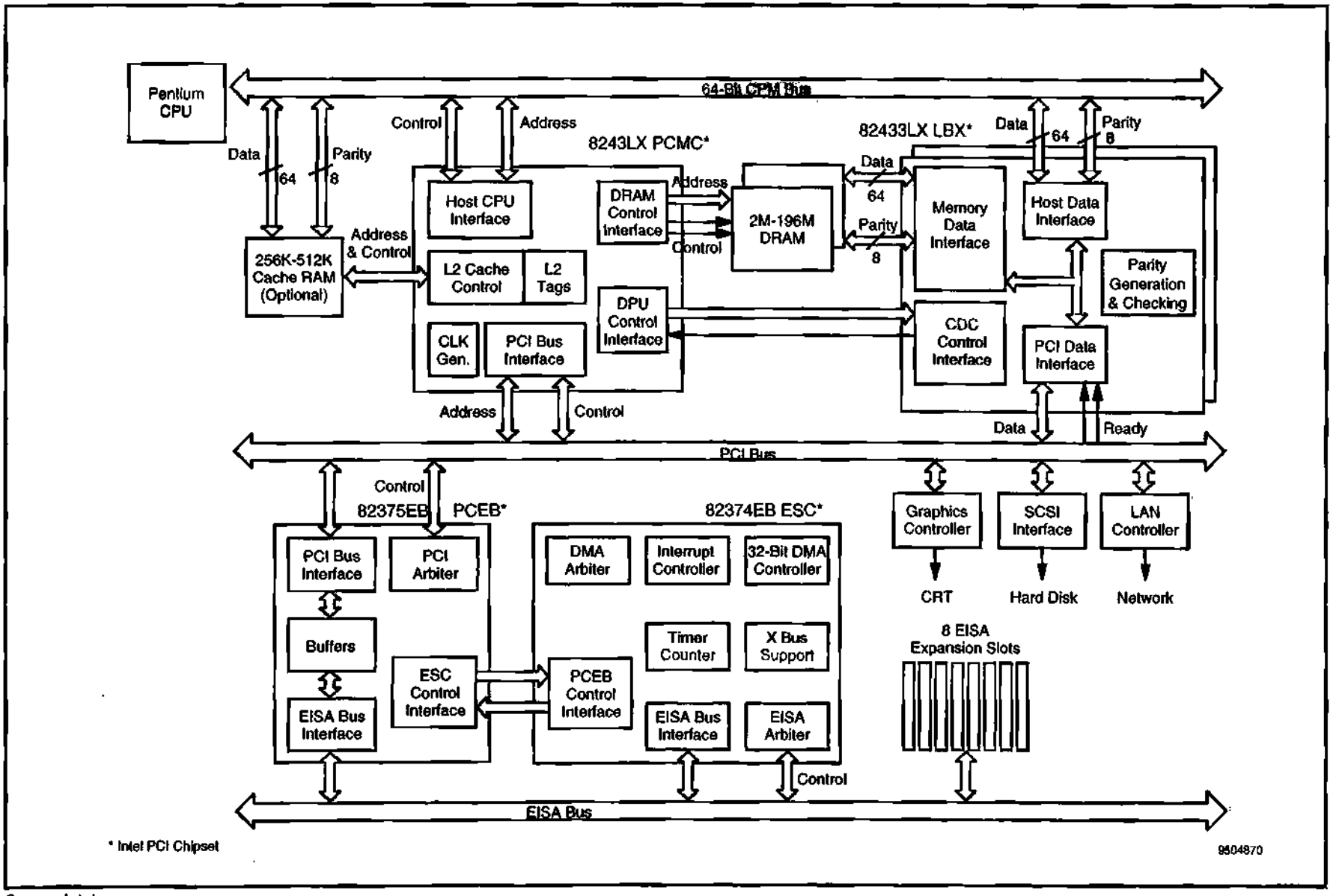
Semiconductor Market Opportunities and Technology Trends

Semiconductor market opportunities and technology trends are as follows:

- New generations of Pentium (P6, P7, and P8), PowerPC, Alpha, PA-RISC, SPARC, and MIPS processors will drive future PCs, workstations, and servers. Future trends include internal frequencies soaring past 100-MHz for PCs and toward 200-MHz for workstations. Multiprocessing features will also be available in many workstations and high-end PCs.
- Proprietary processors such as ARM will continue to be used in palmtop devices.
- PCs with 8 to 12MB average DRAM main memory in 1995 will move to 32MB DRAM in 1998.
- Increased opportunities will emerge for fast/synchronous DRAMs as MPU speeds outstrip conventional memory architectures.
- Bursting, MPU-specific SRAM will be used for cache design. SRAM modules are becoming more popular.
- New chipsets to support MPUs and the new buses (particularly PCI) will continue to emerge.
- Mixed-signal accelerated window graphics on a single chip (with RAMDAC) will be mainstream. High-resolution (1024 x 768, 16-color) 3-D graphics (Open GL) and digital video feature will become more prevalent.
- Mixed-signal I/O chips will support high-speed storage and peripherals communications (fast IDE, SCSI, 1394/Firewire). Chips integrating LAN and SCSI control will complement existing super I/O functions.

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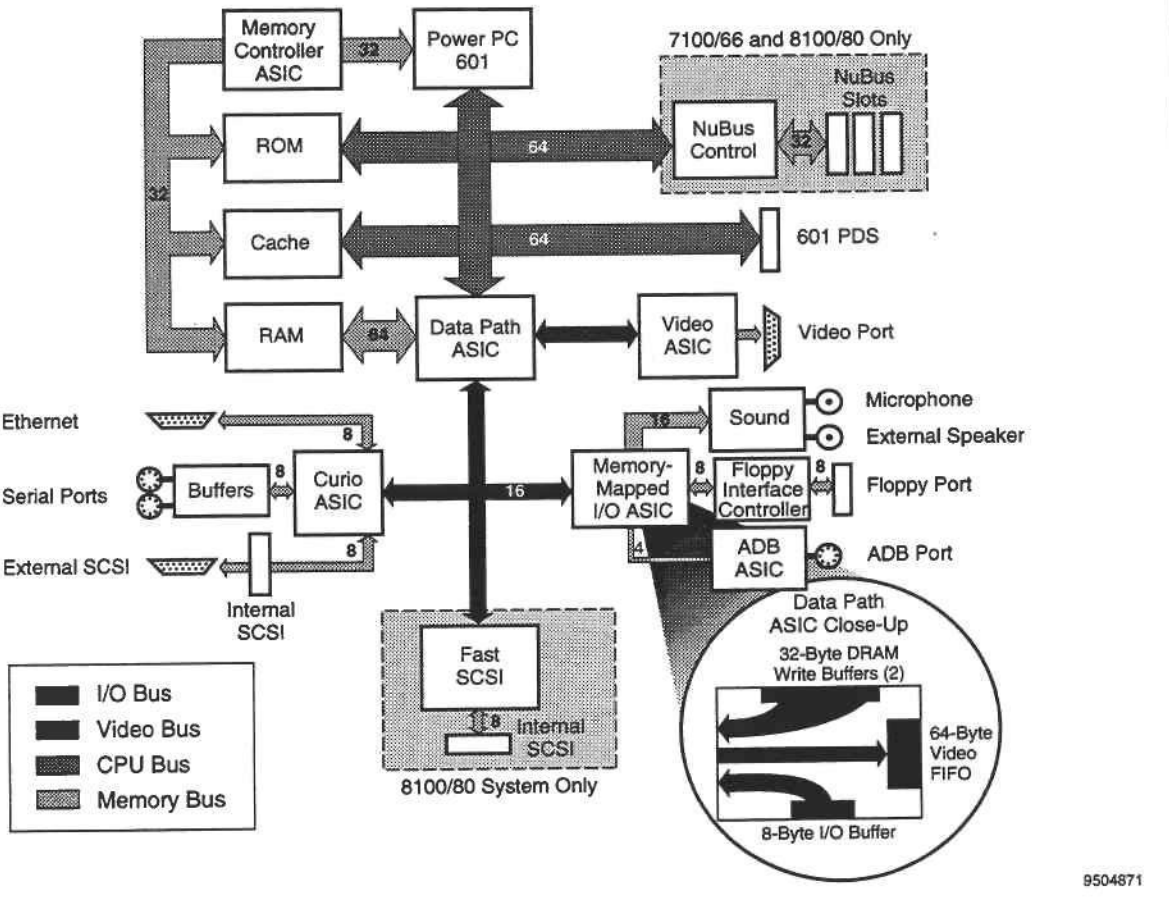
Figure 3-7
Generic Pentium-Based PC Using PCI Bus



Source: Intel

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Figure 3-8
Power Macintosh Hardware Architecture



Source: Dataquest (August 1995)

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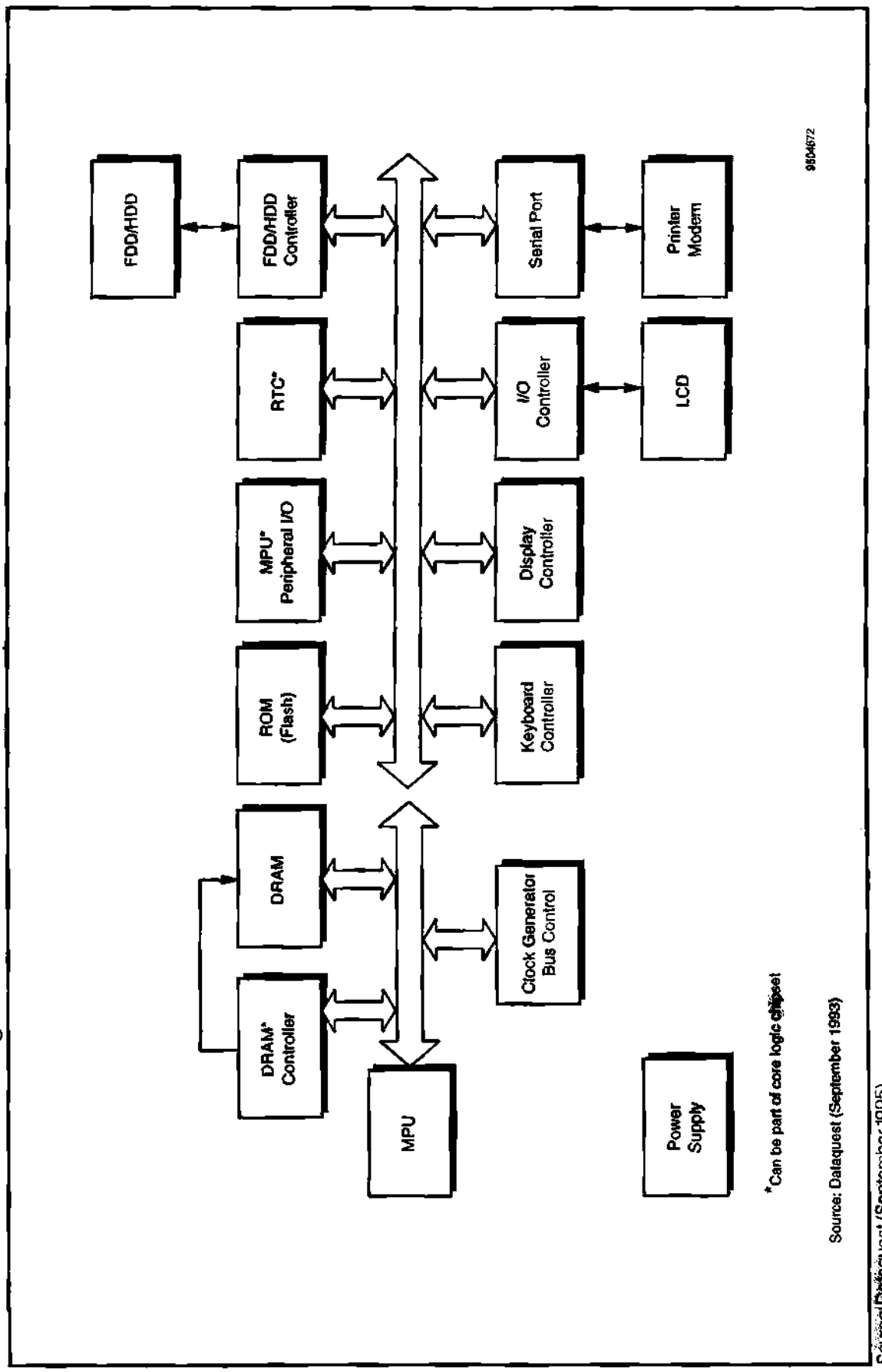
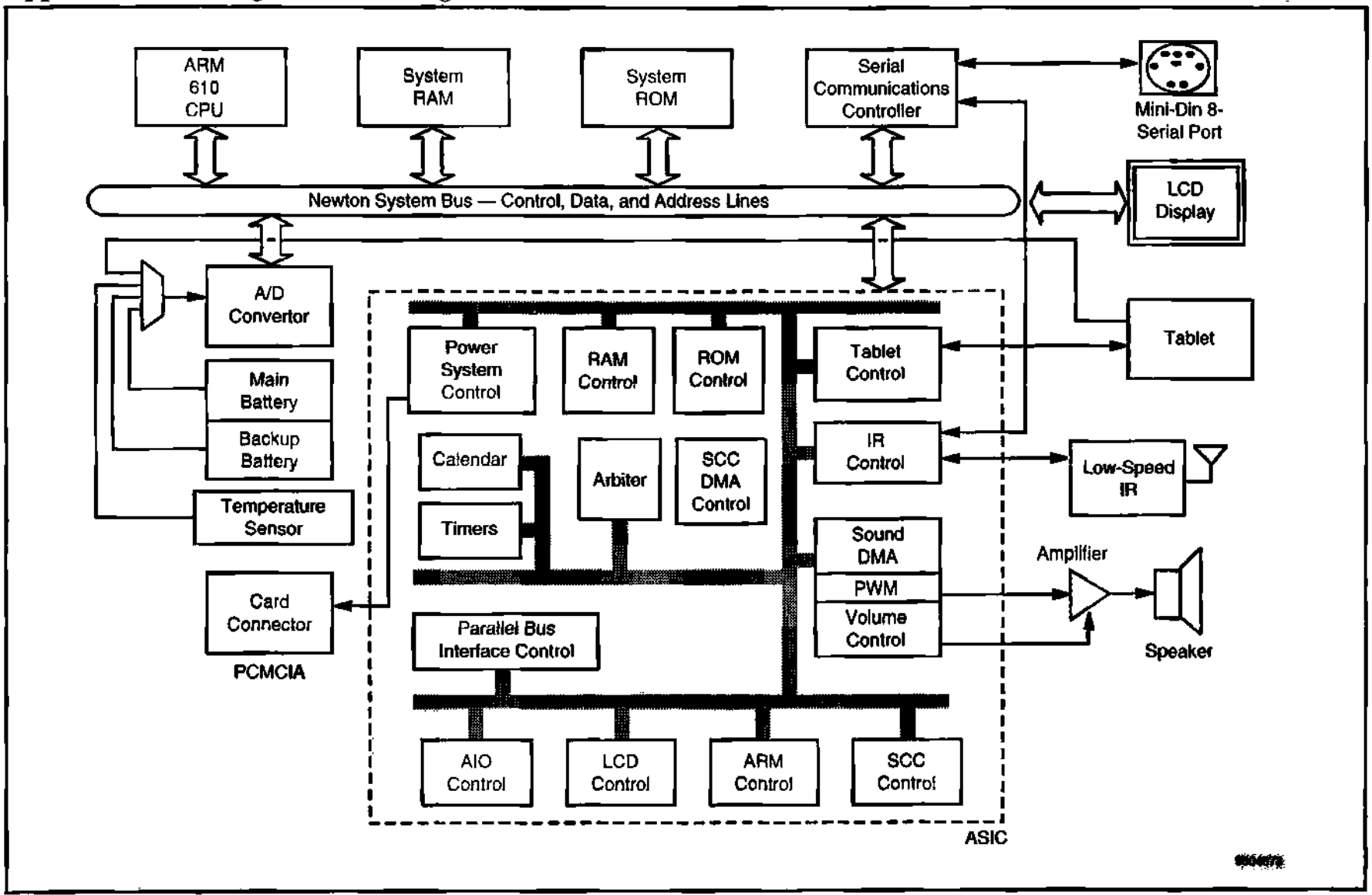


Figure 3-9
Generic Notebook Block Diagram

Source: Dataquest (September 1995)

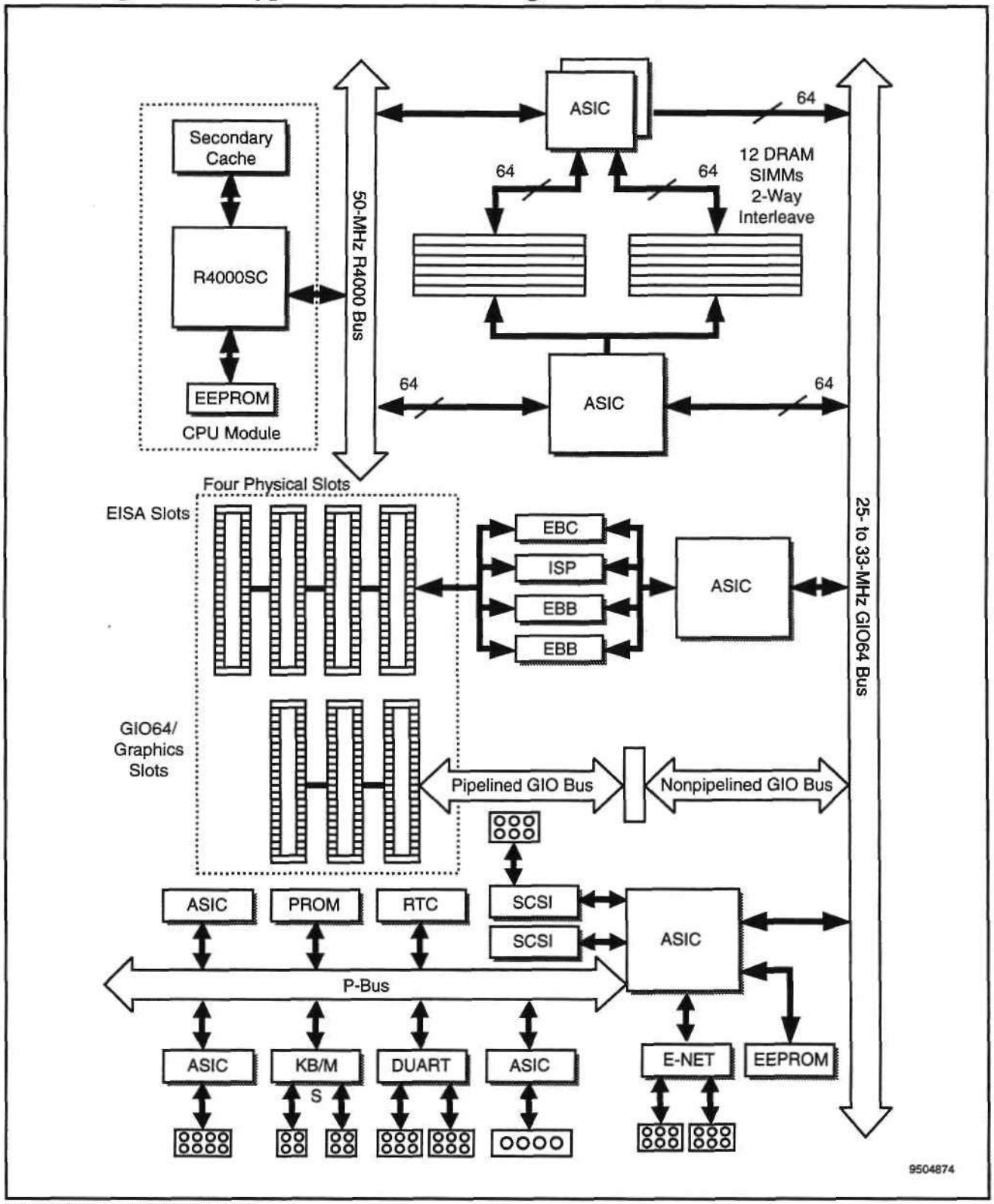
Figure 3-10
Apple Newton MessagePad Block Diagram



Source: Apple, PC Week

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Figure 3-11
Block Diagram for a Typical Workstation: Indigo R4000SC/R4400SC CPU Board



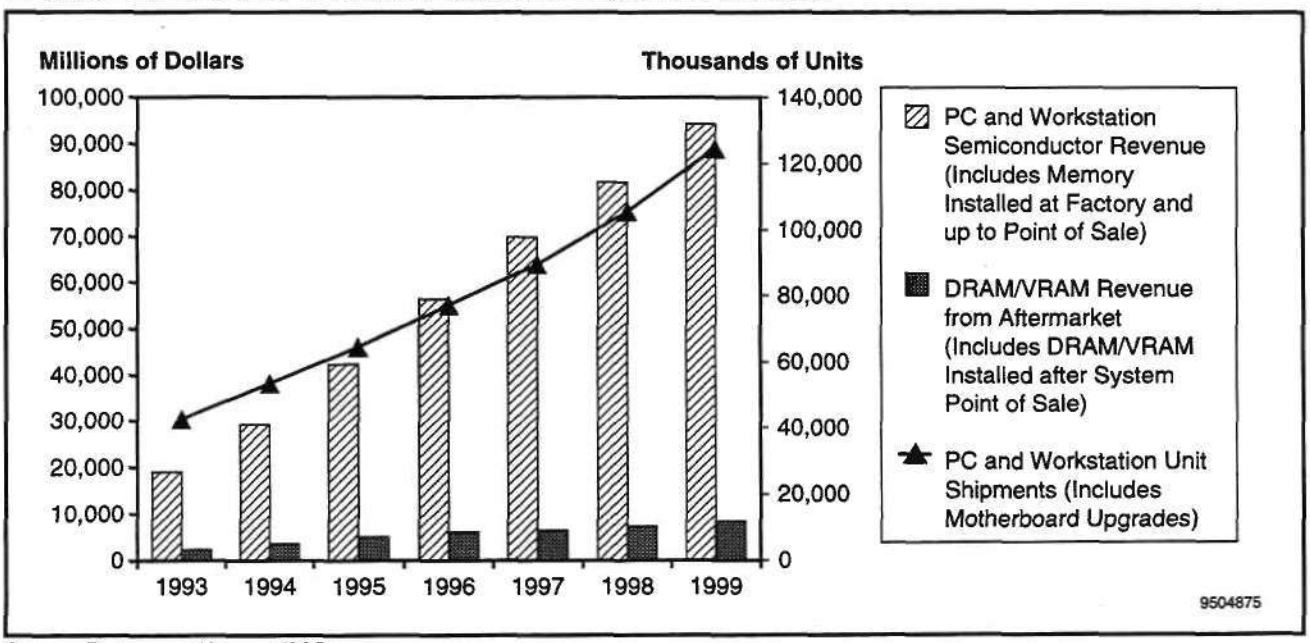
Source: Dataquest (August 1995)

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- Sound and video codecs and I/O functions will be used in multimedia systems. Microsoft, IBM, and Apple are continuing to provide multimedia and telephony interfaces to their operating systems.

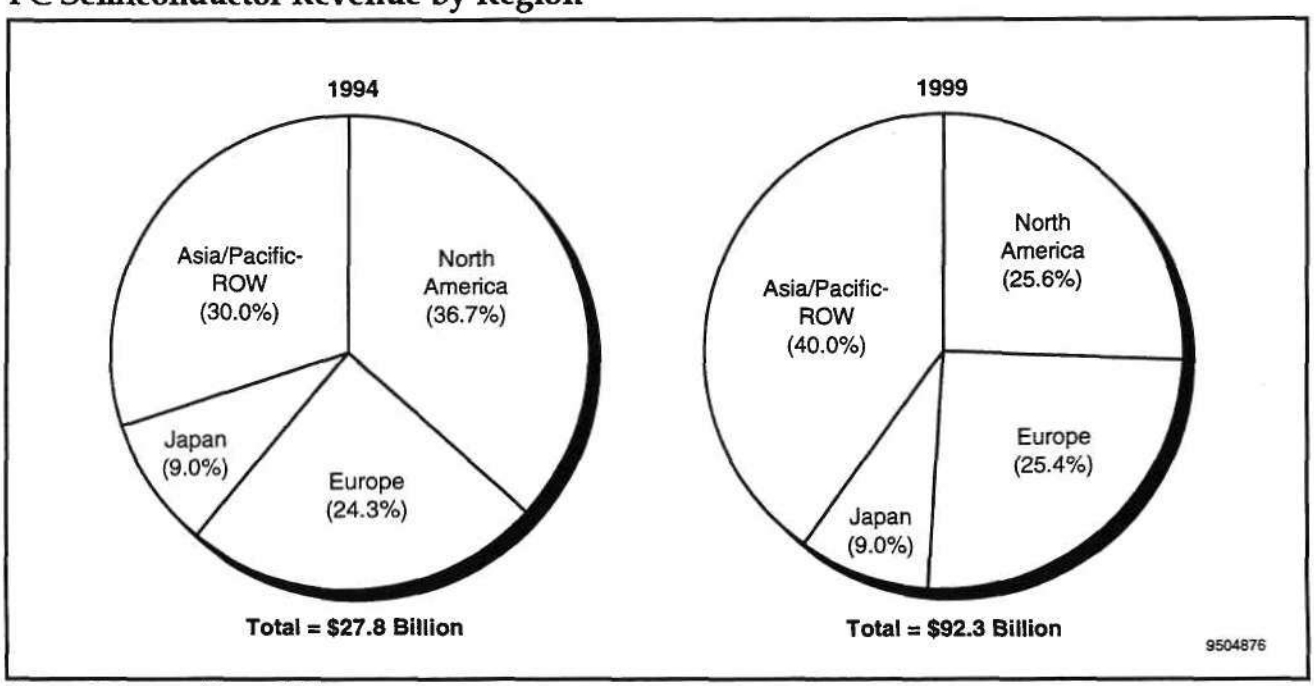
Figures 3-12 through 3-25 and Tables 3-15 through 3-24 provide forecasts and illustrations of semiconductor opportunities in the PC and workstation markets, including a focus on opportunities by region, system type, and semiconductor device type.

Figure 3-12
Worldwide PC and Workstation Semiconductor Market



Source: Dataquest (August 1995)

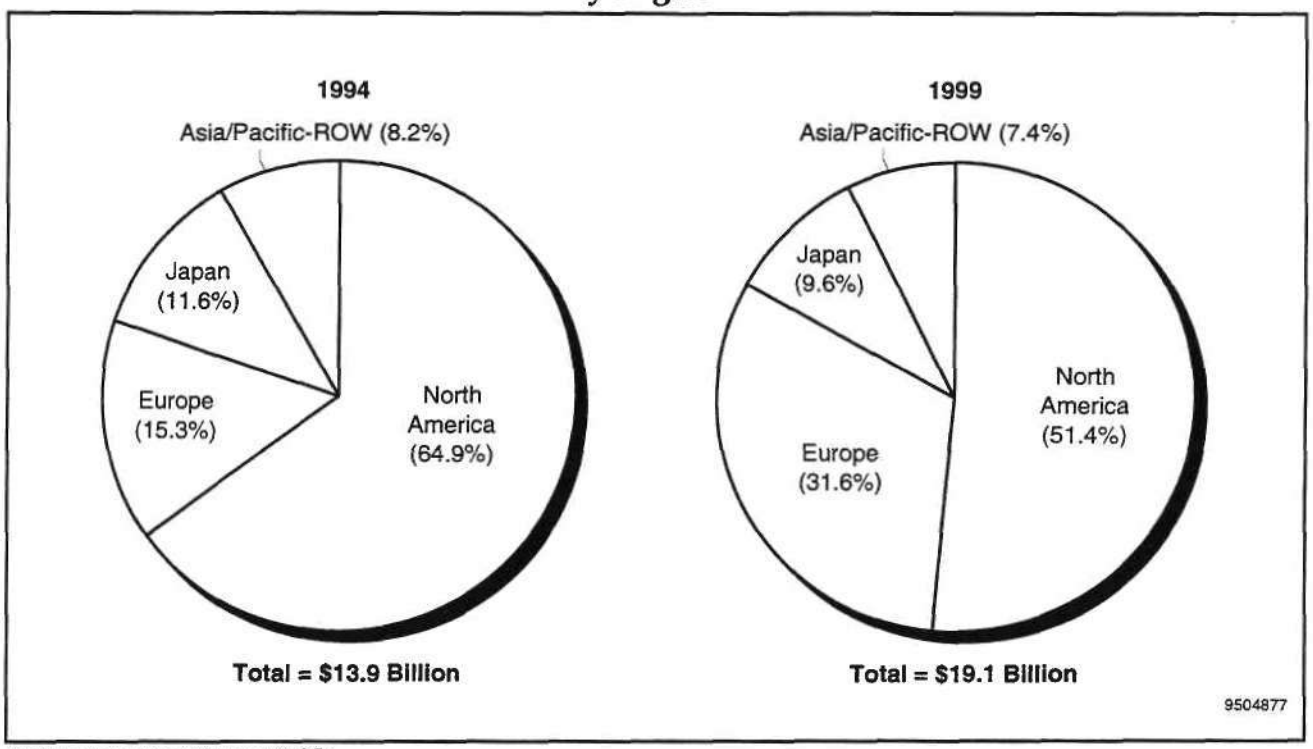
Figure 3-13
PC Semiconductor Revenue by Region



Source: Dataquest (August 1995)

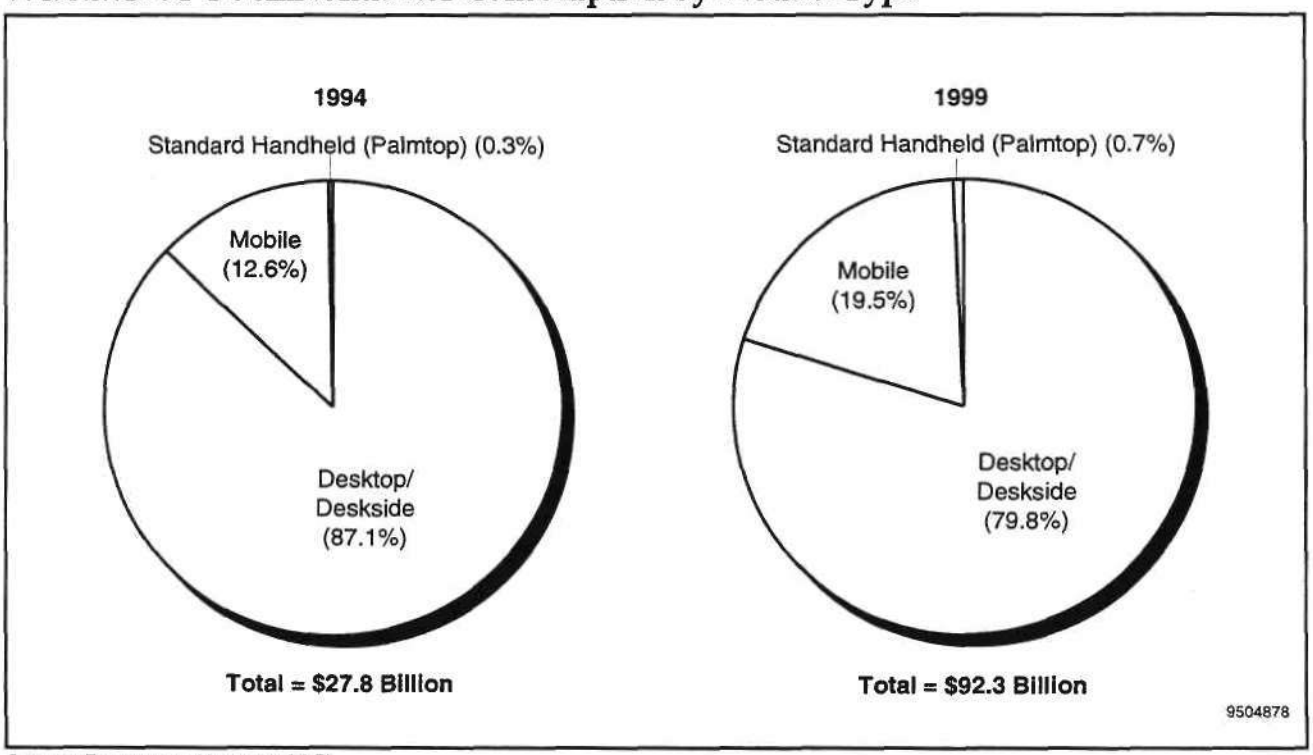
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Figure 3-14
Workstation Semiconductor Revenue by Region



Source: Dataquest (August 1995)

Figure 3-15
Worldwide PC Semiconductor Consumption by Product Type



Source: Dataquest (August 1995)

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Table 3-15
Worldwide PC Production and Semiconductor Market (Less Peripherals; Includes Standard Handhelds)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Complete PC Systems								
Units (K)	39,087	48,266	58,106	69,487	80,538	94,955	112,245	18.4
Factory ASP ($)	1,441	1,541	1,605	1,573	1,515	1,427	1,348	-2.6
Factory Revenue ($M)	56,323	74,379	93,253	109,323	121,989	135,493	151,359	15.3
Semiconductor Content ($)	430	526	638	711	765	760	743	7.2
Semiconductor TAM ($M)	16,799	25,375	37,069	49,390	61,590	72,203	83,436	26.9
Motherboard Upgrades								
Units (K)	2,759	4,404	5,476	6,738	7,992	9,582	11,190	20.5
Factory ASP ($)	1,250	1,320	1,401	1,389	1,333	1,277	1,241	-1.2
Factory Revenue ($M)	3,449	5,813	7,672	9,359	10,653	12,236	13,887	19
Semiconductor Content ($)	444	555	669	731	806	807	796	7.5
Semiconductor TAM ($M)	1,225	2,445	3,666	4,922	6,443	7,732	8,907	29.5
Total Production								
Units (K)	41,846	52,670	63,582	76,225	88,530	104,537	123,435	18.6
Factory ASP ($)	1,428	1,523	1,587	1,557	1,498	1,413	1,339	-2.5
Factory Revenue ($M)	59,772	80,192	100,925	118,682	132,642	147,729	165,246	15.6
Semiconductor Content ($)	431	528	641	713	768	765	748	7.2
Semiconductor TAM ($M)	18,024	27,820	40,735	54,312	68,033	79,935	92,343	27.1

*Includes graphics, serial/parallel I/O, storage adapters, and memory SIMMS installed up to point of sale
Source: Dataquest (August 1995)

Table 3-16
North American PC Production and Semiconductor Market (Less Peripherals; Includes Motherboard Upgrades and Standard Handhelds)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	10,747	13,500	15,979	18,503	20,043	22,427	24,669	12.8
Factory ASP ($)	1,522	1,547	1,622	1,580	1,537	1,436	1,378	-2.3
Factory Revenue ($M)	16,357	20,885	25,918	29,235	30,806	32,205	33,994	10.2
Semiconductor Content ($)	665	756	884	960	1,005	981	959	5.0
Semiconductor TAM ($M)	7,147	10,199	14,125	17,763	20,143	22,001	23,650	18.5

*Includes graphics, serial/parallel I/O, storage adapters, and memory SIMMS installed up to point of sale
Source: Dataquest (August 1995)

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Table 3-17
Worldwide Workstation Production and Semiconductor Market (Less Peripherals)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	623	772	857	902	945	1,033	1,085	7.0
Factory ASP ($)	16,045	15,473	16,028	16,333	16,369	15,649	15,494	0.0
Factory Revenue ($M)	9,996	11,945	13,736	14,732	15,469	16,165	16,811	7.1
Semiconductor Content ($)	1,665	1,795	1,968	2,242	1,972	1,805	1,759	-0.4
Semiconductor TAM ($M)	1,037	1,386	1,686	2,022	1,864	1,865	1,909	6.6

*Includes graphics, serial/parallel I/O, storage adapters, and memory SIMMS installed up to point of sale
Source: Dataquest (August 1995)

Table 3-18
North American Workstation Production and Semiconductor Market (Less Peripherals)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	347	452	498	509	552	563	547	3.9
Factory ASP ($)	17,649	17,020	17,631	17,966	18,003	17,214	17,004	0
Factory Revenue ($M)	6,124	7,693	8,780	9,145	9,938	9,691	9,323	3.9
Semiconductor Content ($)	1,883	1,989	2,138	2,479	2,094	1,913	1,793	-2.0
Semiconductor TAM ($M)	653	899	1,064	1,262	1,156	1,077	981	1.8

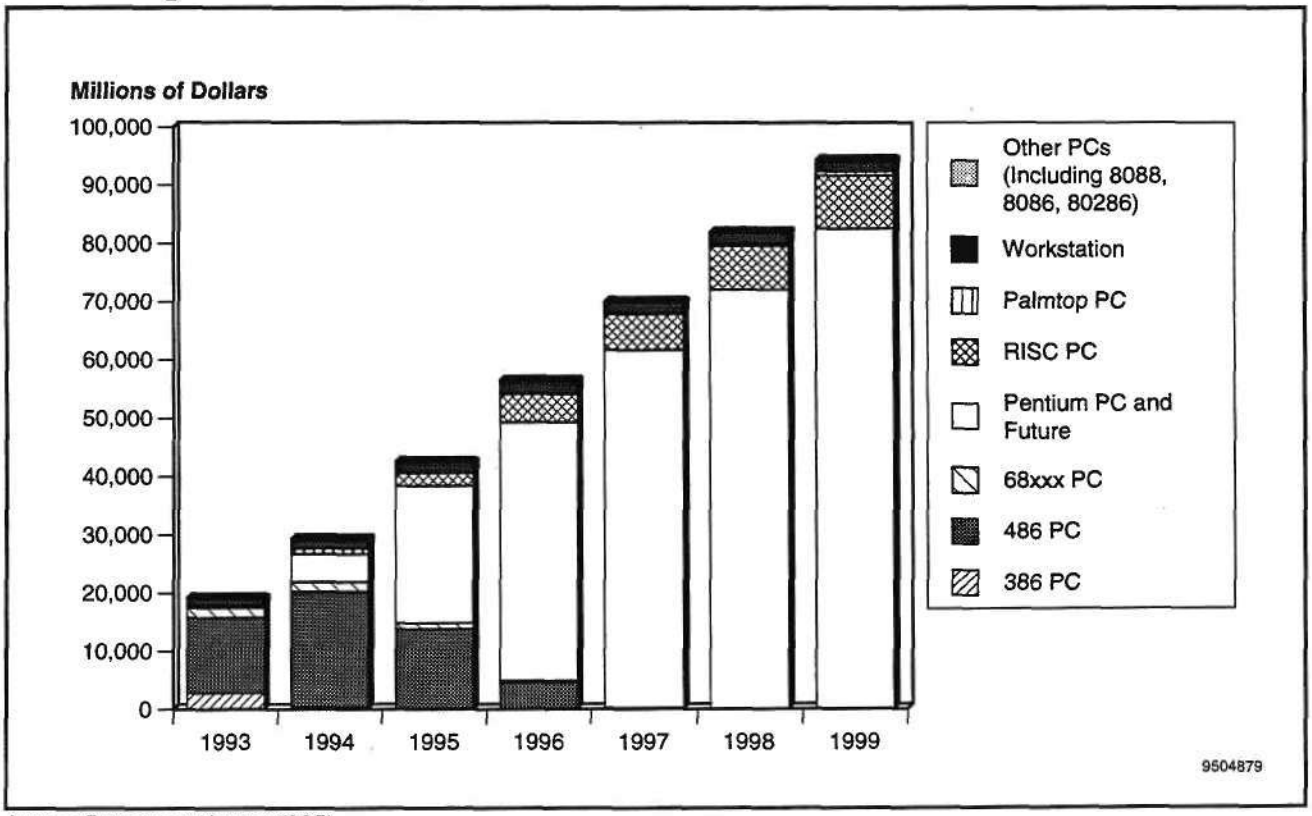
*Includes graphics, serial/parallel I/O, storage adapters, and memory SIMMS installed up to point of sale
Source: Dataquest (August 1995)

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Semiconductor Opportunities by System

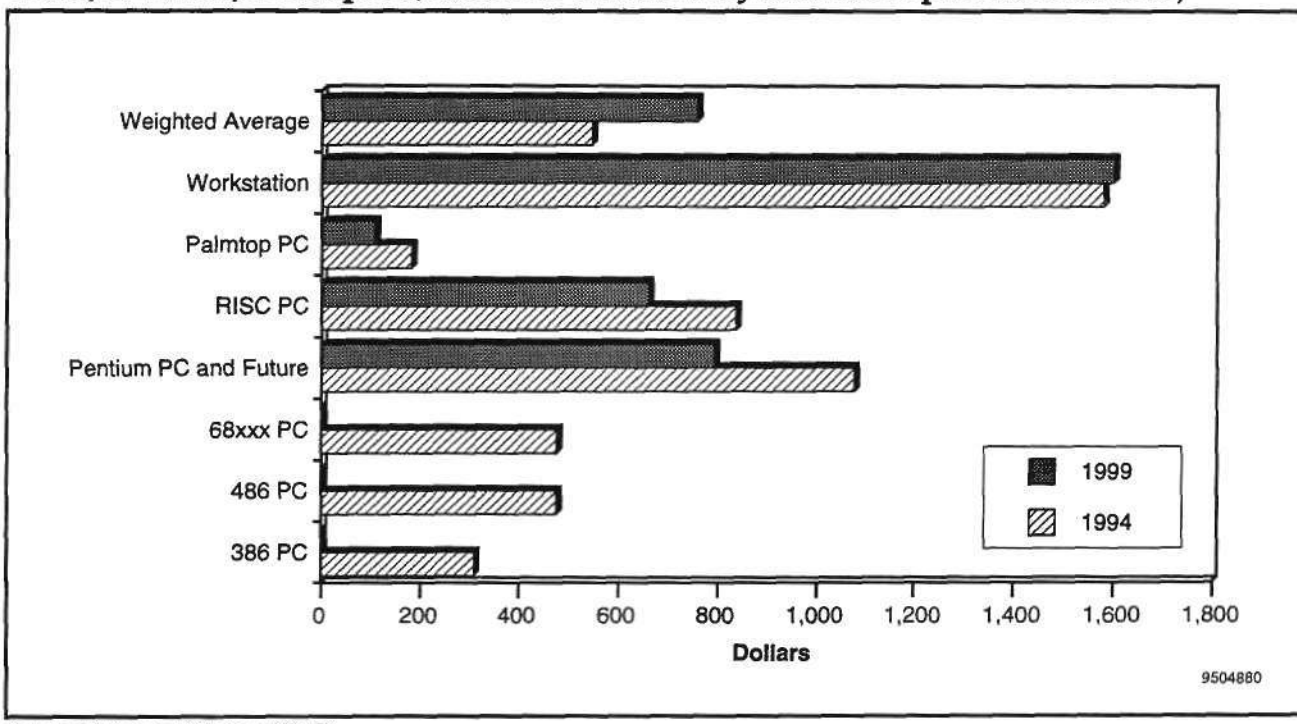
Figures 3-16 through 3-21 and Table 3-19 detail semiconductor opportunities by system.

Figure 3-16
Worldwide PC and Workstation Semiconductor Market by System (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

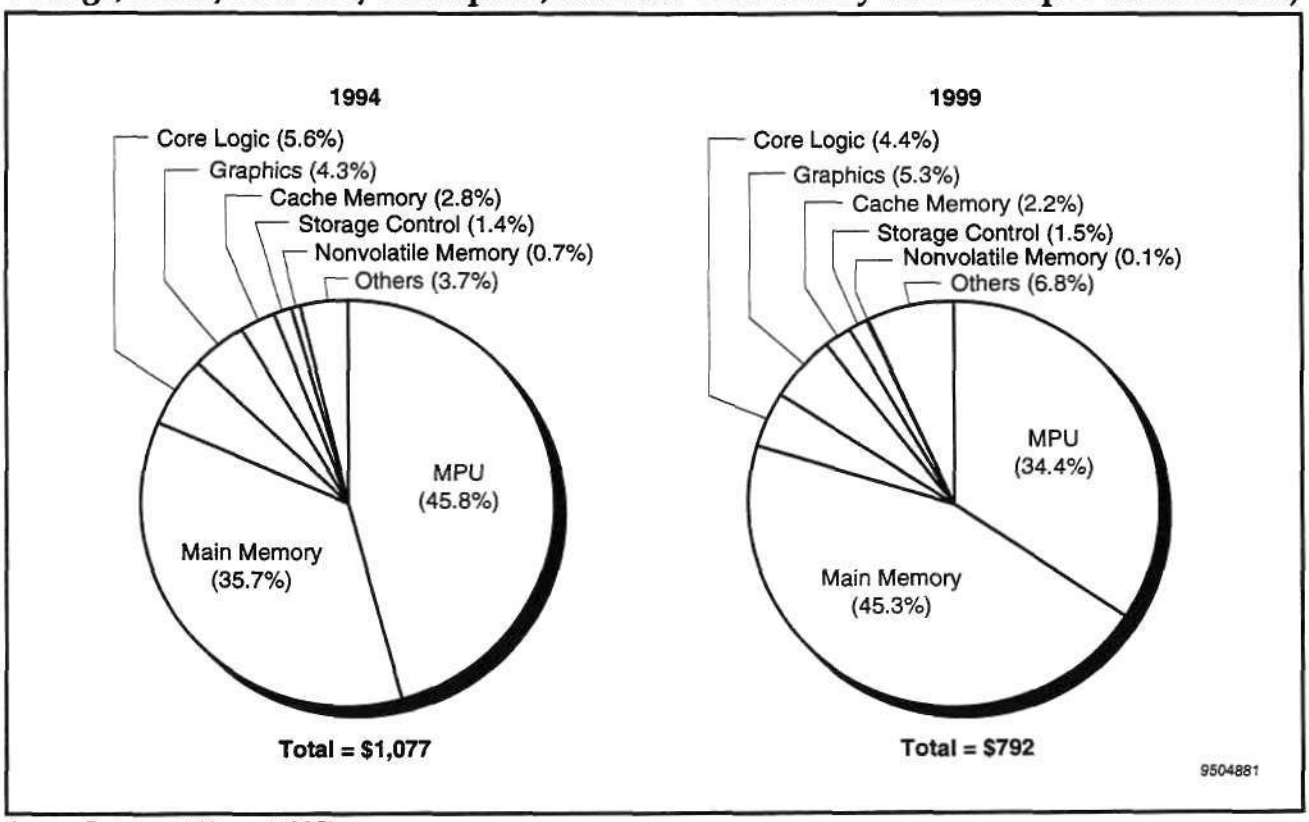
Figure 3-17
Average System Semiconductor Content (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

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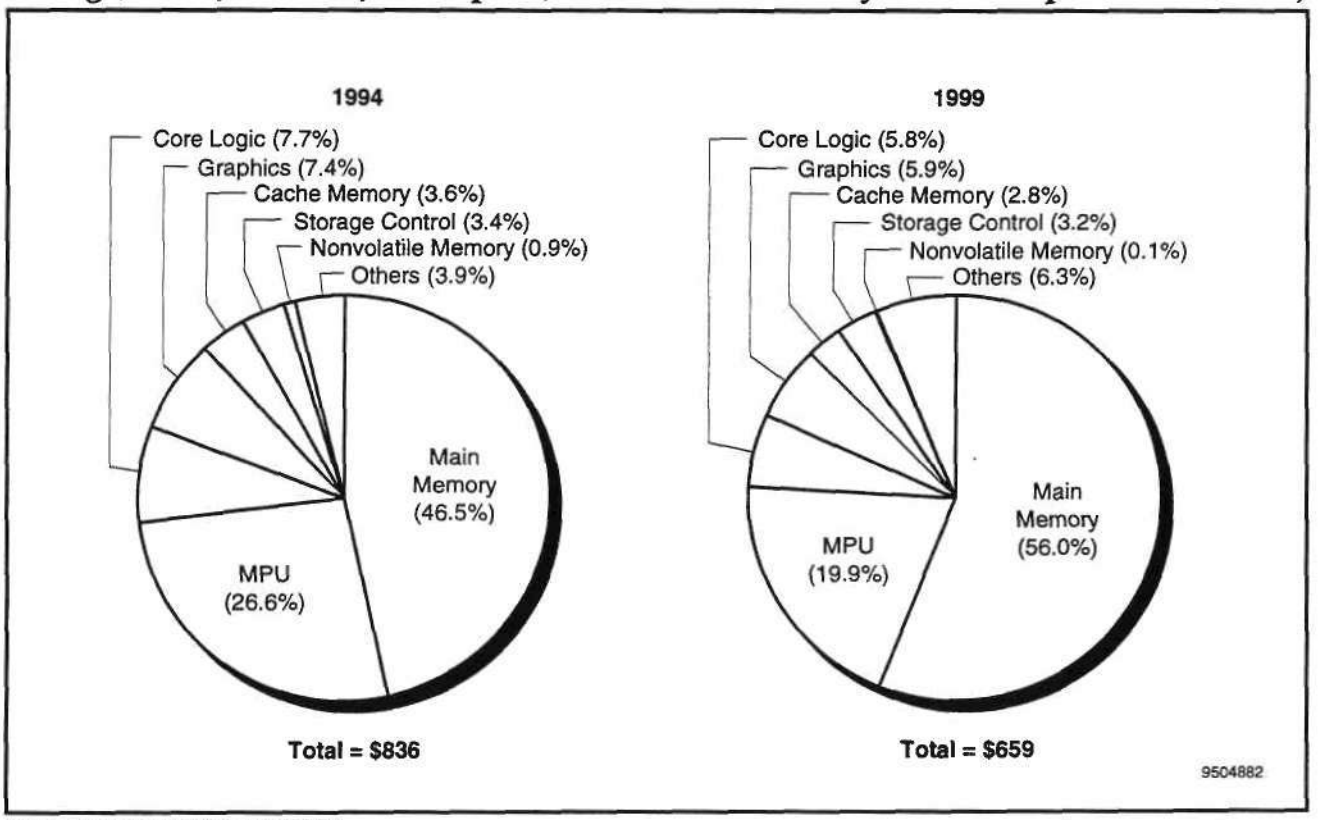
Figure 3-18
Pentium System Semiconductor Content Trend (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

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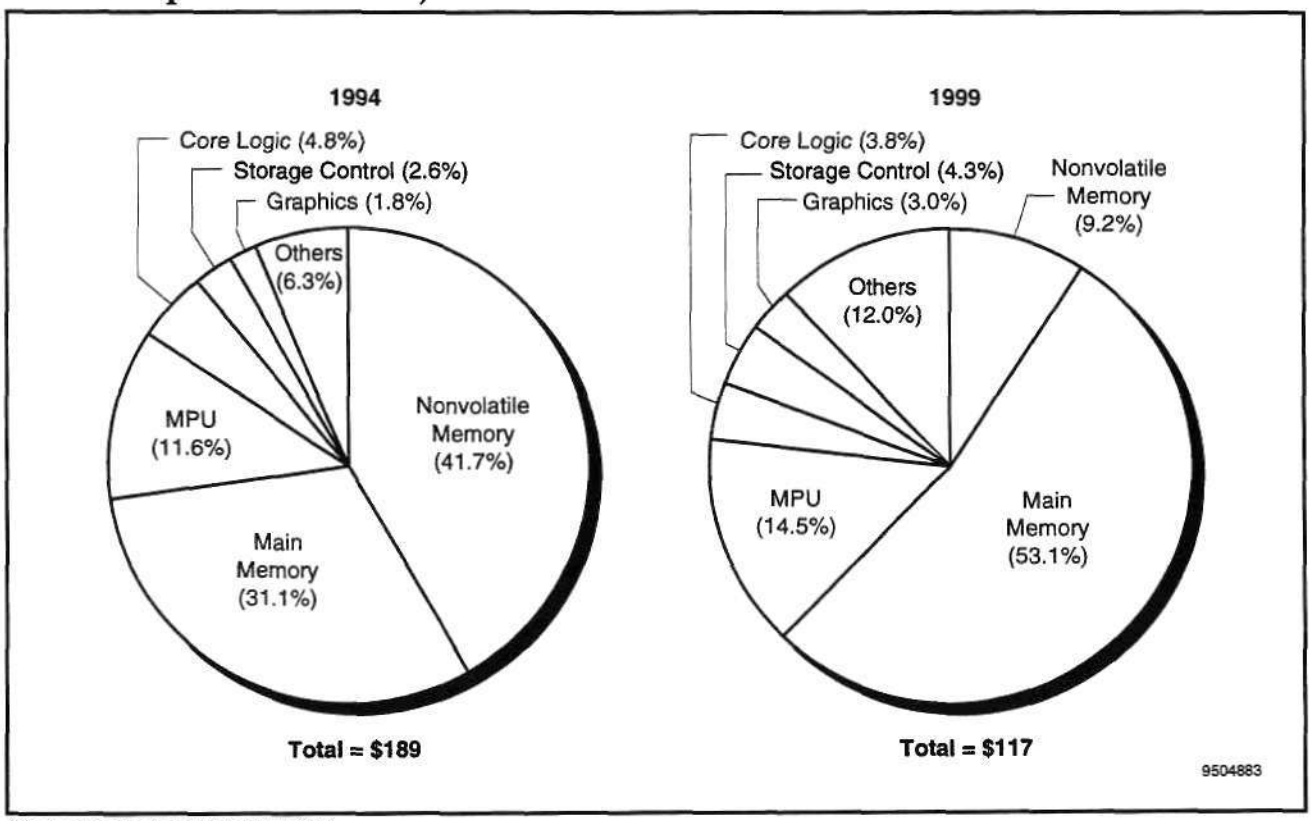
Figure 3-19
RISC-PC System Semiconductor Content Trend (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

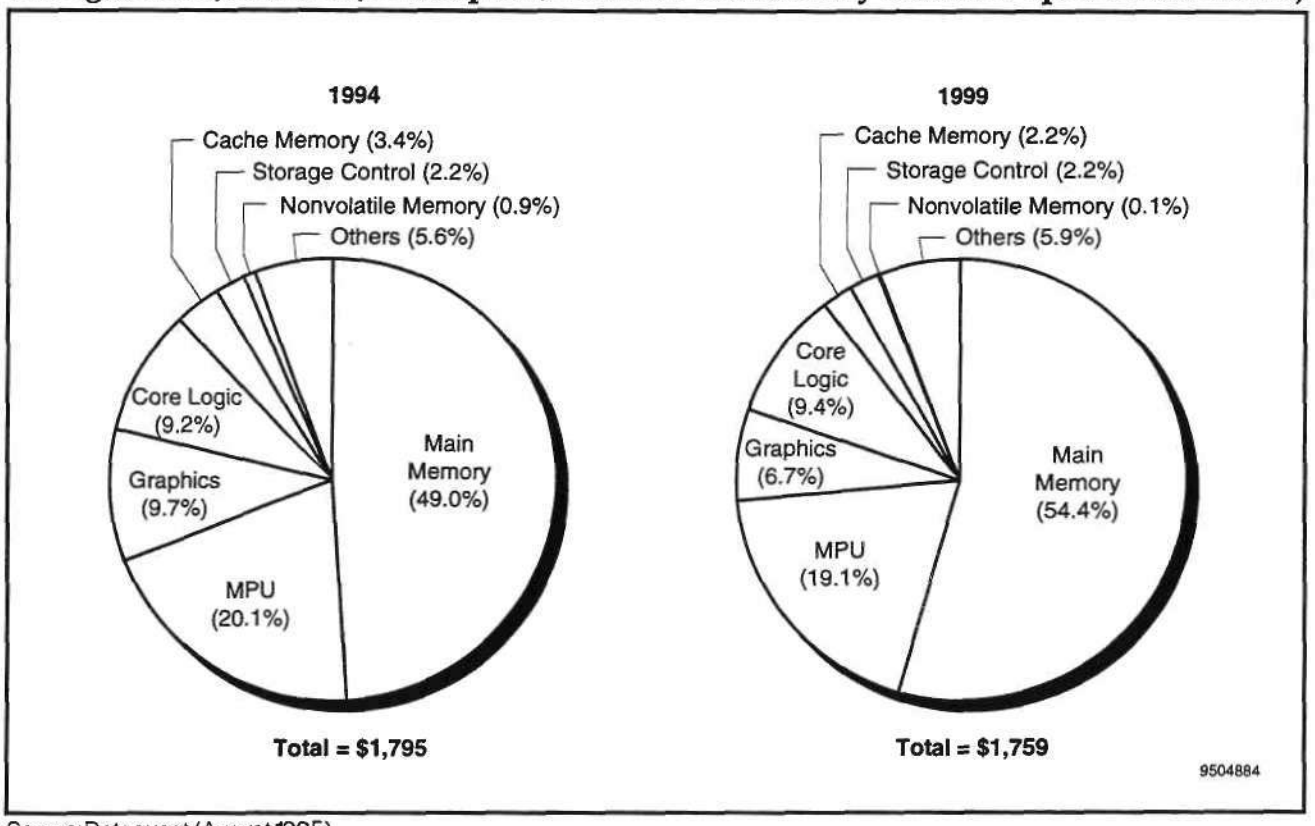
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Figure 3-20
Standard Handheld (Palmtop) System Semiconductor Content Trend (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

Figure 3-21
Workstation System Semiconductor Content Trend (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

Table 3-19
Worldwide PC and Workstation Semiconductor Market by System (Millions of Dollars) (Includes Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)

Processor Type	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
386 PC	2,832	442	13	0	0	0	0	-100.0
486 PC	13,006	19,845	13,820	4,698	153	0	0	-100.0
68xxx PC	1,689	1,672	1,046	208	59	0	0	-100.0
Pentium PC and Future	341	4,794	23,543	44,469	61,510	72,119	82,565	76.7
RISC PC	57	971	2,207	4,797	6,136	7,474	9,164	56.7
Palmtop PC	38	74	106	140	176	343	613	52.7
Workstation	1,037	1,386	1,686	2,022	1,864	1,865	1,909	6.6
Other PCs (inc. 8088, 8086, 80286)	61	22	0	0	0	0	0	-100.0
Total	19,062	29,205	42,421	56,334	69,897	81,799	94,251	26.4
Year-to-Year Growth (%)	49.7	53.5	45.5	32.9	24.2	17.0	15.3	

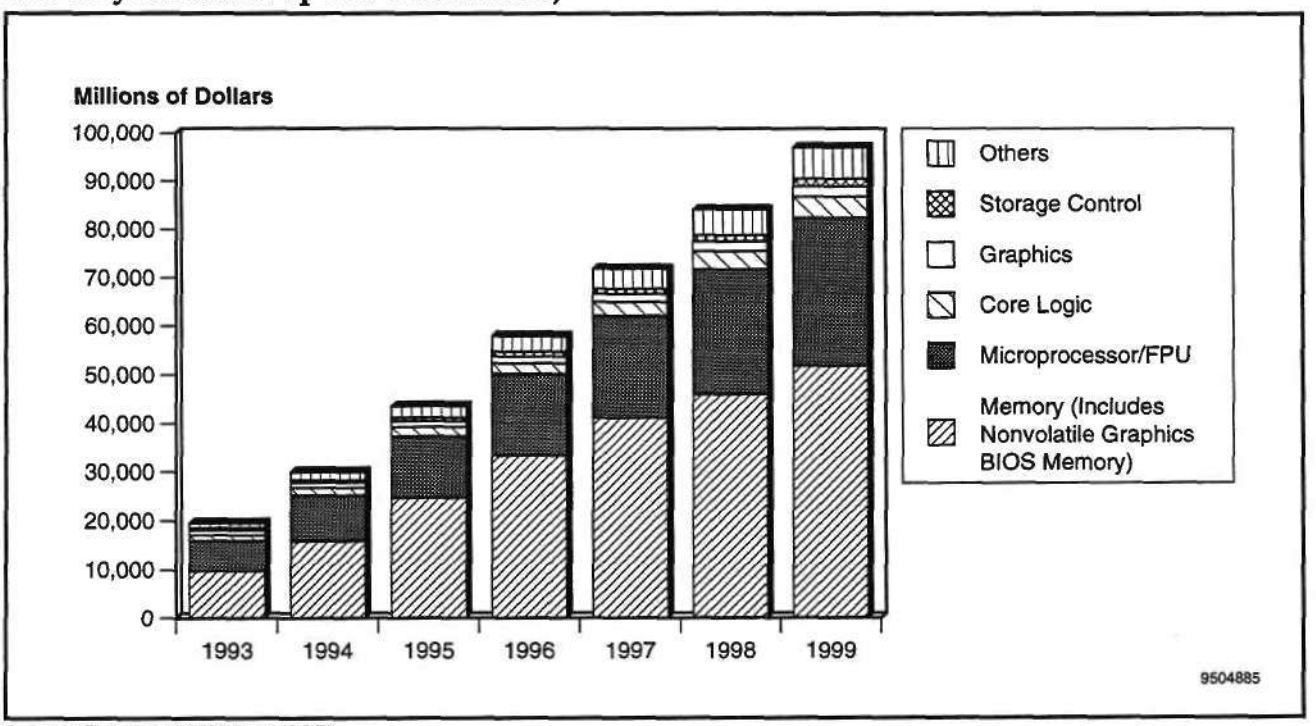
Note: Includes motherboard, graphics, storage, serial/paralle I/O adapters, and add-on memory SIMMs
Source: Dataquest (August 1995)

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Semiconductor Opportunities by Device Type

Figures 3-22 through 3-26 and Tables 3-20 through 3-23 detail semiconductor opportunities by device type.

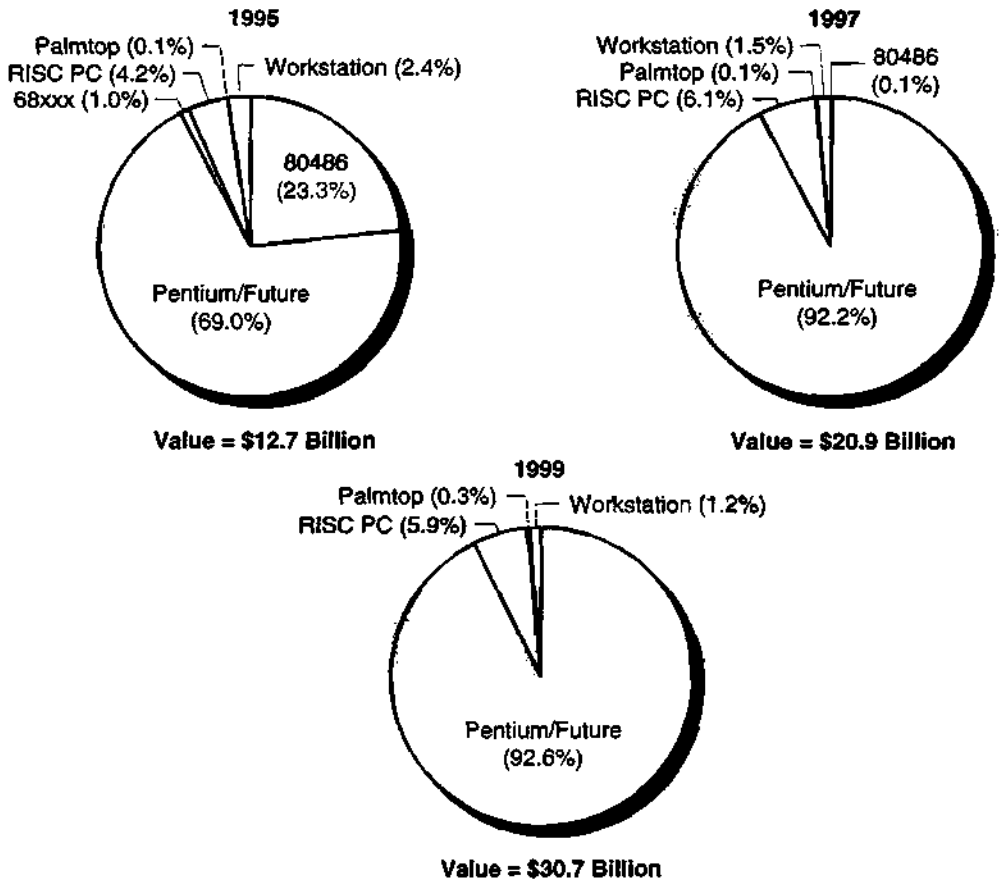
Figure 3-22
Worldwide PC and Workstation Semiconductor Market by Device Type (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)



Source: Dataquest (August 1995)

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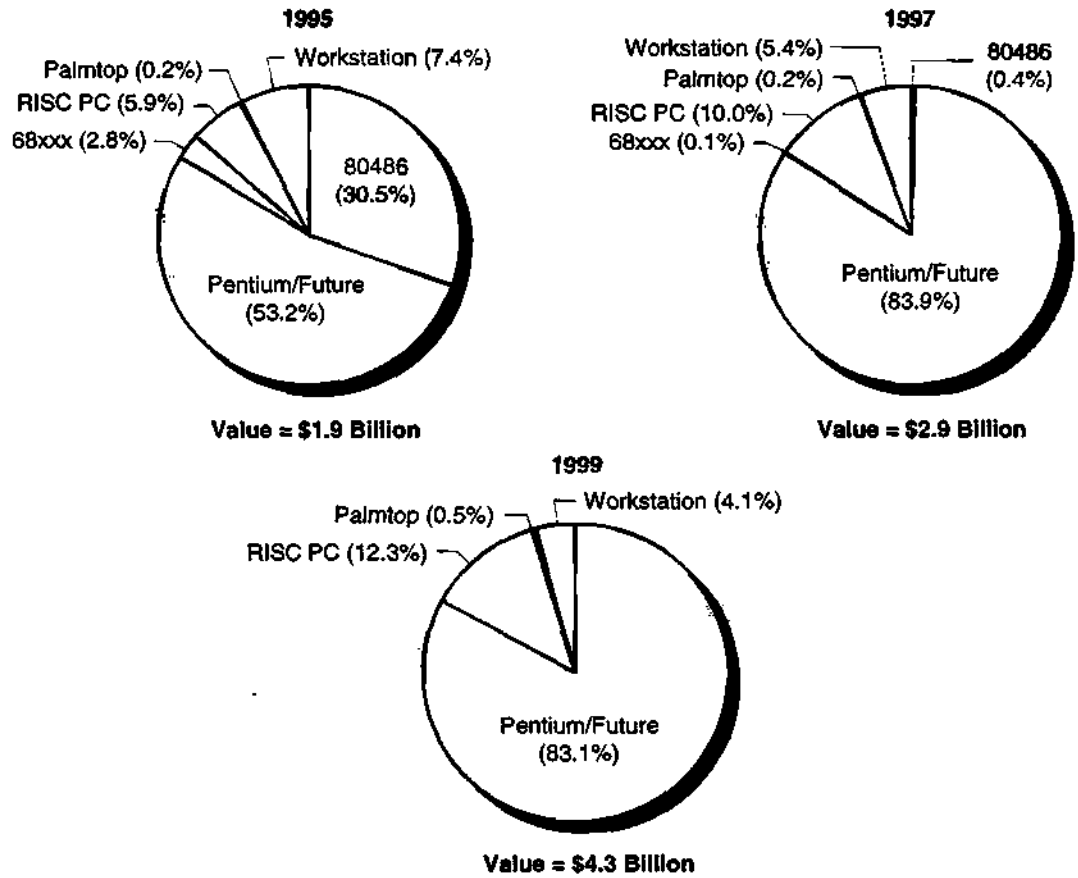
Figure 3-23
Worldwide Microprocessor Opportunities in PCs and Workstations



Source: Dataquest (August 1995)

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Figure 3-24
Worldwide Core Logic Opportunities in PCs and Workstations

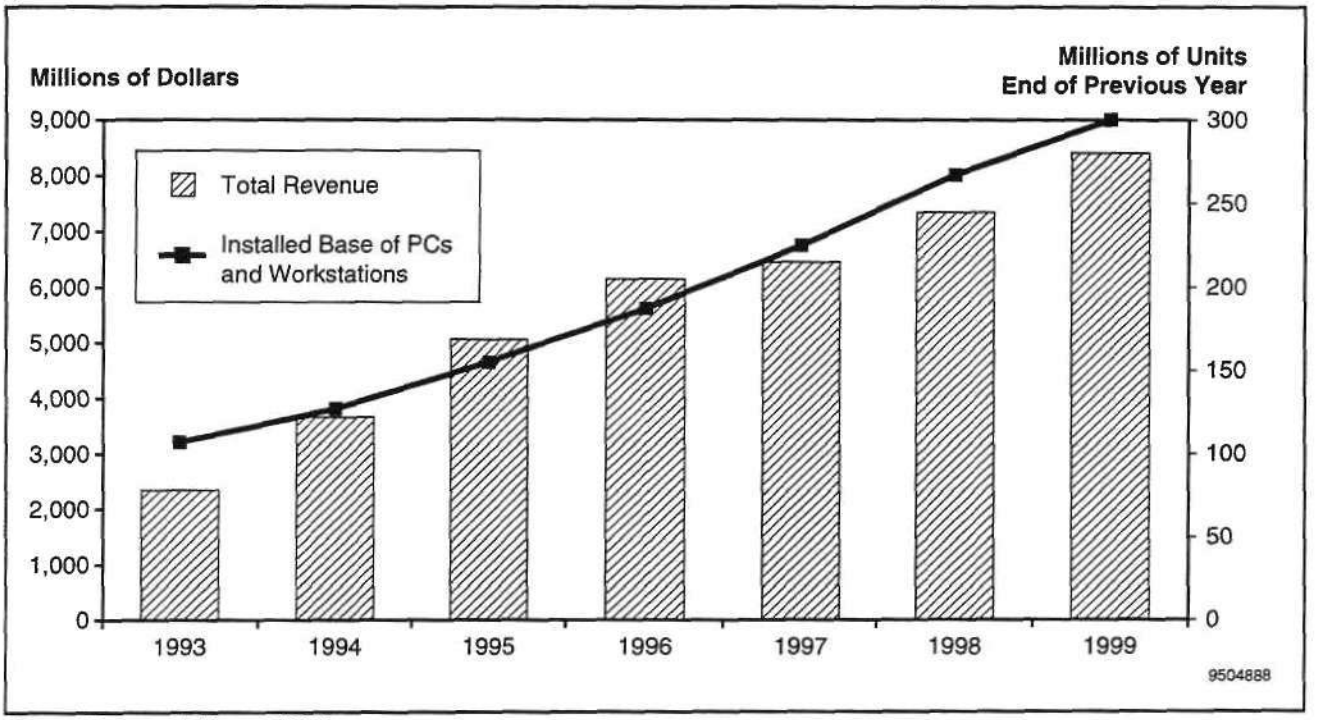


[1] Includes systems based on PowerPC, MIPS, and Alpha processors.
[2] Includes handheld PDA-type systems based on ARM and x86 processors.
[3] Includes systems based on SPARC, PA-RISC, MIPS, Alpha, and PowerPC Processors.

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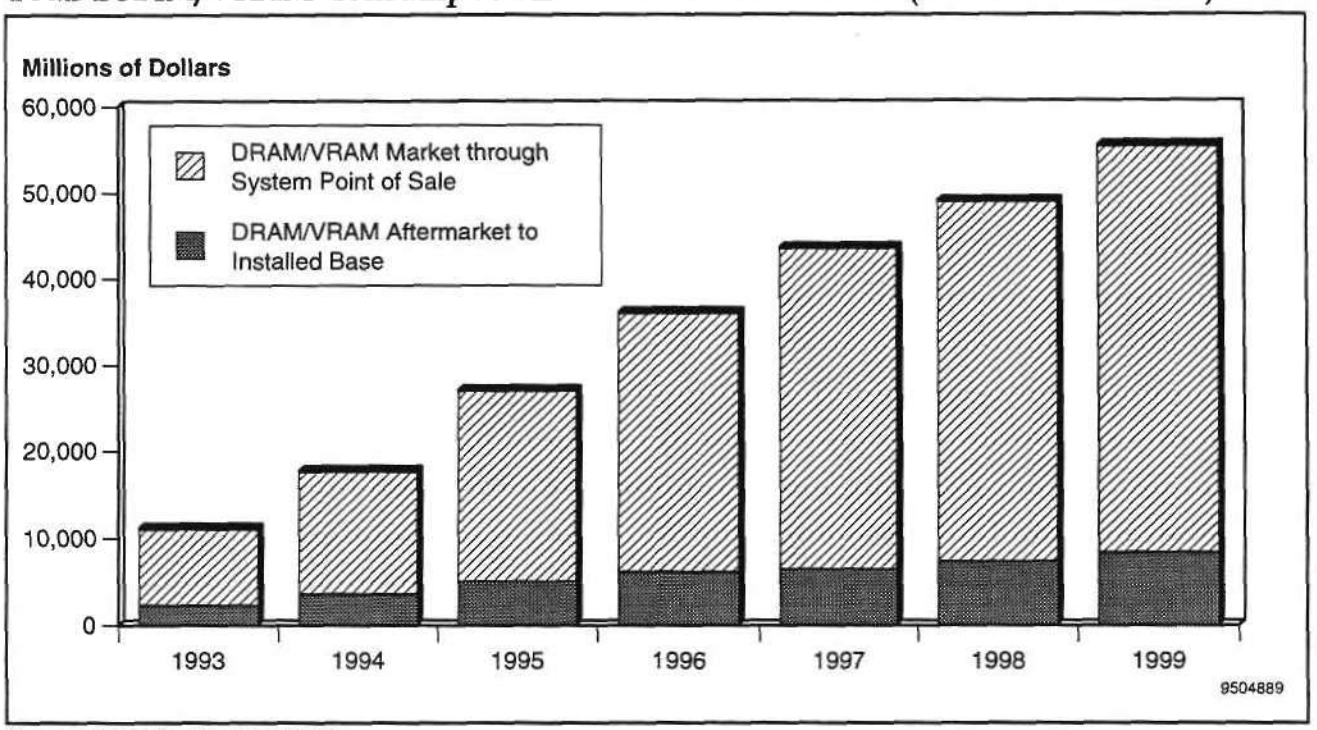
Source: Dataquest (August 1995)

Figure 3-25
Worldwide Aftermarket DRAM/VRAM Memory Demand in PCs and Workstations (Includes Memory Purchased for Installation in PCs after PC System Point of Sale)



Source: Dataquest (August 1995)

Figure 3-26
Total DRAM/VRAM Consumption in PCs and Workstations (Millions of Dollars)



Source: Dataquest (August 1995)

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Table 3-20
Worldwide PC and Workstation Semiconductor Market by Device Type (Millions of Dollars) (Including Motherboard, Graphics, Storage, Serial/Parallel I/O Adapters, and Add-On Memory Installed up to Point of Sale)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Memory*	9,818	15,936	24,776	33,463	41,284	46,094	51,896	26.6
Microprocessor/FPU	6,262	9,391	12,686	16,827	20,920	25,814	30,657	26.7
Core Logic	1,119	1,483	1,920	2,154	2,865	3,747	4,342	24.0
Graphics	970	1,097	1,226	1,383	1,644	1,945	2,105	13.9
Storage Control	516	541	747	991	1,146	1,331	1,563	23.6
Other	812	1,482	2,192	3,049	3,986	5,149	6,384	33.9
Total Semiconductor	19,497	29,930	43,547	57,866	71,845	84,081	96,946	26.5
Percentage Growth	49.7	53.5	45.5	32.9	24.2	17.0	15.3	

* Includes nonvolatile graphics BIOS memory
Source: Dataquest (August 1995)

Table 3-21
Worldwide Semiconductor Memory Demand in PCs and Workstations by Device* (Millions of Dollars) (Includes Memory Installed in Factory and Add-On Memory Installed up to Point of Sale)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
DRAM /VRAM	8,723	13,987	21,870	29,776	36,908	41,407	46,611	27.2
SRAM	416	881	1,373	1,900	2,251	2,255	2,462	22.8
EPROM/OTP/ROM	247	169	50	19	0	0	0	-100.0
Flash	62	254	454	352	311	309	316	4.4
Total	9,447	15,291	23,747	32,046	39,470	43,971	49,388	26.4

* Includes nonvolatile graphics BIOS memory
Source: Dataquest (August 1995)

Table 3-22
Worldwide Aftermarket DRAM/VRAM Memory Demand in PCs and Workstations (Includes Memory Purchased for Installation in PCs after PC System Point of Sale)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total DRAM/VRAM (Millions of Megabytes)	89	142	192	244	358	565	764	40.0
Total Revenue ($M)	2,346	3,659	5,057	6,150	6,452	7,342	8,399	18.1
Installed Base of PCs and Workstations (Millions of Units End of Previous Year)	107	127	155	187	225	267	300	

Source: Dataquest (August 1995)

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Table 3-23
Worldwide Semiconductor Memory Demand by System
(Market Value by Function; Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
386 PC								
Main OEM and POS Add-On	1,438	232	7	0	0	0	0	-100.0
Display Buffer	324	37	1	0	0	0	0	-100.0
Cache	50	7	0	0	0	0	0	-100.0
Nonvolatile	37	6	0	0	0	0	0	-100.0
Total	1,848	282	9	0	0	0	0	-100.0
486PC								
Main OEM and POS Add-On	4,368	8,419	7,187	2,685	91	0	0	-100.0
Display Buffer	940	1,067	903	341	7	0	0	-100.0
Cache	319	633	366	110	0	0	0	-100.0
Nonvolatile	113	195	158	45	1	0	0	-100.0
Total	5,739	10,313	8,613	3,181	100	0	0	-100.0
68xxx PC								
Main OEM and POS Add-On	749	948	583	135	37	0	0	-100.0
Display Buffer	222	199	113	17	3	0	0	-100.0
Cache	4	3	3	1	0	0	0	-100.0
Nonvolatile	69	55	27	2	1	0	0	-100.0
Total	1,044	1,204	726	155	40	0	0	-100.0
Pentium and Future PC								
Main OEM and POS Add-On	96	1,711	10,136	20,593	30,002	33,657	37,470	85.4
Display Buffer	8	114	757	2,064	1,962	2,236	2,611	87.1
Cache	8	134	773	1,352	1,902	1,805	1,840	68.9
Nonvolatile	2	35	157	153	125	91	63	12.2
Total	113	1,994	11,822	24,162	33,992	37,789	41,983	83.9
RISC PC								
Main OEM and POS Add-On	32	451	1,026	2,343	3,375	4,156	5,133	62.6
Display Buffer	2	48	151	334	302	280	306	44.9
Cache	3	35	149	287	214	224	254	48.7
Nonvolatile	1	9	16	17	13	11	8	-1.9
Total	37	543	1,340	2,981	3,904	4,670	5,702	60.0

(Continued)

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Table 3-23 (Continued)
Worldwide Semiconductor Memory Demand by System
(Market Value by Function; Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Palmtop PC								
Main OEM and POS Add-On	12	23	36	70	85	181	326	70.0
Display Buffer	0	0	0	0	0	0	-	
Cache	0	0	0	0	0	0	-	
Nonvolatile	14	31	41	32	33	47	57	13.0
Total	27	54	78	102	118	228	382	48.0
Workstation								
Main OEM and POS Add-On	488	679	914	1,180	1,072	1,021	1,038	8.9
Display Buffer	49	81	93	83	57	57	53	-8.3
Cache	21	46	46	81	50	45	42	-2.0
Nonvolatile	9	12	9	5	3	2	1	-36.1
Total	567	819	1,062	1,349	1,182	1,125	1,134	6.7
Other PC (inc. 8088, 8086,80286)								
Main OEM and POS Add-On	6	1	0	0	0	0	0	-100.0
Display Buffer	1	0	0	0	0	0	0	-100.0
Cache	0	0	0	0	0	0	-	-100.0
Nonvolatile	0	0	0	0	0	0	-	-100.0
Total	7	1	0	0	0	0	0	-100.0
Total PC and WS								
Main OEM and POS Add-On	7,188	12,464	19,888	27,006	34,662	39,015	43,967	28.7
Display Buffer	1,547	1,546	2,018	2,840	2,331	2,573	2,970	13.9
Cache	403	858	1,337	1,831	2,167	2,074	2,136	20.0
Nonvolatile	245	343	408	254	176	151	129	-17.8
Total	9,383	15,211	23,651	31,930	39,336	43,813	49,201	26.5

Source: Dataquest (August 1995)

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Table 3-24
Average Memory Configuration Assumptions by System (Megabytes per System)

	1993	1994	1995	1996	1997	1998	1999
386 PC							
Main (OEM)	4.00	4.00	4.00	NM	NM	NM	NM
Main Add-On[1]	0.84	1.90	1.89	NM	NM	NM	NM
Display Buffer	0.90	1.00	1.00	NM	NM	NM	NM
Cache (KB)	64.00	64.00	64.00	NM	NM	NM	NM
Nonvolatile[2]	0.13	0.13	0.13	NM	NM	NM	NM
486PC							
Main (OEM)	4.44	5.91	7.75	8.80	9.13	NM	NM
Main Add-On[1]	1.02	1.44	1.69	2.24	3.05	NM	NM
Display Buffer	0.97	1.00	1.19	1.40	1.00	NM	NM
Cache (KB)	115.62	162.72	151.53	160.34	27.94	NM	NM
Nonvolatile[2]	0.14	0.15	0.25	0.45	0.28	NM	NM
68xxx PC							
Main (OEM)	4.87	7.26	8.00	8.00	12.00	NM	NM
Main Add-On[1]	0.53	2.58	0.99	3.37	1.00	NM	NM
Display Buffer	1.00	1.00	1.00	1.00	1.00	NM	NM
Cache (KB)	64.00	64.00	128.00	128.00	256.00	NM	NM
Nonvolatile[2]	0.50	0.50	0.50	0.50	0.50	NM	NM
Pentium and Future PC							
Main (OEM)	12.00	11.98	9.90	10.80	15.78	21.55	26.55
Main Add-On[1]	2.00	2.00	3.50	3.15	5.49	6.85	6.11
Display Buffer	1.00	1.00	1.00	1.40	1.39	1.89	2.28
Cache (KB)	256.00	256.00	256.00	256.00	456.42	454.00	454.68
Nonvolatile[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
RISC PC							
Main (OEM)	11.95	12.00	9.93	10.88	15.87	21.73	26.68
Main Add-On[1]	2.00	2.14	3.68	3.17	6.48	8.00	6.87
Display Buffer	1.00	1.50	2.00	2.00	2.00	2.00	2.00
Cache (KB)	256.00	256.00	494.03	480.88	479.16	476.89	470.94
Nonvolatile[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Palmtop PC							
Main (OEM)	1.00	1.25	1.60	2.50	3.25	4.00	4.00
Main Add-On[1]	0	0	0	0	0	0	0
Display Buffer	0	0	0	0	0	0	0
Cache (KB)	0	0	0	0	0	0	0
Nonvolatile[2]	2.00	2.50	3.50	4.00	4.25	4.50	4.50

(Continued)

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Table 3-24 (Continued)
Average Memory Configuration Assumptions by System (Megabytes per System)

	1993	1994	1995	1996	1997	1998	1999
Workstation							
Main (OEM)	22.00	28.00	36.00	46.00	56.00	68.00	78.00
Main Add-On[1]	4.00	4.00	4.50	6.00	7.00	8.00	9.00
Display Buffer	2.00	2.50	3.00	3.00	3.50	4.00	4.00
Cache (KB)	256.00	512.00	512.00	1,000.00	1,000.00	1,000.00	1,000.00
Nonvolatile[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50

[1]Includes memory added through system point of sale
[2]Excludes graphics BIOS typically using a 32Kx8 EPROM/OTP
NM = Not meaningful
Source: Dataquest (August 1995)

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Chapter 4
Midrange—Supercomputer Application Markets

Market Trends

Market trends are as follows:

- There is a continuing trend toward the decentralized client/server model of computing using distributed machines optimized for networking, efficient mass storage, and on-demand number crunching. Mainframes and supercomputers are reinventing themselves as high-I/O-capacity, high-performance servers.
- There is a trend toward open systems with common operating systems (UNIX derivatives), programming interfaces, windowed GUIs (for example, X Windows), and in some cases standard buses.
- There is a trend toward CMOS/BiCMOS, microprocessor-based scalable, multiprocessor architectures that can take an OEM's line from workstation to supercomputer. Midrange systems are turning to symmetrical multiprocessing (SMP) architectures and supercomputer systems are using a massive parallel processing (MPP) approach.

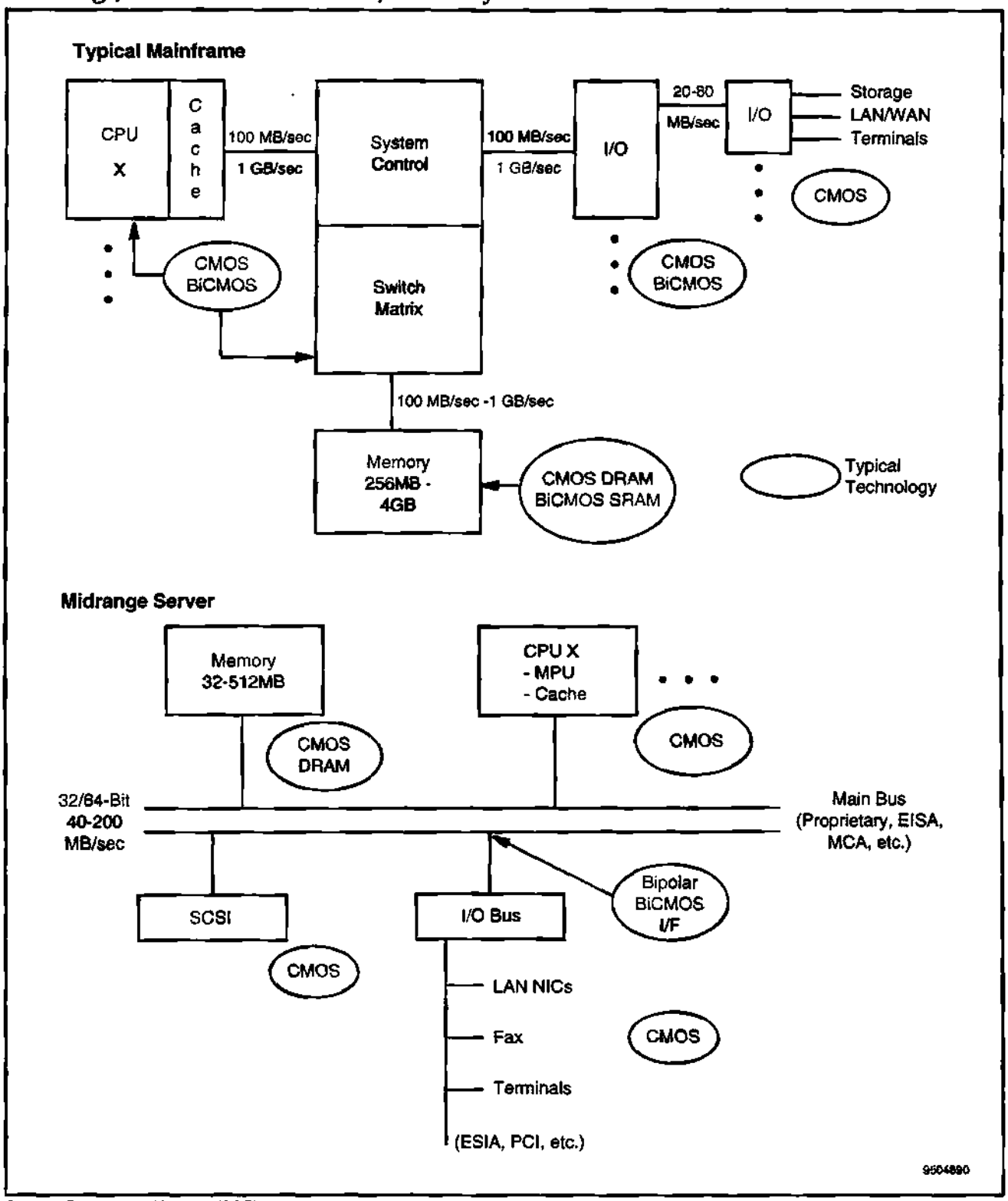
Technology Trends

Technology trends are as follows:

- Midrange computers are defined to be multiuser, cost $20,000 through several hundred thousand dollars, and include such systems as IBM's AS/400.
- Perhaps the most visible form of emerging midrange computer is the servers that can be configured with several gigabytes of disk capacity, tape backup, and multiple LAN network interface cards (NICs) for connection to users. Figure 4-1 presents a block diagram of a generic scalable server architecture as well as a mainframe/server system. Table 4-1 lists some of the specific semiconductor technology requirements of future systems.
- Increasingly midrange and large-scale computers are incorporating RISC and CISC MPUs to achieve scalable architectures. In many cases, systems can simply have compute or I/O performance upgraded with MPU anchored add-in boards. Architectures of many midrange systems will be a scaled-up, multiprocessor versions of workstation families. There is a trend toward OEM-controlled MPU architectures, with IBM (PowerPC), Sun (SPARC), HP (PA-RISC) and Digital (Alpha) being notable examples. Examples of architectural choices for systems include:
  - Sun—SPARC
  - IBM—PowerPC
  - Digital—Alpha
  - HP—PA-RISC
  - NCR—x86
  - Compaq—x86
  - Tandem—MIPS
  - Cray—SPARC/Alpha

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Figure 4-1
Midrange/Server and Mainframe/Server System



Source: Dataquest (August 1995)

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Table 4-1
Semiconductor Technology in Large Computers (Next-Generation Requirements)

	Midrange	Mainframe/Super
Main Memory	DRAM	DRAM
Average	400MB	1GB or 32MB per node
Access Time (ns)	60	60
Cache Memory	CMOS SRAM	CMOS/BiCMOS
Average MB/CPU	512KB	1MB
Access Time (ns)	10	1
MPU	32/64-bit MPU	32/64-bit MPU
	1 to 16 processors	1 to 10,000 processors
Logic	CMOS ASSP/ASIC	CMOS/BiCMOS ASSP/ASIC
LAN	Ethernet/Token Ring; FDDI	Ethernet/Token Ring/FDDI/HiPPI
Peripheral Connection	SCS; Fiber Channel	SCSI, ESCON, Fiber Channel, SSA
Main Bus/Crossbar Switch Speed	40 to 200 MB/sec	500 MB/sec to 4 GB/sec

Source: Dataquest (August 1995)

- In addition to proprietary buses, open versions such as MCA, EISA, VME, and Futurebus+ often are employed as either the main or I/O bus in midrange systems.
- Multichip modules (MCMs) will continue to be employed to reduce off-chip delay and to manage thermal dissipation. Bare die versions of popular processors such as Pentium are available for sale for the first time to populate CPU engine MCMs. New MCM technology can manage beyond 100 die with two to three dozen layers of fine pitch interconnect.
- Massively parallel processors (MPPs) are getting a clear toehold in the world of performance computing. The concept of parallel computing basically involves the partitioning of instructions and data (SIMD or MIMD) across hundreds of computing elements (usually 32-bit or 64-bit MPUs). Computing elements usually have memory dedicated to them ranging from a few megabytes to hundreds. IBM's PowerPC-based SP1 and Thinking Machines CM-5, whose systems are SPARC-based, are examples of upcoming parallel offerings.

Semiconductor Opportunities

Semiconductor opportunities are as follows:

- Key opportunities exist for 32/64-bit MPUs with clock frequencies ranging from 66 MHz to 300 MHz. Useful multiprocessing features are emerging on new MPUs. Many systems will be employing MPUs to manage overhead and I/O functions independent of the main CPU group. Symmetrically and massively parallel systems are requiring multiple CPUs per system.
- In cases where standard buses are used with x86, MIPS, or SPARC MPUs, system logic ASSP chipsets will find opportunity. System logic will remain an ASIC opportunity with the proprietary architectures. CMOS and BiCMOS ASIC system logic opportunities exist for DRAM management, serial and parallel I/O control, and bus controllers.

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- In the local communications area, opportunities for controller ICs and transceivers include local interconnect movement to SCSI/III for fast or wide-bus control of disks and their arrays (also for redundant arrays of inexpensive disks, or RAID). Fiber Channel is an emerging interconnect technology endorsed by the workstation and AS/400 communities. It is scalable to 1.6 Gbps and employs low-cost optical transceivers. High performance parallel interface (HiPPI) (800 to 1,600 Mbps), and IBM's ESCON (Enterprise Systems Connection) (200 Mbps) are examples of other high-speed communications buses in use.
- Increasingly the large/fast systems are turning to commodity CMOS DRAMs for main/extended memory as their architectures evolve. Midrange systems will require in the hundreds of megabytes, and mainframe/supercomputers will require several gigabytes. High-speed DRAM alternatives such as synchronous DRAMs could find early adoption in these large systems. SRAMs are being relegated to primarily a cache role, but higher speeds will be needed to catch up with processor speeds.

Systems and Semiconductor Market

Tables 4-2 through 4-4 present Dataquest's worldwide forecast for the midrange, mainframes, and supercomputers and accompanying semiconductor demand. Supercomputers and their massively parallel variants are the fastest-growing performance category. Mainframes are expected to decline in growth as networked midrange-based systems and LAN-based clusters of PCs and workstations continue displacement of the large machines in certain applications. Likewise, midrange system growth is being clipped by the PC LAN clusters as well. Across all performance categories, server versions oriented toward providing resources (storage, computing, and printing, among others) to LAN clusters are growing rapidly.

The midrange semiconductor market should reach $8.5 billion by 1999, with mainframes and supercomputers reaching $1.1 billion and $385 million, respectively. Overall, the opportunity for CMOS/BiCMOS ASICs/ASSPs and 32/64 bit microprocessors will exceed $4 billion in 1999. DRAM comprises about half of the midrange opportunity, whereas it is a smaller portion of mainframe and supercomputer content.

OEMs

Table 4-5 lists the key OEMs in each of the three areas ranked by revenue market share. Cray remains dominant in the supercomputer market. IBM, with Unisys and the big three Japanese computer companies, continues to dominate the mainframe market. The midrange market remains much more fragmented with IBM and Digital controlling 31 percent.

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Table 4-2
Worldwide and North American Supercomputer Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	0.8	1.2	1.2	1.4	1.6	1.8	2.1	12.4
Factory ASP ($K)[1]	2,199	1,677	1,617	1,518	1,388	1,251	1,132	-7.6
Factory Revenue ($M)	1,855	1,930	2,005	2,087	2,181	2,268	2,339	3.9
Semiconductor Content ($)	188,313	181,984	200,219	223,384	209,246	192,946	186,294	0.5
Main Memory ($)	46,173	63,755	77,364	95,937	84,038	71,955	69,176	1.6
Megabytes per System – OEM	760	1,000	1,250	1,500	1,900	2,400	2,800	22.9
Megabytes per System – Upgrade	860	1,300	1,600	2,100	2,500	2,800	3,100	19.0
Average Megabytes per System	1,534	2,170	2,690	3,390	4,150	4,920	5,590	20.8
Cache ($)	3,600	4,200	4,800	6,000	7,200	8,400	9,600	18.0
Megabytes per System	1.50	1.75	2.00	2.50	3.00	3.50	4.00	18.0
Logic/Microcomponent ($)	127,544	105,645	109,969	113,856	111,067	106,336	101,859	-0.7
Others ($)	10,995	8,385	8,086	7,590	6,942	6,255	5,659	-7.6
Semiconductor Market ($M)	159	209	248	307	329	350	385	12.9
Main Memory/DRAM ($M)[2]	39	73	96	132	132	130	143	14.3
Cache/SRAM ($M)	3	5	6	8	11	15	20	32.6
Logic/Microcomponent ($)	108	121	136	156	174	193	210	11.6
Others ($M)	9	10	10	10	11	11	12	3.9
North America Production ($M)	1,510	1,565	1,600	1,665	1,745	1,805	1,870	3.6
North America Semiconductor Market ($M)	129	170	198	245	263	278	308	12.6

[1] Less standard peripherals
[2] With memory upgrade
Source: Dataquest (August 1995)

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Table 4-3
Worldwide and North American Mainframe Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	8.8	9.5	8.9	8.4	8.0	7.8	7.5	-4.6
Factory ASP ($K)[1]	1,964	1,746	1,730	1,694	1,666	1,611	1,566	-2.2
Factory Revenue ($M)	17,310	16,606	15,360	14,270	13,342	12,508	11,758	-6.7
Semiconductor Content ($)	145,409	141,389	154,500	166,978	170,201	170,531	175,740	4.4
Main Memory ($)	19,274	21,407	28,052	35,092	30,932	26,426	26,396	4.3
Megabytes per System—OEM	310	380	490	610	740	870	990	21.1
Megabytes per System—Upgrade	367	387	539	700	875	1,041	1,270	26.8
Average Megabytes per System	640	729	975	1,240	1,528	1,807	2,133	24.0
Cache ($)	2,400	3,000	3,600	4,800	6,000	7,200	8,400	22.9
Megabytes per System	1.00	1.25	1.50	2.00	2.50	3.00	3.50	22.9
Logic/Microcomponent ($)	113,915	108,252	114,197	118,613	124,939	128,851	133,114	4.2
Others ($)	9,820	8,730	8,651	8,472	8,329	8,053	7,830	-2.2
Semiconductor Market ($M)	1,281	1,344	1,371	1,406	1,363	1,324	1,319	-0.4
Main Memory/DRAM ($M)[2]	170	204	249	295	248	205	198	-0.5
Cache/SRAM ($M)	21	29	32	40	48	56	63	17.2
Logic/Microcomponent ($)	1,004	1,029	1,013	998	1,000	1,000	999	-0.6
Others ($M)	87	83	77	71	67	63	59	-6.7
North America Production ($M)	5,703	6,080	5,828	5,112	5,416	5,047	5,111	-6.5
North America Semiconductor Market ($M)	442	492	520	504	553	534	573	-0.2

[1] Less standard peripherals
[2] With memory upgrade
Source: Dataquest (August 1995)

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Table 4-4
Worldwide and North American Midrange Computer Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	500.1	500.5	530.2	546.4	573.7	590.0	606.6	3.9
Factory ASP ($K)[1]	41	38	36	35	34	33	32	-3.2
Factory Revenue ($M)	20,591	19,329	19,523	19,659	19,777	19,856	19,956	0.6
Semiconductor Content ($)	8,847	10,542	11,717	15,722	15,095	14,176	14,024	5.9
Main Memory ($)	4,455	6,229	7,248	10,980	10,247	9,126	8,935	7.5
Megabytes per System—OEM	130	140	180	280	380	480	560	32.0
Megabytes per System—Upgrade	20	80	80	120	140	160	180	17.6
Average Megabytes per System	148	212	252	388	506	624	722	27.8
Cache ($)	133	129	117	134	95	77	66	-12.5
Megabytes per System	0.75	1.00	1.00	1.25	1.50	1.50	1.50	8.4
Logic/Microcomponent ($)	4,056	3,995	4,171	4,430	4,584	4,807	4,861	4.0
Others ($)	203	190	181	177	170	166	162	-3.2
Semiconductor Market ($M)	4,424	5,276	6,212	8,590	8,660	8,364	8,507	10.0
Main Memory/DRAM ($M)[2]	2,228	3,117	3,843	6,000	5,878	5,384	5,420	11.7
Cache/SRAM ($M)	67	64	62	73	54	45	40	-9.1
Logic/Microcomponent ($)	2,028	1,999	2,212	2,421	2,630	2,836	2,949	8.1
Others ($M)	101	95	96	97	97	98	98	0.6
North America Production	9,073	8,825	8,859	8,424	9,480	9,303	9,909	-0.5
North America Semiconductor Market ($M)	1,950	2,409	2,819	3,681	4,151	3,919	4,224	8.8

[1] Less standard peripherals
[2] With memory upgrade
Source: Dataquest (August 1995)

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Table 4-5
1994 Computer System Worldwide Revenue Market Share (Percent)

Supercomputer	Percent	Mainframe	Percent	Midrange	Percent
Cray Research	37.0	IBM	40.8	Hewlett-Packard	18.2
ATT/GIS	14.5	Hitachi	11.1	IBM	16.3
IBM	11.7	Fujitsu	9.7	Digital	8.2
Fujitsu	9.7	Unisys	7.7	Fujitsu	6.7
Hitachi	8.2	Siemens	7.4	Sun	5.2
Others	18.9	Others	23.4	Others	45.5

Source: Dataquest (August 1995)

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Chapter 5
Storage Application Markets

Storage Market Trends

RDD

RDD market trends are as follows:

- Rigid disk drives (RDD) will remain the dominant computer mass storage medium.
- 3.5-inch RDD will continue to dominate the width with growing but modest presence from 2.5-inch-and-below varieties, which are employed principally in mobile computers. Type III PCMCIA cards can embody 1.8-inch RDDs.
- More than half the RDDs shipped in 1997 will have densities exceeding 1GB. The move to more memory-intensive software based on Windows 95 will continue raising user storage needs considerably in PC applications. The storage of multimedia (audio and video) data as well as rasterized images will become more popular, driving need up as well.
- RAID technology is emerging as a solution for corporate server storage and video server storage for movies on demand in the infant interactive TV market.
- RDD product life cycles are running about one year.

Optical Disk Drives

Optical disk drive (ODD) market trends are as follows:

- ODDs, especially CD-ROM drives, continue surging in sales.
- CD-ROM demand comes from a burgeoning home multimedia market where drives are being incorporated into the system or via upgrade (by kit or standalone) by the end user. Home users are using CD-ROM drives for reference (for example, encyclopedias), education, and games. CD-ROM drives are appearing on many servers and workstations as a software distribution mechanism.
- Rewritable optical drives as comprised principally of magneto-optical (MO) technology are growing modestly as manufacturers work out compatibility and cost reduction issues. Higher capacities in the RDD market also are hurting this market development. The most popular will be 3.5-inch versions.

Tape and Flexible Drives

Tape and flexible drive market trends are as follows:

- With heavy use as PC server and workstation backup devices, 1/4-inch cartridge tape will remain the dominant tape drive device throughout the forecast period. The DC-2000 1/4-inch version, which fits into 3.5-inch bays, will grow to be the dominant version.
- Helical scan technology based on either digital audio tape (DAT) at 4mm, camcorder technology at 8mm, or VHS-type technology will show growth somewhat above average.

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- 3.5-inch, 1.44MB flexible disk drive (FDD) technology is expected to remain dominant throughout the forecast period, whereas 5.25-inch versions are in rapid decline as users become comfortable with one standard. Those 2.88-inch versions are expected to remain a small portion of the market.

Storage Electronics Trends

RDD

RDD market trends are as follows:

- IBM's partial response maximum likelihood (PRML) technology for the RDD read channel is battling with conventional peak detection approaches. PRML appears to be moving into the mainstream with the promise of 20 to 30 percent density improvements.
- Read channel technology is rapidly moving from the 40-Mbps range to 240 Mbps as densities climb, and motor speeds move from 3,000 rpm toward 10,000 rpm. Error correction and new encoding schemes are required (for example, advanced Reed-Solomon, block CRC).
- Thin-film inductive heads are rapidly ramping to the mainstream, achieving two-thirds' share of the head market by 1996. Magneto-resistive (MR) heads are emerging but will not achieve 20 percent share until 1996.
- Figure 5-1 presents an outlook for RDD interface types. Enhanced IDE and refinements are expected to retain the lion's share, but SCSI will grow aggressively on a unit basis. New technologies such as IEEE Fiber Channel Arbitrated Loop, 1394/Firewire, and serial storage architecture (SSA) are vying for a higher-performance/lower-cost interface role in the future.

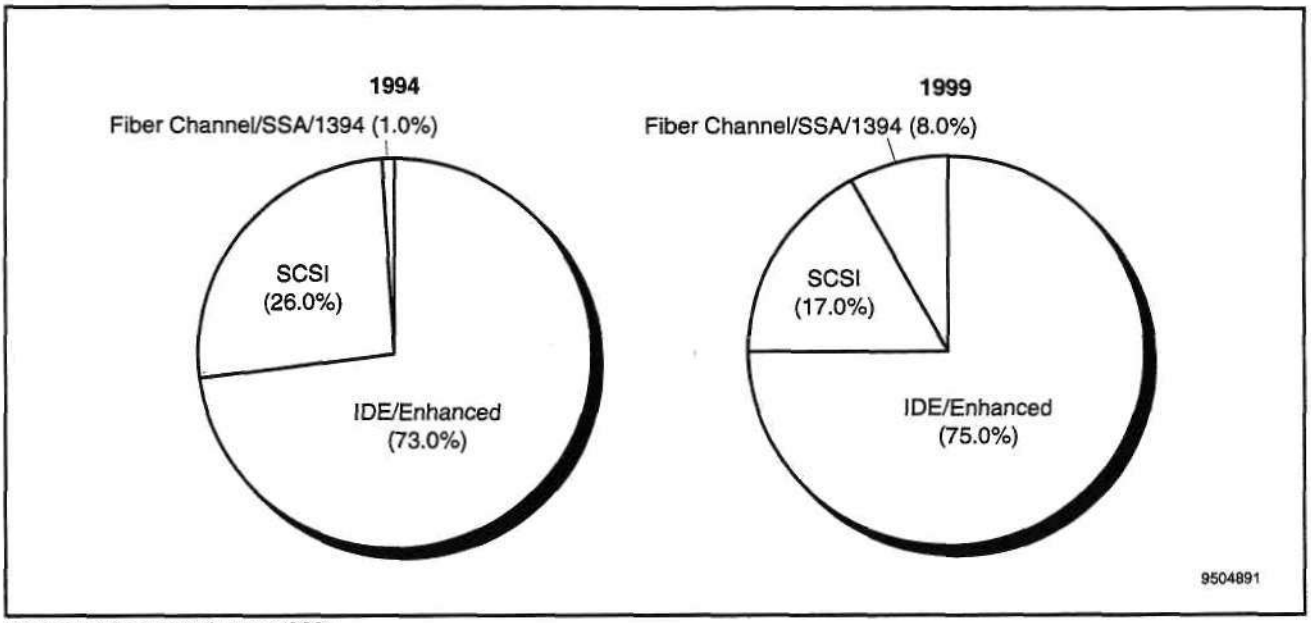
Optical Drives

Optical disk drive market trends are as follows:

- Table 5-1 shows key specification trends of CD-ROMs. 4x-speed (600 KB/sec) CD-ROM drives are rapidly becoming the volume leader. 6x drives are on the horizon as shipments are ramping up.
- The IDE interface has enhanced with what is known as the ATA Packet Interface (ATAPI). One of the impacts is the enablement of CD-ROM to operate with a mainstream IDE interface. Table 5-2 shows the features enhanced IDE will have, versus those of traditional IDE and SCSI. Up to four storage devices are allowed, plus an effective doubling of transfer rate. An additional benefit is the addressability of partitions greater than 520MB. The enhanced IDE standard has become the predominant storage interface standard during the last 12 months.
- Expect 9.3GB optical drive capable of storing 135 minutes of MPEG compressed movies for digital video disks (DVD) to fill the market in late 1996 or early 1997. Higher densities are being enabled by a move from red to blue lasers with shorter wavelengths. Multilayer disk technology has been demonstrated by IBM as a way to increase density.

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Figure 5-1
RDD (5.25-Inch and Less) Interface Mix



Source: Dataquest (August 1995)

Table 5-1
Defining Characteristics of High-End and Entry-Level CD-ROM Drives

High-End Products	
Average Access Time (ms)	<220
Transfer Rate (KB/sec.)	600-1,200
Multisession Capability (Photo-CD)	Yes
Caddy Design or Tray Loading	Both
Interface	SCSI or enhanced IDE
Entry-Level Products	
Average Access Time (ms)	<280
Transfer Rate (KB/sec.)	600
Multisession Capability	Yes
Cadd Design Tray Loading	Both
Interface	Enhanced IDE

Source: Dataquest (August 1995)

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Table 5-2
Comparison among Storage Interfaces

	AT-IDE	SCSI	Enhanced IDE
Peripherals	Limited type – only 2 hard disks	Multiple types – CD-ROM, tape, and hard disk drives	Four IDE devices with dual-channel IDE and more with multiple IDE connectors; IDE CD-ROM; IDE tape
Drive Capacity	Limited – 528MB	High-capacity drives	Up to 8.4GB of hard disk capacity
Transfer Rates	Limited host transfer rates – 2MB-3MB PIO to 5.5MB with local bus	5 and 10 MB/sec.; with high end, up to 40 MB/sec.	Increase data transfer rates with IDE drives to 11 to 13 MB/sec.
Cable Length	18 inches	6m	18 inches
Focus		Both in-box and out-box solution	Primarily in-box solutions

Source: Western Digital, Dataquest (August 1995)

Architecture and Semiconductor Opportunities

Figure 5-2 is a block diagram of a generic RDD controller. An optical drive block diagram looks similar but involves a laser diode/detector and support circuitry and occasionally audio-processing features. State-of-the-art, mainstream, 500MB, 3.5-inch RDDs typically are implemented with 9 ICs; four with pin counts exceeding 40 pins.

New semiconductor opportunities exist for:

- Enhanced single-chip read/write channels for PMRL (240 Mbps or greater) (mixed-signal, bipolar, and CMOS/BiCMOS)
- DSP-based motion control for higher densities and spindle speeds (mixed-signal and CMOS/BiCMOS)
- Improved ECC, enhanced IDE interface, and EPROM embedded controllers (CMOS)
- Preamps to handle thin film and MR technology
- ASIC/megacell versions of the functions described
- DRAM/SRAM, slow, 256Kb to 1Mb
- CD-ROM standard chipsets for similar functions as RDD
- Blue laser (650nm) for higher optical storage densities
- Lower-cost MO read channel/controller ICs
- Lossless data compression ICs for tape storage

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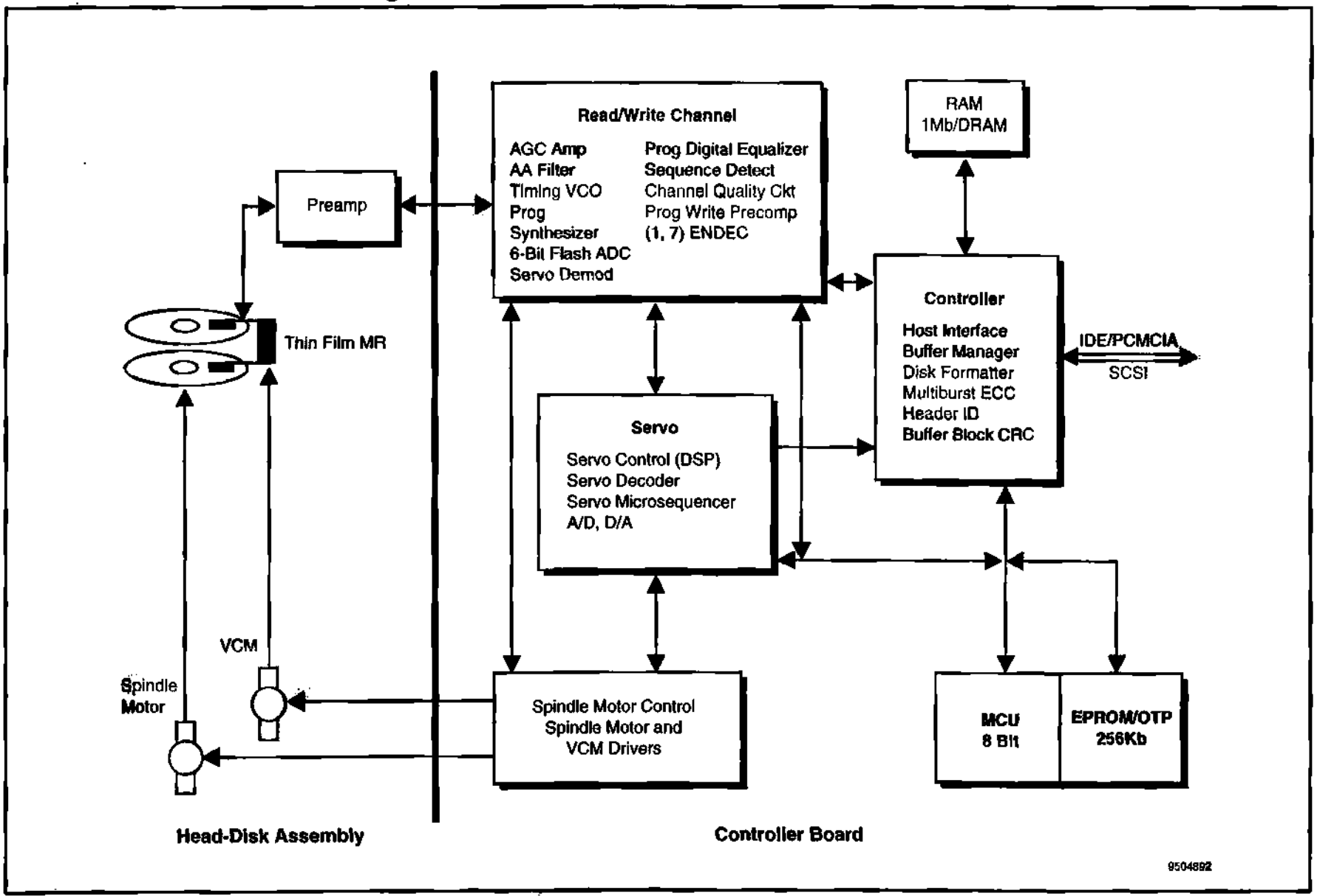
Tables 5-3 through 5-8 present both system and semiconductor content data for RDDs, ODDs, tape drives, and FDDs. The RDD semiconductor market is expected to reach $4.4 billion by 1999, while the ODD market ramps aggressively to nearly $1 billion from $355 million in 1993. The biggest opportunity in RDDs will remain ASSP functional. The tape and FDD chip markets are expected to reach $573 million and $294 million, respectively, by 1998.

OEMs

Table 5-9 shows the leading OEMs in each of the storage technologies. Quantum has jumped into the lead on a quantity basis in the RDD market. Panasonic/Matsushita is out in front in optical drive shipments, based on strong multimedia relationships. HP and TEAC are the leaders in the tape and FDD areas, respectively.

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Figure 5-2
Generic RDD Controller Block Diagram



Source: Cirrus Logic, Dataquest (August 1995)

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Table 5-3
Worldwide Rigid Disk Drive Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)								
1.8 Inch	97.8	295.3	329.0	933.0	2,430.0	4,900.0	12,120.0	110.2
2.5 Inch	5,459.9	8,146.7	10,906.0	14,870.0	19,066.0	23,860.0	27,420.0	27.5
3.5 Inch	44,433.2	60,234.3	68,656.0	74,828.0	89,020.0	106,700.0	116,900.0	14.2
5.25 Inch	1,157.0	515.6	250.0	110.0	18.0	7.2	4.0	-62.2
8-10 Inch	277.4	142.3	42.4	17.2	4.0	2.0	0	-100.0
Total	51,425.3	69,334.2	80,183.4	90,758.2	110,538.0	135,469.2	156,444.0	17.7
ASP ($)								
1.8 Inch	251.0	239.7	194.7	253.3	264.6	184.5	192.6	-4.3
2.5 Inch	260.5	240.3	237.3	186.5	150.9	146.0	146.8	-9.4
3.5 Inch	248.5	213.0	182.0	194.5	178.8	170.3	153.9	-6.3
5.25 Inch	1,229.9	1,419.5	1,445.9	1,569.1	1,466.7	1,433.3	1,200.0	-3.3
8-10 Inch	14,441.5	11,467.0	8,943.4	3,860.5	2,000.0	1,600.0	0	-100.0
Revenue ($M)								
1.8 Inch	24.5	70.8	64.1	236.3	643.0	904.1	2,334.3	101.2
2.5 Inch	1,422.3	1,957.7	2,588.0	2,773.3	2,877.1	3,483.6	4,025.3	15.5
3.5 Inch	11,041.7	12,829.9	12,495.4	14,554.0	15,916.8	18,171.0	17,990.9	7.0
5.25 Inch	1,423.0	731.9	361.5	172.6	26.4	10.3	4.8	-63.4
8-10 Inch	4,006.1	1,631.8	379.2	66.4	8.0	3.2	0	-100.0
Total	17,917.6	17,222.0	15,888.1	17,802.6	19,471.2	22,572.1	24,355.3	7.2

Source: Dataquest (August 1995)

Table 5-4
Worldwide Rigid Disk Drive Forecast by Density (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
0-30MB	58.0	1.0	0	0	0	0	0	-100.0
31-60MB	1,954.0	17.0	5.0	0	0	0	0	-100.0
61-100MB	5,263.9	218.6	11.0	1.0	0	0	0	-100.0
101-200MB	19,438.5	8,104.6	1,535.0	594.0	756.0	300.0	120.0	-56.9
201-500MB	18,238.7	42,459.2	35,510.0	17,980.0	9,950.0	4,610.0	8,120.0	-28.2
501-1000MB	2,517.5	11,655.8	28,200.0	37,502.0	43,880.0	37,800.0	24,700.0	16.2
1.1-2GB	2,573.1	4,288.3	9,068.4	19,763.2	31,006.0	53,851.0	58,000.0	68.4
2.1-4GB	1,381.6	2,255.9	4,458.0	9,818.0	15,764.0	22,902.2	40,300.0	78.0
4.1+GB	0	333.8	1,396.0	5,096.0	9,182.0	16,006.0	25,204.0	137.5
Total	51,425.3	69,334.2	80,183.4	90,754.2	110,538.0	135,469.2	156,444.0	17.7

Source: Dataquest (August 1995)

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Table 5-5
Worldwide Rigid Disk Drive Semiconductor Market

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Content ≤2.5 Inches ($)	38.52	37.51	36.86	36.26	35.70	35.20	-1.8
Semiconductor Market ≤2.5 Inches ($M)	325	421	582	779	1,027	1,392	33.8
Semiconductor Content≥3.5 Inches ($)	38.72	36.01	35.36	34.76	34.20	33.70	-2.7
Semiconductor Market ≥3.5 Inches ($M)	2,357	2,483	2,650	3,095	3,650	3,939	10.8
Semiconductor Content All RDD ($)	38.69	36.22	35.62	35.05	34.52	34.08	-2.5
Semiconductor Market All RDD ($M)	2,682	2,904	3,233	3,874	4,677	5,331	14.7
Memory	428	519	632	825	1,078	1,322	25.3
Analog	824	802	889	1,062	1,275	1,443	11.9
Microcontroller	395	435	471	547	640	708	12.4
ASIC/ASSP	981	1,086	1,171	1,357	1,583	1,743	12.2
Standard Logic	32	36	41	49	59	68	16.1
Discrete	22	25	29	34	42	48	16.4
North America Production							
Drives (K Units)	2,850	2,600	2,400	2,000	1,900	1,800	-8.8
Drives (ASP $)	680	645	635	580	541	520	-5.2
Drives (Revenue $M)	1,938	1,677	1,524	1,160	1,028	936	-13.5
Semicoductor Content ($)	116	118	122	123	120	118	0.3
Semiconductor Market ($M)	329	307	292	246	228	212	-8.4

Source: Dataquest (August 1995)

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Table 5-6
Worldwide Optical Disk Drive Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
CD-ROM Drives (K Units)	6,740.0	17,966.0	28,540.1	33,650.0	37,800.0	41,000.0	43,000.0	19.1
CD-ROM Drives (ASP $)	140.0	114.0	102.0	90.0	80.0	75.0	70.0	-9.3
CD-ROM Drives (Revenue $M)	943.6	2,048.1	2,911.1	3,028.5	3,024.0	3,075.0	3,010.0	8.0
Semiconductor Content ($)	41.6	29.2	26.0	24.0	21.5	19.6	17.3	-10.0
Semiconductor Market ($M)	280.2	524.9	742.3	806.8	813.2	802.3	743.5	7.2
WORM/Rewritable (K Units)	374.7	595.5	719.5	770.1	817.6	865.0	903.1	8.7
WORM/Rewritable (Revenue $M)	494.1	643.9	616.7	599.8	558.8	518.0	548.5	-3.2
Semiconductor Content ($)	201.8	162.2	142.3	168.2	216.0	254.5	258.1	9.7
Semiconductor Market ($M)	75.6	96.6	102.4	129.6	176.6	220.2	233.1	19.3
Total Optical (K Units)	7,114.7	18,561.5	29,259.6	34,420.1	38,617.6	41,865.0	43,903.1	18.8
Total Optical (Revenue $M)	1,437.7	2,692.0	3,527.8	3,628.3	3,582.8	3,593.0	3,558.5	5.7
Semiconductor Content ($)	50.0	33.5	28.9	27.2	25.6	24.4	22.2	-7.9
Semiconductor Market ($M)	355.8	621.5	844.7	936.3	989.7	1,022.4	976.6	9.5
North America Production								
Drives (K Units)	68	116	229	294	369	456	478	32.7
Drives (ASP $)	445	317	295	275	252	238	225	-6.6
Drives (Revenue $M)	30	37	67	81	93	108	108	23.9
Semiconductor Content ($)	76	67	60	55	52	49	40	-9.8
Semiconductor Market ($M)	5	8	14	16	19	22	19	19.7

Source: Dataquest (August 1995)

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Table 5-7
Worldwide Tape Drive Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Tape Drives (K Units)	3,920.1	4,869.8	5,917.2	6,795.9	7,571.0	8,270.7	8,967.1	13.0
Tape Drives (ASP $)	545.6	446.0	452.8	436.3	396.7	355.4	336.3	-5.5
Tape Drives (Revenue $M)	2,138.7	2,171.8	2,679.5	2,964.8	3,003.4	2,939.1	3,015.5	6.8
Semiconductor Content ($)	87.3	73.6	77.0	76.3	71.4	65.7	63.9	-2.8
Semiconductor Market ($M)	342.2	358.3	455.5	518.8	540.6	543.7	572.9	9.8
North America Production								
Drives (K Units)	1,443.4	2,107.8	2,510.1	2,956.9	3,121.6	2,999.3	2,738.3	5.4
Drives (ASP $)	654.7	535.2	543.4	523.5	476.0	426.4	403.5	-5.5
Drives (Revenue $M)	945.0	1,128.0	1,364.0	1,548.0	1,486.0	1,279.0	1,105.0	-0.4
Semiconductor Content ($)	104.7	88.3	92.4	91.6	85.7	78.9	76.7	-2.8
Semiconductor Market ($M)	151.2	186.1	231.9	270.9	267.5	236.6	210.0	2.4

Source: Dataquest (August 1995)

Table 5-8
Worldwide Flexible Disk Drive Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Flexible Drives (K Units)	68,070.0	75,200.0	83,123.1	85,905.2	87,700.0	88,300.0	86,250.0	2.8
Flexible Drives (ASP $)	35.7	29.4	25.1	21.5	20.1	20.1	20.1	-7.4
Flexible Drives (Revenue $M)	2,433.0	2,210.2	2,088.5	1,849.0	1,766.2	1,772.0	1,730.2	-4.8
Semiconductor Content ($)	5.0	4.3	3.8	3.3	3.2	3.3	3.4	-4.4
Semiconductor Market ($M)	340.6	320.5	313.3	286.6	282.6	292.4	294.1	-1.7

Source: Dataquest (August 1995)

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Table 5-9
Leading Storage OEMs (1994 Unit Percentage Share)

Rigid Disk Drives	
Quantum	23.1
Seagate	18.7
Conner	15.8
IBM	11.5
Maxtor	6.9
Toshiba	2.8
Samsung	2.7
Fujitsu	1.7
Digital	1.1
Hewlett-Packard	1.0
Others	14.7
Optical Drives	
Panasonic	39.8
Mitsumi	14.0
Sony	13.2
NEC	8.9
Toshiba	7.5
Sanyo	2.2
Philips	1.6
Plexter	1.5
Fujitsu	1.1
IBM	0.4
Others	9.8
Tape Drives	
Hewlett-Packard	41.0
Conner	25.3
Rexon	7.8
Tandberg	6.4
Iomega	6.2
Exabyte	4.8
Mountain Network	2.6
Sony	1.6
AIWA	0.7
Quantum	0.6
Others	3.0

(Continued)

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Table 5-9 (Continued)
Leading Storage OEMs (1994 Unit Percentage Share)

Flexible Drives	
Mitsumi	18.0
TEAC	16.8
Sony	11.9
Panasonic	9.9
Seiko Epson	9.7
Mitsubishi	7.2
Citizen	5.0
Y-E Data	4.9
NEC	4.8
Alps	4.3
Others	7.5

Source: Dataquest (August 1995)

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Chapter 6
Printer Application Markets

Printer Market Trends

Printer market trends are as follows:

- The small office/home office market continues to drive much of the low-end printer market growth for economical ink jet and laser versions.
- Dot matrix technology is being displaced rapidly by ink jet technology on the low end of the market. Ink jet technology is now a larger market than dot matrix.
- 300 dots per inch (dpi) laser/LED technology page printers are being replaced by true 600-dpi laser/LED and higher-quality 300-dpi ink jet technology.
- 1,200-dpi technology is deployed into the high end of page printer market.
- The 1-to-6-pages-per-minute (ppm) and the greater-than-10-ppm page printers have the fastest growth.
- New high-speed serial and parallel interfaces are emerging (P1394 and Bi-Tronics).
- Both Adobe's PostScript Level 2 and HP's PCL 5 font technology are becoming more prevalent in mid- and low-end page printers.
- Corporate page printers are upgradable with NICs and 8 to 16MB of DRAM memory. Low-end page printers are shipping with only 1MB of memory as host rasterization rendering emerges.
- Color page printers remain expensive. It should be some time before they become economical and mainstream. Color "capable" and full-color ink jets rapidly are becoming the majority in that market.
- HP continues to dominate both the laser printer and ink jet segments.
- Multifunction (printer, fax, copier) systems are beginning to see market ramp-up.

Printer Electronics Trends and Semiconductor Opportunities

Printer electronics trends and semiconductor opportunities are as follows:

- Basic page printer functions include description language processing (for example, PostScript), edge enhancement, rasterization, video buffer management, and marking engine control (see Figure 6-1). Serial/ink jet printers have many of the same basic features but lack the memory intensity and have different print engine/head technology.
- PostScript and PCL, the major page printer description languages, process the outline of the character and fill it in. They are capable of an infinite number of point sizes. PostScript Level 2 has built-in compression and memory management to conserve buffer size. Companies such as Destiny, Peerless, Lexmark, and Phoenix Technologies have created

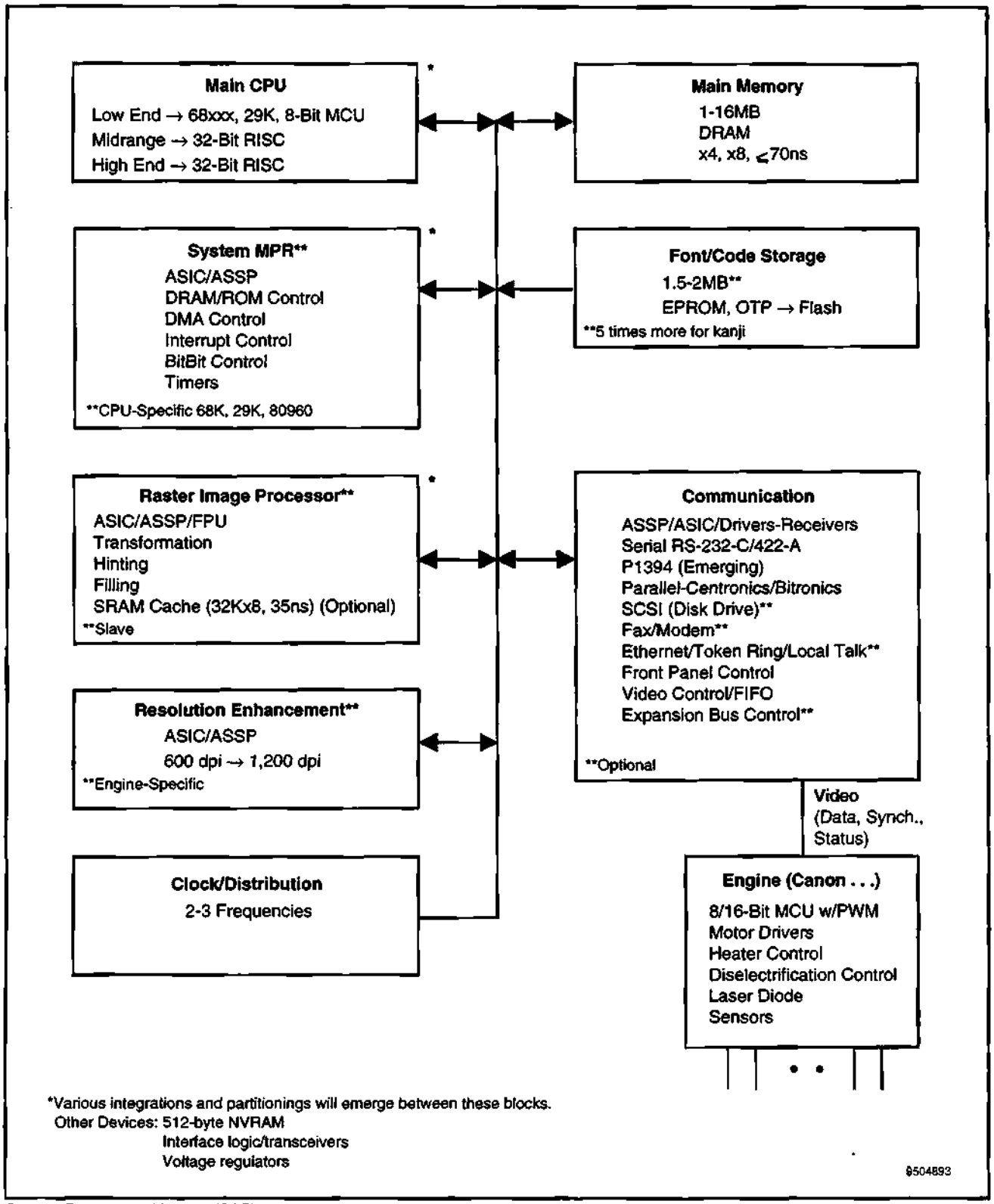
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PostScript-like interpreters. High-performance printers are capable of dealing with emulation switching automatically. Hardware accelerators or FPUs are optional in some designs to speed processing up.

- Host rasterization with Adobe's Type Manager or Microsoft's TrueImage to support WYSIWYG display could displace much of the rasterization process done on the printer. This creates the concept known as host-based printing. Pentium or PowerPC-based systems under multitasking operating systems (such as Windows 95) should be able to do this easily. This opens a market opportunity for "not-so-smart" page printers.
- EPROM/flash is required for both font and description language processing interpreter code. High-end printers have nonvolatile storage to support 35 or more fonts plus interpreter code. In these cases, 16Mb or more nonvolatile storage is required. 2MB EPROM flash most likely will become the norm by 1999. Most serial and low-end page printers have at least 256Kb for storing various bit-mapped fonts. Asian character sets will require four to six times that amount.
- The other memory array on a printer is the DRAM-based data or raster buffer. Description language printers can require 2MB to 4MB minimally. Future mainstream page printer requirements, as configured by the OEM, will double to 4MB by 1999. Lossless hardware data compression is being considered to accelerate the compressed buffer storage/retrieval process. Networked printers can require 10 times this amount of DRAM. In some cases SRAM buffers are used if speed is essential.
- Either 8-bit MCUs or an embedded 16-bit MPU are employed on serial printers. Page printers have evolved from being primarily 68K-based to relying primarily on the Intel 80960, AMD 2920X, Weitek, or MIPS architectures. High-end page printers use 25- and 33-MHz processors.
- Edge enhancement was popularized by HP's Resolution Enhancement Technology (RET), which could take 300-dpi technology and effectively turn it into 600-dpi technology. Now this has evolved to where 600-dpi is being sharpened into 1,200 dpi. Companies such as XLI, Destiny, and DP-Tek lead a list of independent resolution-enhancement providers. This usually comes in the form of an ASSP ($8 to $12).
- Oki, Panasonic, and TI (Samsung) lead a list of OEMs that have turned to LED arrays for the marking page printer engine technology. Canon, Matsushita, Minolta, and Lexmark lead a list of at least a dozen engine makers. Most engines involve power discretes (up to 400V), motor/actuator drivers, and sensors. Serial printers also involve motor controls, plus printhead circuits (pin driver or ink cartridge).
- Communications interfaces choices include RS-232, RS-422, Centronic parallel, Bi-Tronics parallel, SCSI, and the common LAN standards. Much recent talk has centered around using P1394 (Firewire), a low-cost (six conductors), high-performance link (100 MB/sec).
- Page printers with a wattage use of less than 30W to 45W when idle can qualify for the coveted U.S.-based Energy Star label.

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Figure 6-1
Next-Generation Laser Printer Controller



Source: Dataquest (August 1995)

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Tables 6-1 to 6-7 show the market outlook for serial and page printers and accompanying semiconductor demand for worldwide and North American markets. Worldwide serial printer shipments are expected to reach 32 million units by 1999, while page printers will reach 13.5 million units. The serial printer chip market is expected to exceed $830 million and the page printer chip market to reach $1.4 billion in 1999.

About 60 percent of the page printer opportunity is for DRAM and nonvolatile memory, with ASSP/ASICs, and 32-bit MPUs growing in the double-digit range. Average serial printer semiconductor content will remain at about $26, where page printer content will ride the memory price per bit curve until settling at about $102.

Table 6-1
Worldwide Printer Market Forecast (Thousands of Units)*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Serial	20,281	22,055	24,358	26,166	27,944	30,057	31,841	7.6
Serial Ink Jet	8,315	12,130	14,128	17,270	20,399	24,046	27,065	17.4
Full-Color Ink Jet	1,247	3,275	4,521	6,390	8,568	11,301	13,532	32.8
Page	5,903	7,096	7,967	8,976	10,315	11,801	13,500	13.7
1-6 ppm	2,833	3,548	4,143	4,847	5,673	6,609	7,695	16.7

*Based on worldwide estimates
Source: Dataquest (August 1995)

Table 6-2
Worldwide Average Serial Printer Semiconductor Content (Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Volatile Memory	2.6	2.6	2.6	3.1	2.3	3.3	3.7	7.1
Nonvolatile Memory	4.8	3.6	3.6	3.6	3.6	3.6	3.6	0
MPU/MCU	4.8	4.8	4.9	4.9	4.9	4.9	4.9	0.4
ASSP/ASIC	5.0	5.0	5.0	5.1	5.2	5.4	5.4	1.6
Analog/Logic	12.4	11.5	11.0	10.1	9.5	8.3	8.3	-6.3
Discrete	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0
Optoelectronic	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
Total Semiconductor	30.1	27.9	27.6	27.3	25.9	25.9	26.3	-1.2

Source: Dataquest (August 1995)

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Table 6-3
Worldwide Serial Printer Semiconductor Market (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Volatile Memory	52.7	57.3	64.1	82.3	62.9	97.7	116.8	15.3
Nonvolatile Memory	97.3	79.4	87.7	94.2	100.6	108.2	114.6	7.6
MPU/MCU	97.3	105.9	119.4	128.2	136.9	147.3	156.0	8.1
ASSP/ASIC	101.4	110.3	121.8	133.4	145.3	162.3	171.9	9.3
Analog/Logic	251.5	253.6	267.9	264.3	265.5	249.5	264.3	0.8
Discrete	7.1	7.5	8.3	8.9	9.5	10.2	10.8	7.6
Optoelectronic	2.0	2.2	2.4	2.6	2.8	3.0	3.2	7.6
Total Semiconductor	609.4	616.2	671.6	713.9	723.5	778.2	837.6	6.3

Source: Dataquest (August 1995)

Table 6-4
Worldwide Average Page Printer Semiconductor Content (Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Volatile Memory	44.6	53.8	55.2	55.4	48.6	45.5	39.6	-5.9
Nonvolatile Memory	50.3	49.0	48.0	36.8	29.9	26.9	28.0	-10.6
MPU/MCU	12.0	12.0	12.5	12.5	12.3	12.1	12.1	0.2
ASSP/ASIC	12.5	12.2	12.2	12.2	12.2	12.2	12.2	0
Analog/Logic	7.3	7.3	7.3	7.3	7.3	7.3	7.3	0
Discrete	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0
Optoelectronic	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0
Total Semiconductor	129.6	137.0	138.0	126.9	113.1	106.8	102.0	-5.7

Source: Dataquest (August 1995)

Table 6-5
Worldwide Average Page Printer Semiconductor Content (Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Volatile Memory	263.5	381.5	440.0	496.8	501.3	536.9	534.6	7.0
Nonvolatile Memory	297.0	347.4	382.4	330.3	308.6	317.2	378.0	1.7
MPU/MCU	70.8	85.2	99.6	112.2	126.9	142.8	163.4	13.9
ASSP/ASIC	73.8	86.6	97.2	109.5	125.8	144.0	164.7	13.7
Analog/Logic	43.1	51.8	58.2	65.5	75.3	86.1	98.6	13.7
Discrete	2.1	2.4	2.7	3.1	3.5	4.0	4.6	13.7
Optoelectronic	14.5	17.4	19.5	22.0	25.3	28.9	33.1	13.7
Total Semiconductor	764.8	972.2	1,099.6	1,139.4	1,166.7	1,260.0	1,376.9	7.2

Source: Dataquest (August 1995)

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Table 6-6
North American Serial Printer Production and Semiconductor Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	1,677	1,680	1,816	2,024	2,164	2,291	2,468	8.0
Factory ASP ($)	497	478	439	395	377	362	348	-6.1
Factory Revenue ($M)	834	802	798	800	816	830	858	1.4
Semiconductor Content ($)	25	38	36	33	32	32	31	-4.0
Semiconductor TAM ($M)	43	64	65	67	70	73	77	3.8

Source: Dataquest (August 1995)

Table 6-7
North American Page Printer Production and Semiconductor Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	1,688	1,812	1,866	1,979	2,122	2,276	2,606	7.5
Factory ASP ($)	1,129	1,115	1,170	1,170	1,112	1,053	989	-2.4
Factory Revenue ($M)	1,907	2,021	2,183	2,316	2,360	2,398	2,579	5.0
Semiconductor Content ($)	158	185	169	135	130	125	122	-8.0
Semiconductor TAM ($M)	266	335	315	267	276	285	318	-1.0

Source: Dataquest (August 1995)

OEMs

Table 6-8 shows the leading printer OEMs and their overall market share. HP continues its dominance of both the high-growth areas of page and ink jet printers.

Table 6-8
Leading Page Printer OEMs
(Based on North America and Europe 1994 Unit Market Share)

Company	Percent
Hewlett-Packard	54.0
Apple	6.8
Okidata	5.9
Lexmark	5.7
Brother	5.4
Epson	3.8
Lexmark	3.1
Others	15.3

Source: Dataquest (August 1995)

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Chapter 7
Input/Output and Dedicated Systems

Tables 7-1 through 7-10 detail system and semiconductor market data on selected computer I/O systems and high-volume dedicated systems such as copiers and expandable organizers.

Key Trends

Sound Boards

Key trends in sound boards are as follows:

- Market ramp-up continues through 1995, then saturation points are hit for the home market. PC motherboard embedded sound I/O becomes more prevalent in later years for "home" and mobile PC use.
- Microsoft has adopted DSP Group's TrueSpeech technology as a compression standard. Several vendors already support ADPCM for compression.
- Movement to 16 bit is nearly complete. Wave-table synthesis is rapidly becoming dominant.
- Key chip functions include FM and wave-table synthesis (1MB to 4MB ROM-based), ASSP/ASICs (mixed-signal and digital CMOS), audio amplifiers, and mixers. SCSI host adapters are found on many boards. IDE (fast IDE) is becoming more prevalent.

Graphics Boards

Key trends in graphics boards are as follows:

- There is steady replacement by embedded motherboard chips.
- Boards are moving to greater than 1Kx1K-pixel resolutions, accelerated BitBLT-based, 64-bit data paths, and RAMDAC technology moving from 85 MHz to 135 MHz. Also, digital video, 3-D, and sound capability are appearing in the high-end boards.
- VRAM, and especially EDO DRAM, is becoming more common. Minimal buffers start at 1MB and move to 4MB with optional SIMMs. Most high-end add-in boards have separate RAMDAC, and in some case digital video functions are being integrated.

Digital Video Boards

Key trends in digital video boards are as follows:

- There will be continued penetration into the multimedia content creator market (software title development, market communications, and training). Playback board growth will be limited to full-screen 15- to 30-fps acceleration. Other opportunities exist for TV tuner, capture pass through, and integrated audio and graphics boards.

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- MPEG 1 decode boards became popular in 1994 and are expected to become the dominant type of digital video cards. Use of MPEG chips on PC motherboards will begin in late 1995 on some models.
- Key semiconductor opportunities include compression decoders for MPEG and JPEG, among others (and encoders for real-time algorithms), PAL/NTSC to CCIR decoders and encoders, ASICs (CMOS), digital video processors (scaling, among others), and DRAM/VRAM pixels buffers.

Leading digital video board OEMs worldwide are ATI, Creative Technologies, Diamond Multimedia, FutureTel, IBM, Intel, Matrox, Media Vision, Optibase, Optivision, Orchid, Sigma Designs, SuperMac, and Video Logic.

Monitors

Key trends in monitors are as follows:

- Color will grow to 98 percent of the market in 1999.
- 15 inches will become the predominant size in 1995; 16/17 inches will be predominant in 1997.
- There will be a chip content of about $5 for primarily video amplifier (moving to 135 MHz) and CRT controls.

Copiers

Key trends in copiers are as follows:

- There will be a mature market in the traditional office; the home office is driving new volumes.
- Multifunction systems that combine the printing, fax, and copying functions are at last hitting the right price/performance points to attract buyers. Digital and color copiers (combine printing and scanning, among others) will emerge slowly as price and use patterns preclude early market ramp.
- There will be a modest semiconductor content oriented toward motor/actuator control and user interface (MPU/MCU).

Leading copier OEMs worldwide are Canon, Kodak, Konica, Minolta, Mita, Océ, Panasonic, Ricoh, Sharp, Toshiba, and Xerox.

Scanners

Key trends in scanners are as follows:

- Expanding desktop/digital document tool
- Bulk of market 300 dpi today, moving to 600 dpi; color is moving from 35 percent to 60 percent of market by 1999.
- Handheld projected to be 35 percent of the market by 1999
- Content includes linear CCD array, 8-bit MCU, ASICs, and DRAM

Leading scanner OEMs worldwide are HP, Apple, Canon, Mustek, Fujitsu, Microtech, and Logitech.

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Keyboards

The trend in keyboards is commodity items moving toward ergonomic and wireless versions.

Leading keyboard OEMs worldwide are Keytronic, Silitek, and MaxiSwitch.

Table 7-1
Worldwide Sound Board Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Board Units (M)	4.7	13.7	14.4	15.0	15.7	16.4	17.9	5.5
Board ASP ($)	93.0	64.6	50.0	44.0	39.0	35.0	32.0	-13.1
Board Factory Revenue ($M)	440.4	883.1	718.5	661.1	612.2	575.3	573.1	-8.3
Percentage of 16-Bit	65.0	97.0	99.0	100.0	100.0	100.0	100.0	
Semiconductor Content ($)	18.6	16.1	15.0	13.6	12.5	11.6	10.6	-8.1
Semiconductor Market ($M)	88.1	220.8	215.6	205.0	195.9	189.8	189.1	-3.0
ASSP/ASIC ($M)	37.0	94.9	92.7	84.0	74.4	72.1	71.9	-5.4
Synthesis ($M)	33.5	81.7	75.4	65.6	54.9	53.2	53.0	-8.3
Analog/Discrete ($M)	13.2	33.1	32.3	30.7	27.4	26.6	26.5	-4.4
Memory/Others ($M)	4.4	11.0	15.1	24.6	39.2	38.0	37.8	27.9

Source: Dataquest (August 1995)

Table 7-2
Worldwide Sound Board OEMs (1994 Unit Share)

Company	Percent
Creative Technologies/Labs	66
Aztech	19
Media Vision	4
Cardinal	3
Others	8

Source: Dataquest (August 1995)

Table 7-3
Worldwide Graphic Board Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Board Units (K)	4,020	8,423	8,408	8,846	9,466	9,924	10,191	3.9
Board ASP ($)	218	160	141	125	112	104	97	-9.5
Board Factory Revenue ($M)	876	1,344	1,187	1,109	1,064	1,030	988	-6.0
Semiconductor Content ($)	76	57	51	45	40	37	35	-9.5
Semiconductor Market ($M)	307	484	427	399	383	371	356	-6.0

Source: Dataquest (August 1995)

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Table 7-4
Worldwide Graphic Board OEMs (1994 Percentage)

Company	Percent
Diamond Computer	20
ATI	14
Matrox	14
RasterOps	13
Radius/SuperMac	10
Others	29

Source: Dataquest (August 1995)

Table 7-5
Worldwide Digital Video Board Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Board Units (K)	232.0	605.0	1,139.0	1,464.0	1,713.0	1,815.0	1,967.0	11.5
With Compression and/ or Decompression	35.0	169.0	448.0	589.0	695.0	744.0	580.0	5.3
With TV Tuner	30.0	100.0	250.0	340.0	425.0	500.0	750.0	24.6
Board ASP ($)	387.5	310.0	279.0	251.1	226.0	203.4	183.1	-8.1
Board Factory Revenue ($M)	139.5	187.6	317.8	367.6	387.1	369.2	360.1	13.9
Semiconductor Content ($)	92.9	87.8	78.2	67.2	57.5	52.8	48.2	-11.3
Semiconductor Market ($M)	21.6	53.1	89.1	98.4	98.5	95.9	94.8	12.3
TV Signal Processsing ($M)	0.5	1.5	3.8	5.1	6.4	7.5	11.3	49.6
Video Scaling/Processing ($M)	9.3	20.0	28.5	29.3	27.4	23.6	23.6	3.4
Compression/ Decompression ($M)	1.6	5.9	11.2	11.8	11.1	9.7	7.5	5.0
Memory (DRAM/VRAM) ($M)	9.1	22.7	40.0	45.0	45.1	46.0	42.6	13.4
Others ($M)	1.2	3.0	5.7	7.3	8.6	9.1	9.8	26.6

Source: Dataquest (August 1995)

Table 7-6
Worldwide Monitor Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
System Units (K)	33,865	41,227	48,211	55,422	61,243	68,836	76,725	13.2
System ASP ($)	356	352	356	366	368	375	364	0.7
System Factory Revenue ($M)	12,054	14,494	17,140	20,300	22,550	25,820	27,900	14.0
Semiconductor Content ($)	5	5	5	5	5	5	5	2.2
Semiconductor Market ($M)	157	188	231	274	304	361	391	15.7

Source: Dataquest (August 1995)

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Table 7-7
Worldwide Monitor Label/OEMs (1994 Percentage)

Company	Percent
Compaq	7
IBM	6
NEC	6
Apple	6
Samtron	4
Packard Bell	4
CTX International	4
Philips	3
Others	61

Source: Dataquest (August 1995)

Table 7-8
Worldwide Copier Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
System Units (K)	4,017.5	4,156.7	4,284.3	4,392.6	4,501.3	4,617.9	4,717.6	2.6
Personal Copiers (K)	853.2	900.1	938.7	972.0	1,004.7	1,036.5	1,077.2	3.7
Semiconductor Content ($)	60.0	65.0	65.0	66.0	66.0	66.0	66.0	0.3
Semiconductor Market ($M)	241.1	270.2	278.5	289.9	297.1	304.8	311.4	2.9

Source: Dataquest (August 1995)

Table 7-9
Worldwide Scanner Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
System Units (M)	2,405.0	2,934.1	3,579.6	4,295.5	5,068.7	5,829.0	6,411.9	16.9
Semiconductor Content ($)	74.0	73.0	75.0	77.0	79.0	79.0	79.0	1.6
Semiconductor Market ($M)	178.0	214.2	268.5	330.8	400.4	460.5	506.5	18.8

Source: Dataquest (August 1995)

Table 7-10
Worldwide Keyboard Application Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
System Units (K)	46,318.8	55,961.6	65,304.4	75,797.7	85,541.1	97,527.6	110,180.8	14.5
Semiconductor Content ($)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.2
Semiconductor Market ($M)	113.5	137.1	160.0	185.7	209.6	238.9	273.2	14.8

Source: Dataquest (August 1995)

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Market Analysis



Semiconductor Application Markets Worldwide

Market Analysis

PC OEMs Shift Cost of Memory to PC Buyers

Abstract: *The DRAM and PC markets are inherently intertwined: PCs consume more DRAM than any other application and DRAM is the largest single cost in a typical PC. The current dynamic between these two markets is increasingly interdependent because unit growth for PCs and their increasing memory requirements continue to create demand for DRAM. This high demand has kept prices up and has created a growing point-of-sale market for PC memory because PC OEMs are caught between consumer demands for more memory and relatively constant average selling prices for PCs. The average PC appears to have less memory than the average buyer demands, so PC buyers are adding more megabytes at the point of sale.*
By Geoff Ballew

PC and DRAM Markets Are Still Strongly Correlated

The high correlation between DRAM and personal computer revenue is tied to the fact that DRAM represents the largest single cost in a typical PC. When DRAM is in short supply, as it is now, PC OEMs are squeezed between demands for larger memory sizes and relatively constant (or even declining) PC prices. As process technologies improve, semiconductor devices are supposed to become smaller, faster, and cheaper, but the severe DRAM shortage has caused prices for many DRAM devices to increase from 1994 to 1995 rather than decrease. DRAM prices are expected to ease slightly from 1995 to 1996 and then follow a more traditional model where prices decline appreciably over time.

The higher DRAM prices affect the PC industry because most other components (notably microprocessors) are declining rapidly in price for a given performance. Larger microprocessors generally require larger amounts of memory, so computer buyers expect more memory to be offered in the basic models with relatively constant average selling prices. As long as

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DRAM prices were declining, PC OEMs could install more memory each year for about the same cost per system. Average selling prices for PCs have remained relatively constant over time because OEMs add as many features to new models as they can without increasing or compromising the historical price points. This strategy works well as long as component prices decline for a given capacity or level of performance. However, when the new models have a faster MPU, better graphics, and a larger rigid disk drive, users want more memory to complete the package. If memory prices do not decline at the rate that other components' prices decline, then OEMs are faced with either spending more per system on DRAM or configuring their models with less DRAM than buyers expect. Dataquest believes that the typical PC is underconfigured when it is shipped from the factory, and this creates increasing demand for add-in memory at the point of sale of the PC.

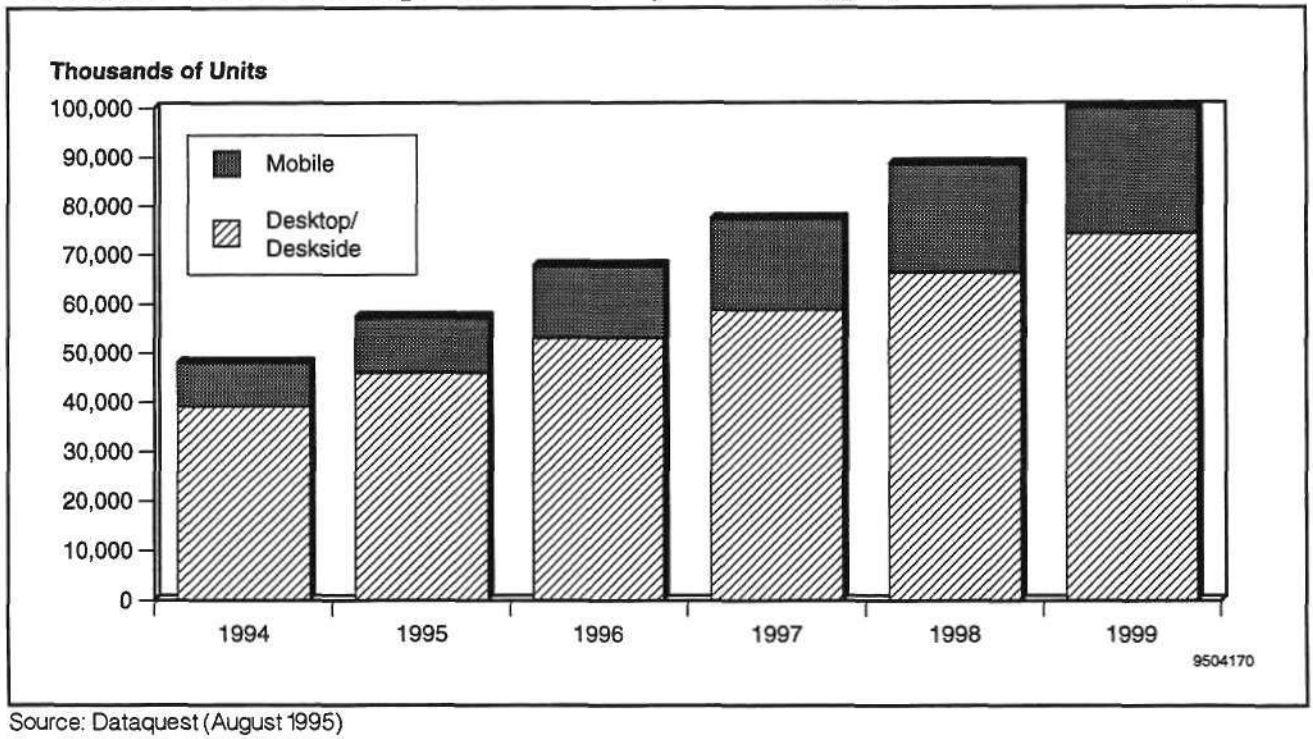
Tables 1 and 2 and Figures 1, 2, and 3 show the latest forecasts for worldwide PC unit shipments and revenue.

Table 1
Worldwide PC Market Shipment Forecast by Product Type (Thousands of Units)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Desktop/Deskside	39,219	45,984	53,056	58,815	66,421	74,419	13.7
Mobile	8,664	11,278	14,656	18,448	22,134	25,581	24.2
Total	47,883	57,262	67,712	77,263	88,555	100,000	15.9
Percentage Growth	22.3	19.6	18.2	14.1	14.6	12.9	

Source: Dataquest (August 1995)

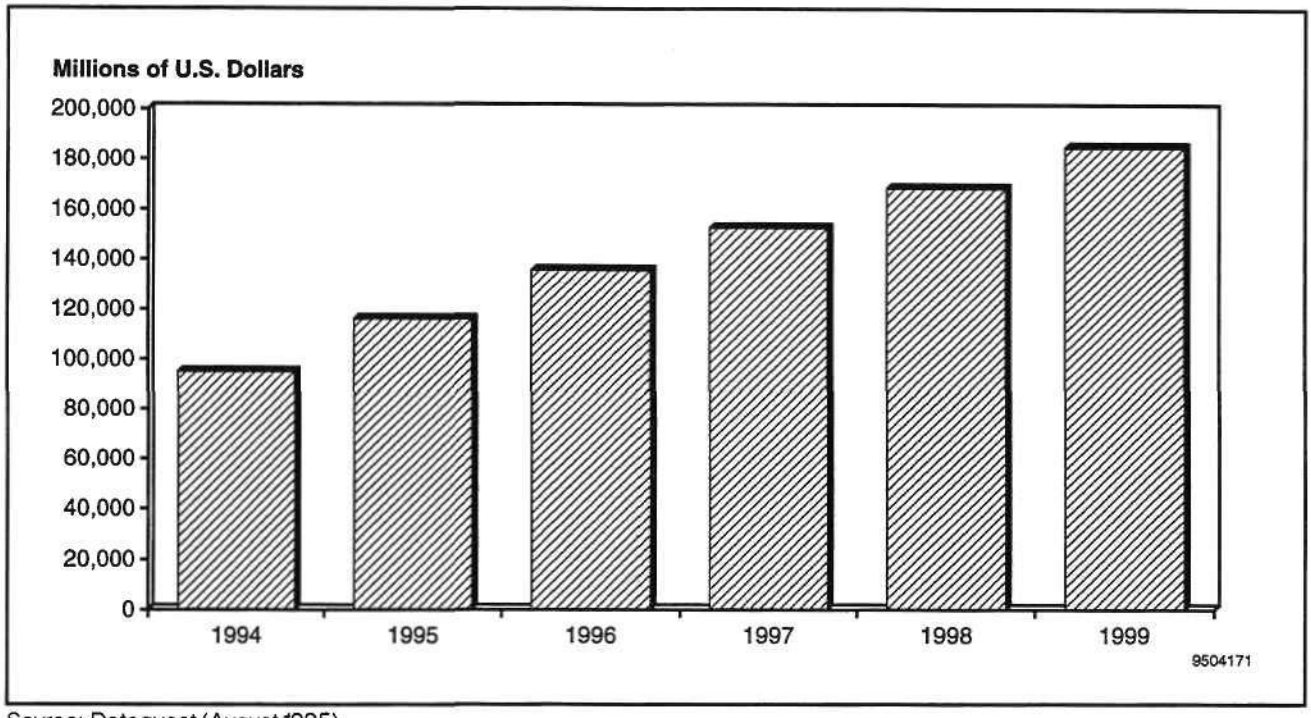
Figure 1
Worldwide PC Market Shipment Forecast by Product Type (Thousands of Units)



Source: Dataquest (August 1995)

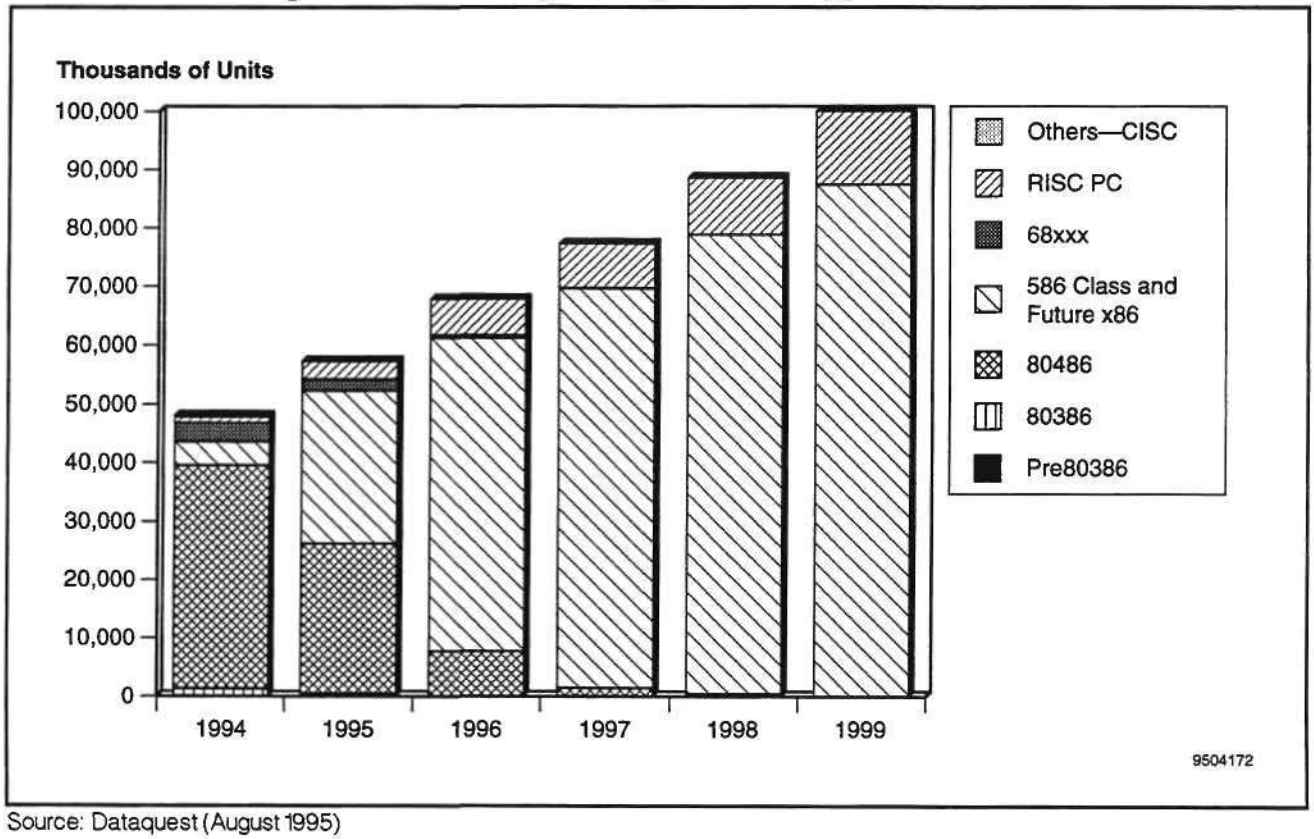
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Figure 2
Worldwide PC Market Revenue Forecast



Source: Dataquest (August 1995)

Figure 3
Worldwide PC Shipment Forecast by Microprocessor Type



Source: Dataquest (August 1995)

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Figure 3 shows PC unit shipments by microprocessor, with the numerical data in Table 2. The lion's share of PC units are forecast to have 586-class- and future x86 MPUs. Intel's rapid introduction of faster versions of the P54C (120-MHz and 133-MHz versions this spring alone) and aggressive pricing ensure that shipments of the Pentium MPU will increase at a record pace. The P6 is not broken out from the 586-class and future x86 category, but will have shipments of a couple of hundred thousand units by the end of this year and rapid growth in 1996 and 1997.

Dataquest Perspective

As a consequence of the short supply of DRAM, PC manufacturers are likely to produce PCs with less memory than the average user requires. This has the effect of passing on the cost of the memory to the consumer without significantly increasing the advertised price for the PC. Those buyers who demand additional memory will pay for it themselves, increasing the total market for point-of-sale memory revenue, which is not reflected in system unit prices. It is a "hidden" way of increasing the average selling price without impacting standard configuration prices. An additional benefit for the PC manufacturer is greater inventory flexibility. By reducing the total amount of DRAM their assembly operations consume, these manufacturers have reduced the probability that a DRAM inventory shortage will affect their production schedule.

Semiconductor vendors are advised to consider the point-of-sale upgrade market when planning their products. DRAM vendors should see a larger market outside of their large OEM accounts as more memory is added at the point of sale of PCs. Other semiconductor vendors may realize some benefit from this dynamic as PC OEMs search for ways to add features and value to their standard models without requiring more DRAM. Some examples might be a faster modem, better graphics controller, or audio features.

Figures 4 and 5 show a forecast for the average megabytes per system installed by the PC manufacturer (factory-installed megabytes) and the average megabytes per system purchased by the user at the point of sale (POS megabytes). The gap between the top line on both figures (total

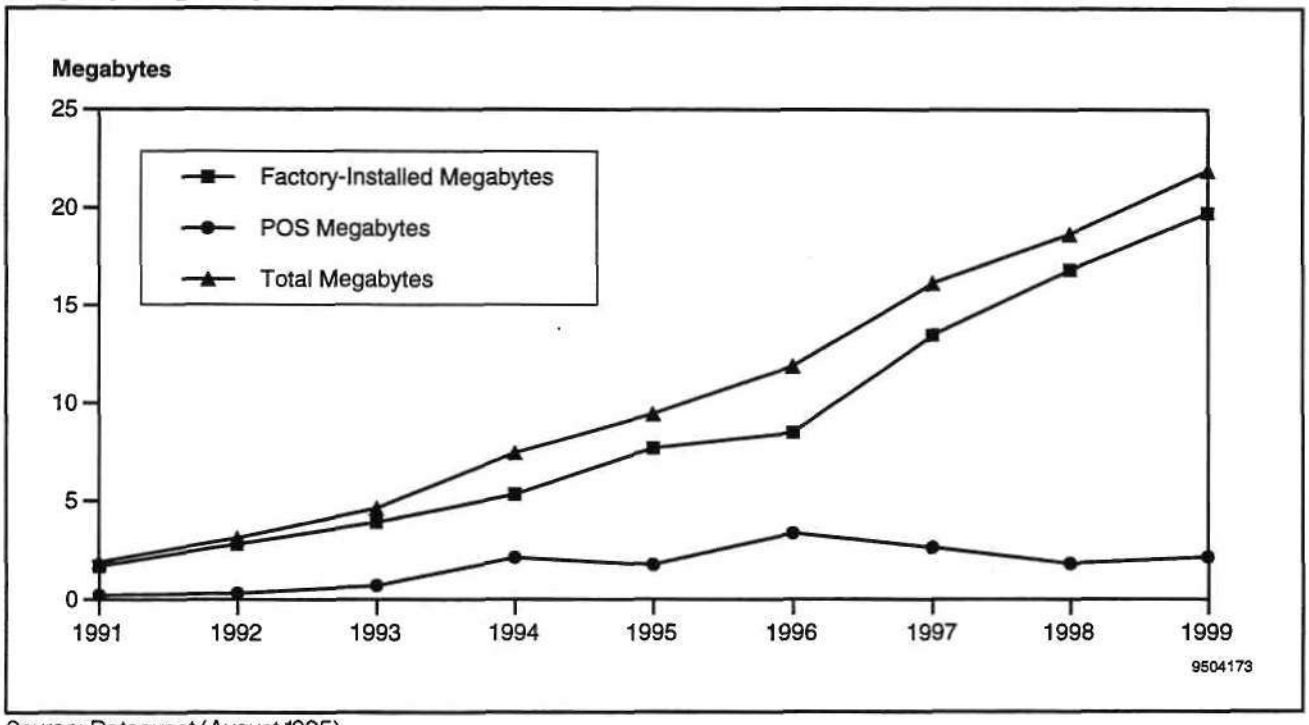
Table 2
Worldwide PC Shipment Forecast by Microprocessor Type (Thousands of Units)

	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Pre80386	32	0	0	0	0	0	-100.0
80386	1,323	530	0	0	0	0	-100.0
80486	38,261	25,748	7,801	1,490	494	0	-100.0
586-Class and Future x86	4,004	26,100	53,500	68,093	78,421	87,500	85.3
68xxx	3,214	1,950	426	140	0	0	-100.0
RISC PC	1,044	2,934	5,985	7,540	9,640	12,500	64.3
Others – CISC	3	0	0	0	0	0	-100.0
Total	47,883	57,262	67,712	77,263	88,555	100,000	

Source: Dataquest (August 1995)

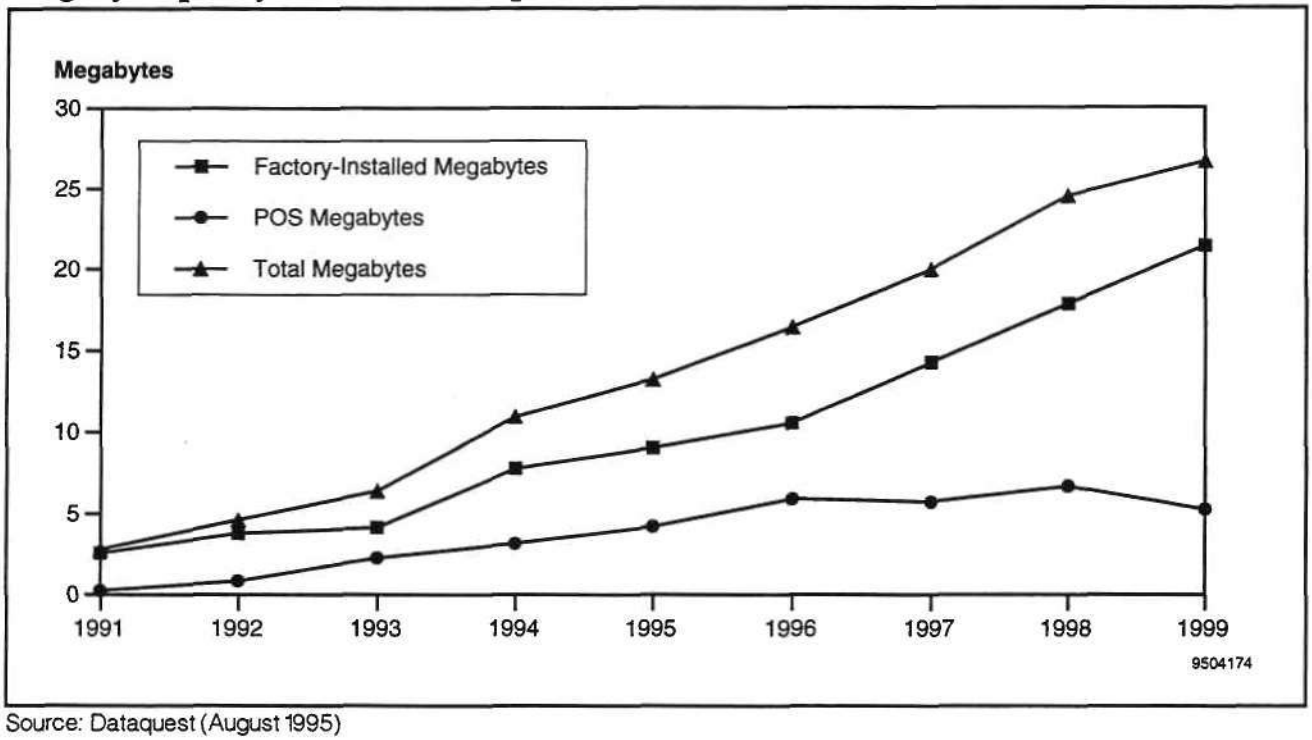
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Figure 4
Megabytes per System for Mobile PCs



Source: Dataquest (August 1995)

Figure 5
Megabytes per System for Desktop PCs



Source: Dataquest (August 1995)

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megabytes) and the factory-installed megabytes line is equal to the POS megabytes line. Figure 5 shows this best – the gap between total megabytes and factory-installed megabytes starts to increase in 1993 but gets wider and wider through 1994, 1995, and 1996. This gap represents the additional memory that PC buyers must purchase to have the systems they want.

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Market Analysis



Semiconductor Application Markets Worldwide

Market Analysis

Digital Drives Demand for Future Cellular/PCS Semiconductor Markets

Abstract: *This report provides details of Dataquest's forecast for the cellular and personal communications (PCS) markets. The number of cellular and PCS subscribers is predicted to grow to 251 million worldwide by 1999. This will drive annual cellular handset production to almost 100 million units by then, which will require $6.2 billion in semiconductors. A list of semiconductor companies supplying or planning to supply baseband products for this market is also included.*
By Dale Ford

Forecast: Cellular and PCS Markets Soar, Driving Major Growth in Wireless Semiconductors

The worldwide growth in cellular and PCS markets in 1994 was explosive. The number of cellular subscribers worldwide grew by 57 percent over 1993, driving the number of cellular handset shipments up 68 percent to 27.4 million units in 1994. In addition to the major growth taking place in Europe and developing regions, the North American market continues its robust growth. The number of cellular subscribers in North America grew by more than 44 percent in 1994, which resulted in cellular handset shipments growing by 50 percent to 13.5 million units. The number of cellular and PCS subscribers in the United States alone is predicted to reach 79 million by 1999. Tables 1 and 2 and Figures 1 through 4 illustrate this growth and Dataquest's forecast through 1999. Dataquest forecasts strong growth in the cellular and PCS markets to continue through 1999 as increased competition, enhanced services, and lower prices drive increased use of wireless services by current users and entrance to the market of new subscribers.

Dataquest

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Table 1
Worldwide Cellular and Broadband PCS Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Subscribers (K)	34,184	53,629	77,533	107,954	144,305	193,215	251,368	36.2
Handset Shipments (K)	16,300	27,397	36,230	47,687	59,869	80,146	99,836	29.5
Average Factory ASP ($)	478.13	435.61	389.49	349.95	314.02	281.37	252.71	-10.3
Handset Factory Revenue ($M)	7,794	11,934	14,111	16,688	18,800	22,551	25,229	16.2

Source: Dataquest (May 1995)

Table 2
North American Cellular and Broadband PCS Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Cellular Market								
Subscribers (K)	17,934	25,903	34,950	45,012	53,710	61,559	69,749	21.9
Handset Shipments (K)	9,008	13,491	17,225	20,938	22,715	24,555	27,313	15.2
Average Factory ASP ($)	451.87	423.01	377.57	339.09	301.86	268.98	243.18	-10.5
Handset Factory Revenue ($M)	4,071	5,707	6,504	7,100	6,857	6,605	6,642	3.1
Broadband PCS Market								
Subscribers (K)	-	-	-	500	2,000	9,000	15,750	
Handset Shipments (K)	-	-	-	500	1,570	7,380	8,910	
Average Factory ASP ($)	-	-	-	370.00	300.00	255.00	225.00	
Handset Factory Revenue ($M)	-	-	-	185	471	1,882	2,005	
Total Market								
Subscribers (K)	17,934	25,903	34,950	45,512	55,710	70,559	85,499	27.0
Handset Shipments (K)	9,008	13,491	17,225	21,438	24,285	31,935	36,223	21.8
Average Factory ASP ($)	451.87	423.01	377.57	339.81	301.74	265.75	238.71	-10.8
Handset Factory Revenue ($M)	4,071	5,707	6,504	7,285	7,328	8,487	8,647	8.7

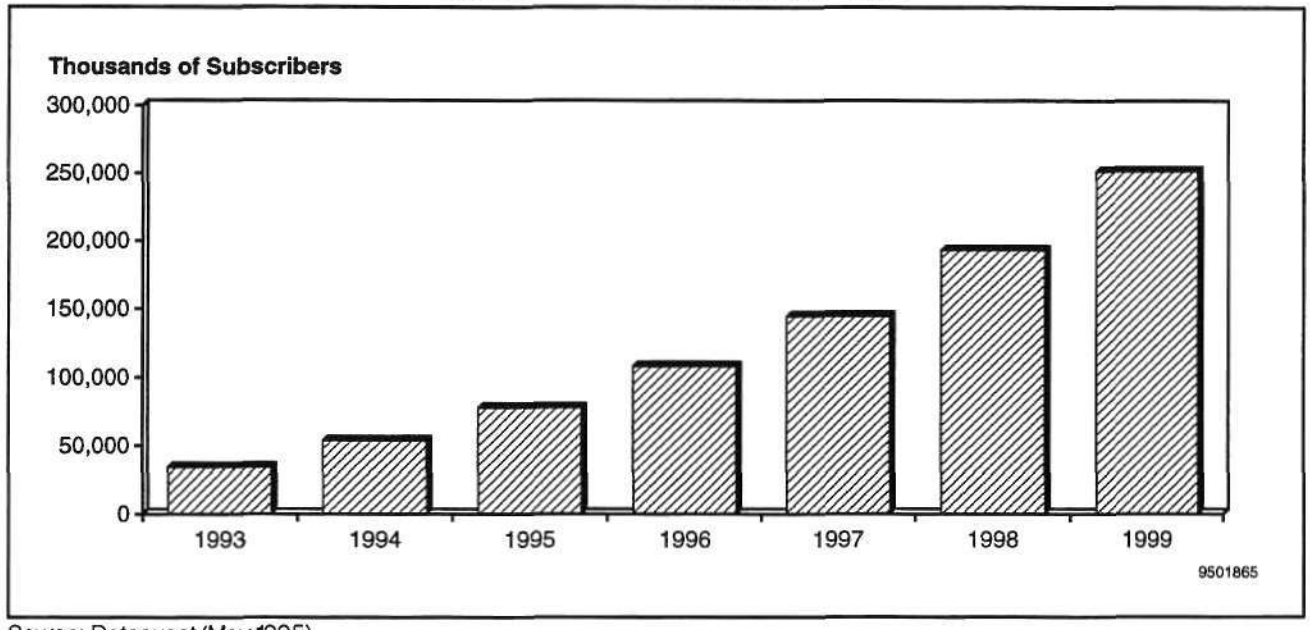
Source: Dataquest (May 1995)

Semiconductor suppliers to the cellular and PCS markets will both enable and benefit from this growth. New digital standards and advances in semiconductor technologies are providing improvements in fundamental areas important to both subscribers and service providers. Advanced semiconductors are extending talk time and stand-by time on cellular handsets, improving voice and transmission quality, and enabling new data services. These new technologies are also making wireless video communications possible. Service providers are benefiting from improved capacity in their networks and the ability to deliver new services to their subscribers.

As the fundamental enabler of these new wireless capabilities, semiconductor manufacturers stand to reap major rewards. Dataquest predicts the worldwide semiconductor market for cellular and PCS handsets to grow from $1.6 billion in 1994 to almost $6.3 billion by 1999, a 31.3 percent compound annual growth rate (CAGR). Semiconductor suppliers for handsets produced for North American markets and standards will also benefit from this growth. The demand for semiconductors in handsets produced in

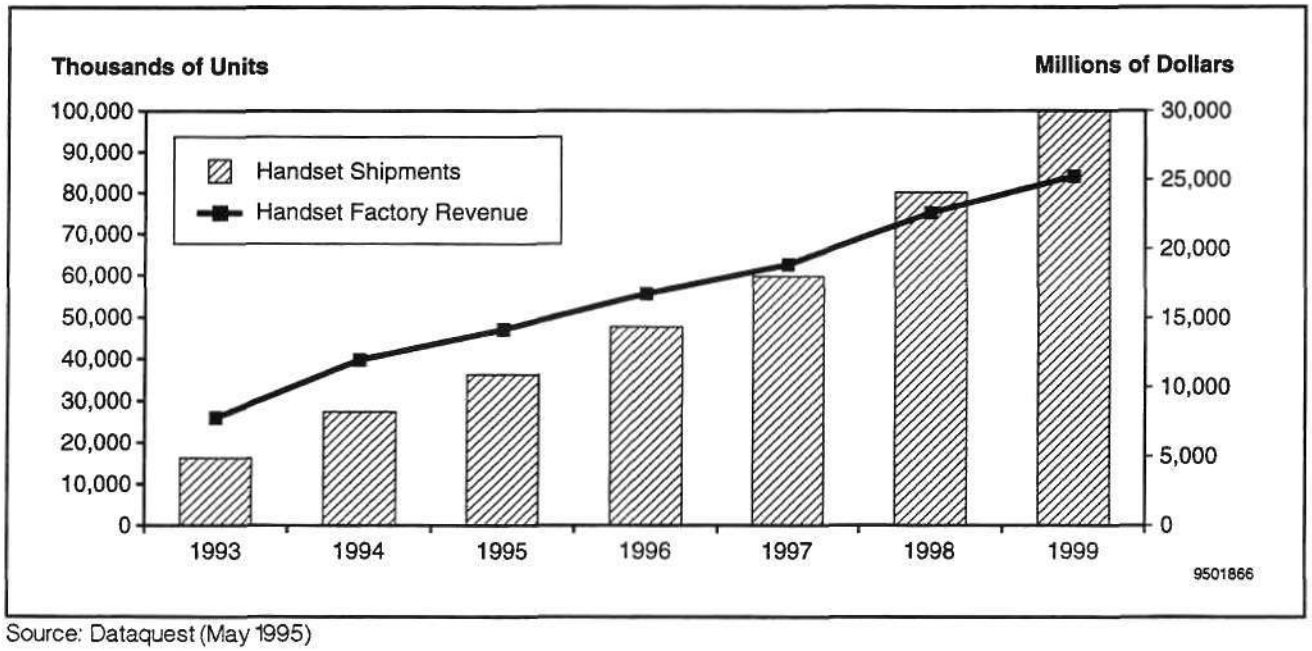
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Figure 1
Worldwide Cellular and Broadband PCS Subscriber Forecast



Source: Dataquest (May 1995)

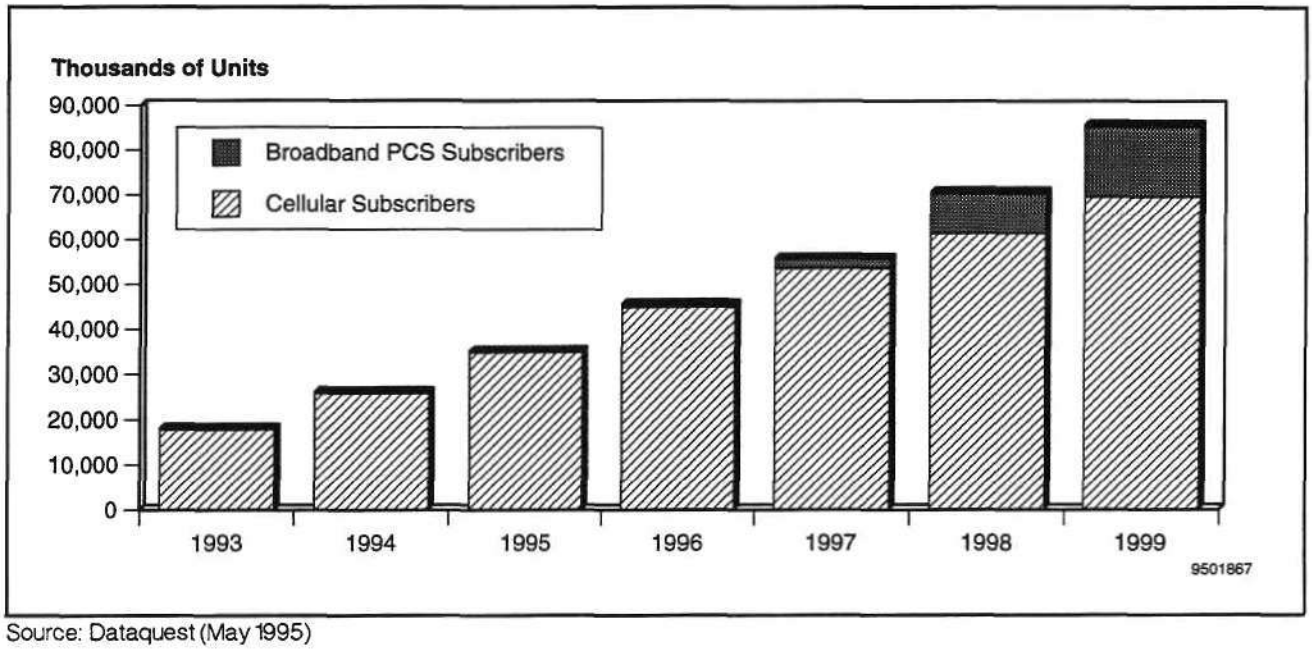
Figure 2
Worldwide Cellular and Broadband PCS Handset Market



Source: Dataquest (May 1995)

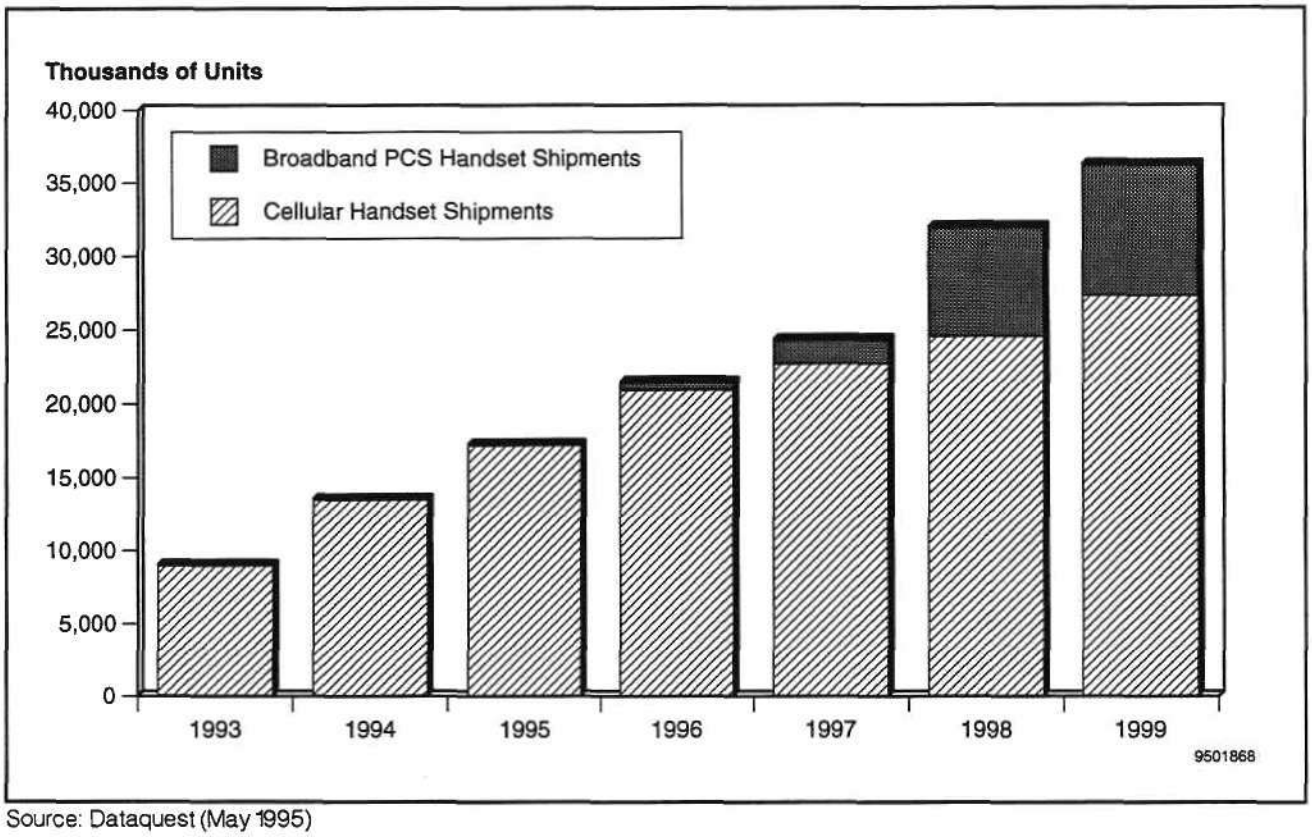
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Figure 3
North American Cellular and Broadband PCS Subscriber Forecast



Source: Dataquest (May 1995)

Figure 4
North American Cellular and Broadband PCS Handset Market



Source: Dataquest (May 1995)

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North America is forecast to grow from $526 million in 1994 to more than $2.2 billion in 1999. It is important to note that, although there is a definite distinction between cellular and PCS "dual-mode" handsets in North America now, this distinction will blur as the market moves to "dual-band" handsets approaching 1999. Tables 3 and 4 and Figures 5 through 8 illustrate Dataquest's forecast.

Table 3
Worldwide Cellular and Broadband PCS Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Analog Production								
Shipments (K)	14,871	22,537	24,370	24,690	23,011	20,814	15,705	-7.0
Factory ASP ($)	448	420	370	330	295	275	285	-7.5
Handset Factory Revenue ($M)	6,662	9,466	9,017	8,148	6,788	5,724	4,476	-13.9
Semiconductor Content ($)	43	42	42	43	43	43	45	1.4
Semiconductor Market ($M)	639	947	1,024	1,062	989	895	707	-5.7
Digital Production								
Shipments (K)	1,429	4,859	11,860	22,997	36,858	59,332	84,131	76.9
Factory ASP ($)	810	500	420	360	310	265	235	-14.0
Handset Factory Revenue ($M)	1,158	2,430	4,981	8,279	11,426	15,723	19,771	52.1
Semiconductor Content ($)	215	135	115	99	86	74	66	-13.3
Semiconductor Market ($M)	307	656	1,364	2,277	3,170	4,391	5,553	53.3
Total Production								
Shipments (K)	16,300	27,397	36,230	47,687	59,869	80,146	99,836	29.5
Factory ASP ($)	480	434	386	344	304	268	243	-11.0
Handset Factory Revenue ($M)	7,820	11,895	13,998	16,427	18,214	21,447	24,247	15.3
Semiconductor Market ($M)	947	1,603	2,387	3,338	4,159	5,286	6,259	31.3

Source: Dataquest (May 1995)

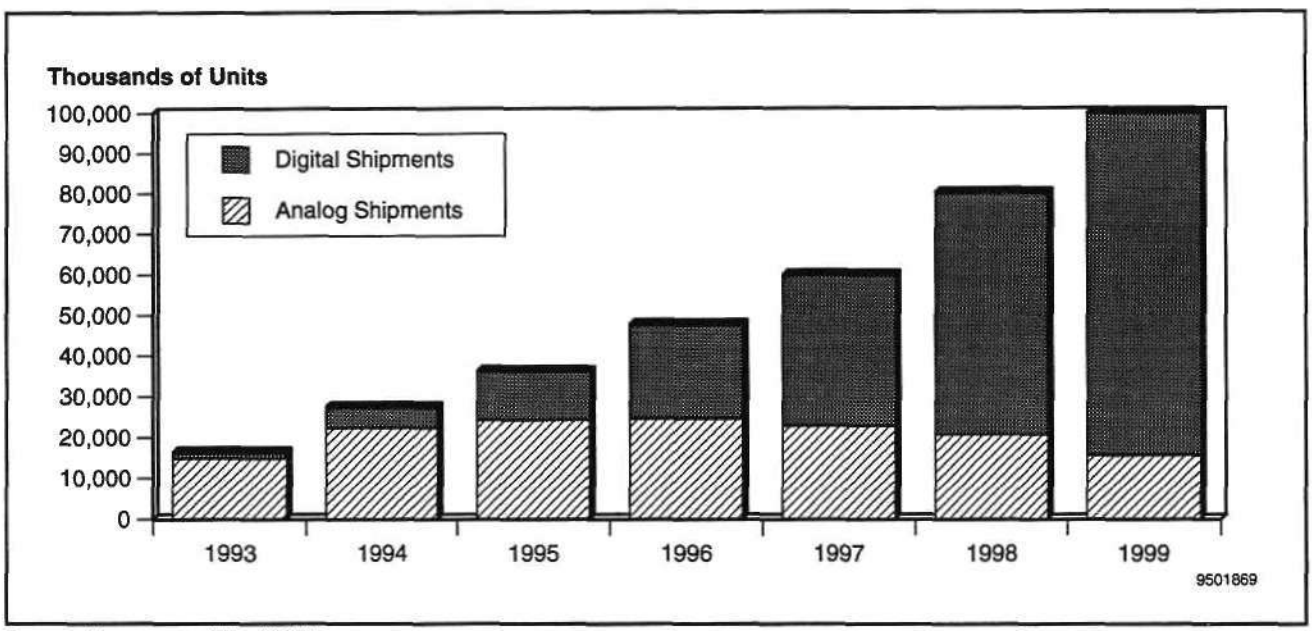
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Table 4
North American Cellular and Broadband PCS Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Analog Production								
Total Shipments (K)	7,628	11,120	12,863	13,280	11,593	9,381	4,310	-17.3
Factory ASP ($)	448	420	370	330	295	275	285	-7.5
Handset Factory Revenue ($M)	3,417	4,670	4,759	4,382	3,420	2,580	1,228	-23.4
Semiconductor Content ($)	43	42	42	43	43	43	45	1.4
Semiconductor Market ($M)	328	467	540	571	498	403	194	-16.1
Digital Production								
Total Digital Shipments (K)	119	434	2,295	6,269	11,298	21,351	30,601	134.2
Digital Factory ASP ($)	810	500	420	361	309	262	232	-14.2
Handset Factory Revenue ($M)	97	217	964	2,262	3,487	5,586	7,106	100.9
Total Semiconductor Content ($)	215	135	115	99	86	73	66	-13.4
Semiconductor Market ($M)	26	59	264	621	969	1,566	2,011	102.8
Total Production								
Shipments (K)	7,747	11,554	15,158	19,549	22,891	30,732	34,911	24.8
Factory ASP ($)	454	423	378	340	302	266	239	-10.8
Handset Factory Revenue ($M)	3,514	4,888	5,723	6,644	6,907	8,166	8,334	11.3
Semiconductor Market ($M)	354	526	804	1,192	1,467	1,969	2,205	33.2

Source: Dataquest (May 1995)

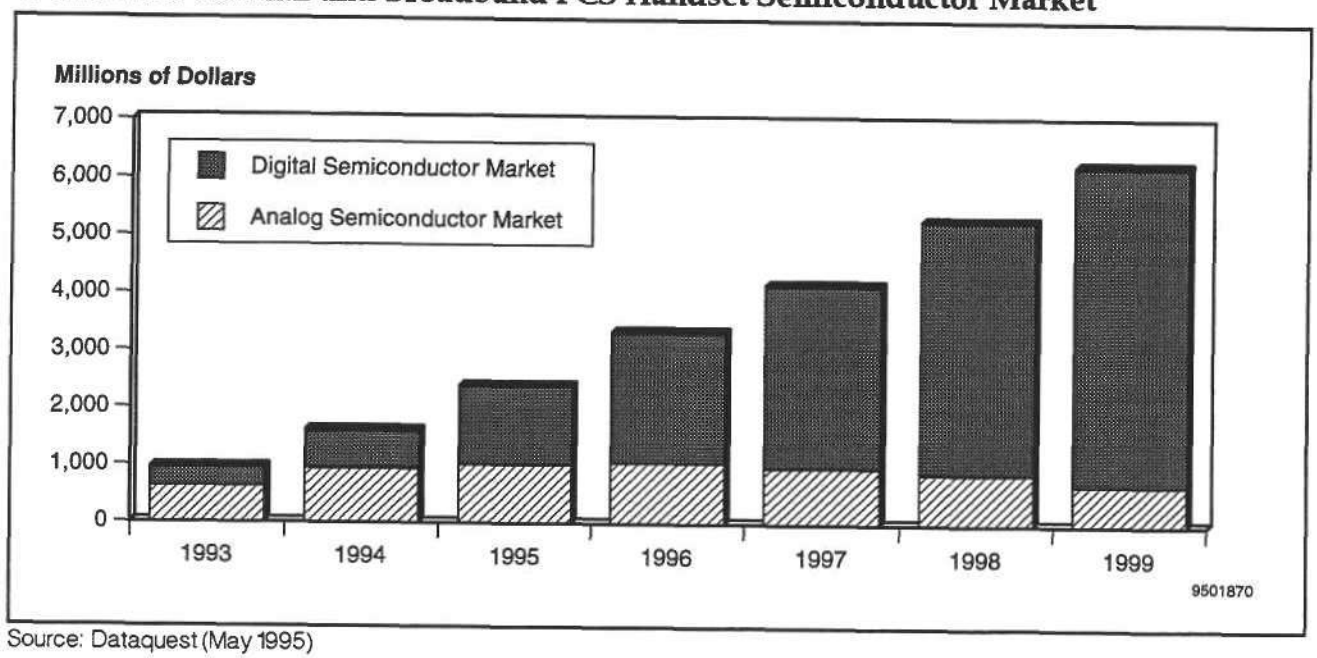
Figure 5
Worldwide Cellular and Broadband PCS Handset Production



Source: Dataquest (May 1995)

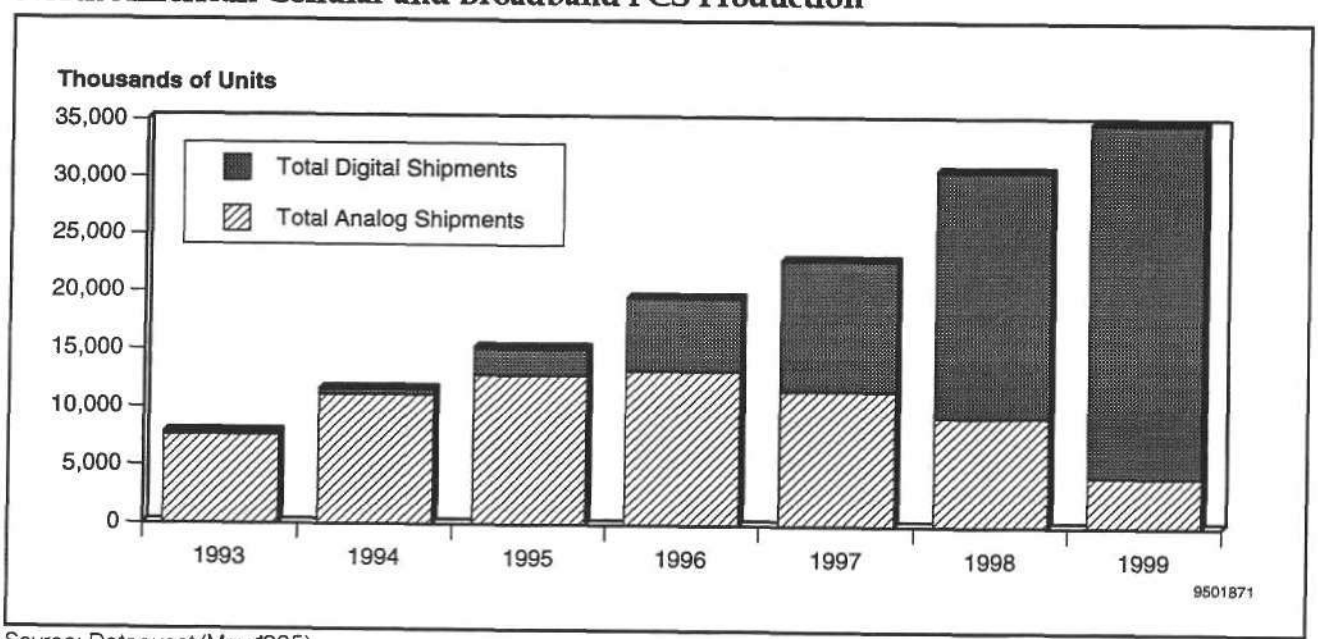
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Figure 6
Worldwide Cellular and Broadband PCS Handset Semiconductor Market



Source: Dataquest (May 1995)

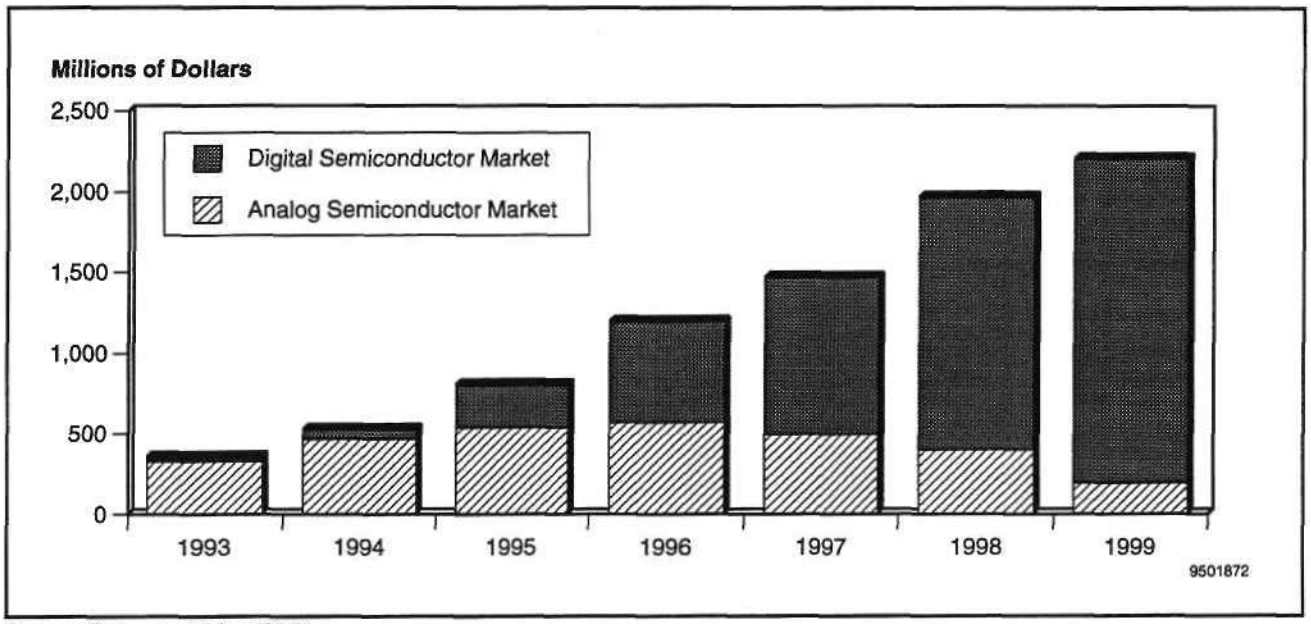
Figure 7
North American Cellular and Broadband PCS Production



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Figure 8
North American Cellular and Broadband PCS Semiconductor Market



Source: Dataquest (May 1995)

Major Suppliers of Baseband Products for Wireless Markets

A number of companies provide semiconductor products for the GSM, DCS-1800, DCS-1900, TDMA, CDMA, Personal Digital Cellular (PDC), and Personal Handy Phone (PHP) markets. Semiconductor companies supplying or with announced plans to supply baseband products for the cellular and PCS markets are as follows:

- Analog Devices
- AT&T Microelectronics
- Ericsson
- GEC Plessey Semiconductors
- Hitachi
- LSI Logic
- Mietec (Alcatel subsidiary)
- Motorola
- NEC
- PCSI
- Philips Semiconductor
- Qualcomm
- Rockwell
- SGS-Thomson Microelectronics
- Siemens Semiconductor
- Siliconix (Temic subsidiary)

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- Texas Instruments
- Toshiba
- VLSI Technology

Dataquest Perspective and Conclusions

The major growth forecast for semiconductors in the cellular handset market will drive chip companies to develop creative solutions to capture as much of the expanding pie as they can. As standard chipset solutions increase the competition with proprietary solutions developed by tier-one handset manufacturers, chip suppliers to the merchant market will be seeking strategies to compete more effectively.

The teaming of Wavecom and VLSI Technology, Texas Instruments and Teknekron, and Analog Devices and The Technology Partnerships for the development of their new wireless products highlights a strategy becoming more common for semiconductor manufacturers seeking to supply chips to the wireless arena. These semiconductor companies recognize that they can gain significant advantages by offering complete solutions to the market. To create these products they are developing partnerships with design houses offering expertise in wireless technologies. Such partnerships have allowed these companies to move quickly into the market with complete chipset solutions. As the demand for new digital cellular and PCS handsets accelerates, companies that can respond with solid, timely products developed through synergistic partnerships will reap the benefits.

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Market Analysis



Semiconductor Application Markets Worldwide

Market Analysis

The Winter Consumer Electronics Show: Not Just Fun and Games

Abstract: *This newsletter presents the most recent statistics on the U.S. consumer electronics market. Information on some of the major product announcements at the Winter Consumer Electronics Show is also presented, along with highlighted semiconductor details related to these products.*
By Dale Ford

Surrounded by the near circuslike atmosphere of the Winter Consumer Electronics Show (CES) in Las Vegas, it is easy to forget that we are witnessing the introduction of new technologies and products that will reshape a major industry in very fundamental ways. Digital technologies are not only driving the development of a new generation of products, they are also changing the way consumers will purchase and access information and entertainment hardware and services. Products and strategies developed by consumer electronics manufacturers and semiconductor suppliers are being impacted by competing digital standards and technologies. In this changing environment, manufacturers will need to be keenly aware of changing consumer preferences and behavior patterns and will have to keep up with rapidly advancing technologies.

This report presents the most recent statistics on the U.S. consumer electronics market. Information on some of the major product announcements at the Winter CES is also presented, along with highlighted semiconductor details related to these products.

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New Market Statistics on the U.S. Consumer Electronics Market

The Winter CES began with the presentation, by the Consumer Electronics Group (CEG) of the Electronic Industries Association (EIA), of statistics for U.S. consumer electronics sales in 1994 and a forecast for 1995. The EIA estimates that 1994 sales increased 9.2 percent from $51.3 billion in 1993 to almost $56.0 billion in 1994. It forecast sales growth to slow to 6.9 percent in 1995, reaching $59.8 billion. It is important to note that Dataquest definitions of consumer electronics differ from the categories used by the EIA. For example, Dataquest counts all personal computers and peripherals in the "data processing" category and cordless telephones and cellular handsets in the "communications" category. The CEG includes purchases of these products in its "consumer electronics" category under the headings of "home information" and "mobile electronics" if it determines that the sales were consumer rather than business purchases.

Video product sales, the largest sales category, rose by 4 percent to $14.8 billion in 1994. The industry expects growth to continue at 2.4 percent to $15.2 billion in 1995. Sales of home and portable audio products in the United States grew from $5.6 billion in 1993 to almost $6.2 billion in 1994, a 10.6 percent growth rate. It is expected that growth in audio products sales will slow to 5.3 percent in 1995 to reach $6.5 billion. The EIA estimates that electronic gaming hardware sales fell from $1.65 billion to $1.58 billion in 1994, while electronic gaming software sales rose from $2.63 billion to $2.93 billion in the same time frame. It expects a continuation of this trend in electronic gaming, with hardware sales dropping to $1.55 billion and software sales hitting $3.1 billion. Table 1 shows EIA statistics for consumer electronics sales in selected high-volume categories.

The impact of digital technologies on consumer electronics products is becoming more evident in both the products themselves and the way these products will be purchased and used by consumers. A more comprehensive view of consumer electronics places them in the central role of delivering information and entertainment to the consumer. A new generation of digital electronic delivery systems will alter the way these information and entertainment products are accessed by consumers. In a speech to CES attendees, Michael Schulhof, president and chief executive officer of Sony America, highlighted this issue and presented a key question: "Who will be the link between content providers and the consumer? Will it be consumer electronics retailers that sell the packaged media players and the devices that decode incoming digital signals? Or will it be the cable and phone companies that lease hardware, and avoid using retail to reach the consumer?" An example of a competing delivery method is found in video software, where digital video brings with it new delivery systems such as video-on-demand through set-top boxes that will compete with packaged media and standalone devices such as VCR players sold at retail stores. In a competitive communications arena going through an aggressive process of deregulation, cable and telephone companies will become major players in the consumer electronics market. Entry of these new competitors into the world of consumer electronics will forever change the dynamics of this market.

The following sections in this newsletter describe some of the top product announcements that took place at the Winter CES. Each of these announcements illustrates the driving factor of digital technology in the consumer electronics world and the fundamental enabling role of semiconductors.

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Table 1
U.S. Consumer Electronics Sales for Selected High-Volume Categories

	1990	1991	1992	1993	1994[1]	1995[1]
Color TV (Direct View)[2]						
Units (K)	20,384	19,474	21,056	23,005	24,820	25,600
Factory ASP ($)	304	307	313	318	293	290
Factory Revenue ($M)	6,197	5,979	6,591	7,316	7,272	7,424
TV/VCR Combination[3]						
Units (K)	424	662	936	1,629	2,220	2,680
Factory ASP ($)	419	401	401	368	349	338
Factory Revenue ($M)	178	265	375	599	775	906
VCR Decks						
Units (K)	10,119	10,718	12,329	12,448	13,000	13,270
Factory ASP ($)	241	229	239	229	220	215
Factory Revenue ($M)	2,439	2,454	2,947	2,851	2,860	2,836
Camcorders						
Units (K)	2,962	2,864	2,815	3,088	3,220	3,340
Factory ASP ($)	763	703	654	634	625	610
Factory Revenue ($M)	2,260	2,013	1,841	1,958	2,013	2,037
Rack Audio Systems						
Units (K)	1,557	1,415	1,341	1,116	1,150	1,100
Factory ASP ($)	516	471	458	488	522	526
Factory Revenue ($M)	804	667	614	545	600	579
Compact Audio Systems						
Units (K)	2,447	3,139	3,877	4,100	5,130	5,550
Factory ASP ($)	190	190	195	224	218	216
Factory Revenue ($M)	446	597	756	919	1,118	1,201
CD Players						
Units (K)	9,155	11,595	16,134	20,425	26,550	30,390
Factory ASP ($)	220	206	186	174	166	159
Factory Revenue ($M)	2,016	2,391	3,005	3,552	4,411	4,824
Portable Headset Audio[4]						
Units (K)	24,064	23,952	23,567	24,329	28,075	29,570
Factory ASP ($)	31	34	36	37	36	36
Factory Revenue ($M)	735	823	846	911	1,000	1,075

[1]Values for 1994 and 1995 are estimates.
[2]Excludes LCD and TV/VCR combinations
[3]Excludes LCD combinations
[4]Includes radios, tape players, radio/tape combinations, and portable CD players
Source: EIA Market Research Department

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Interactive Set-Top Box Announcements

Mr. Schulhof pointed to three digital technologies in his CES speech that "have considerably altered the balance between retail and electronic delivery." The first technology he pointed to was digital compression, which allows high-quality motion pictures, sound, and large amounts of data to be digitized so they can be delivered across narrow bandwidths. Second, he illustrated the role Asynchronous Transfer Mode (ATM) technology plays in enabling cable systems and telephone companies to deliver everything from uniquely personalized entertainment programs to complex computer applications, all on a broadband digitally switched network. Finally, he discussed how high-capacity servers allow cable and telephone operators to store huge quantities of digitized motion pictures and other interactive programming and deliver them on demand to thousands of homes in a given market. These technologies play a key role in the development of interactive, digital set-top box products. Two highlights of CES came in major set-top box introductions by AT&T and the Sun Microsystems/Thomson Consumer Electronics (TCE) alliance. For more information on set-top box technology, please see the *Dataquest Perspective* article entitled, "Digital Set-Top Boxes: Satellite Is Beeping while Cable Is Creeping," published December 26, 1994 (SAMM-WW-DP-9407). Additional information on compression technology can be found in the *Dataquest Perspective* article entitled, "Codecs—The Great Savior of Multimedia, or Just One Step Closer?" published December 12, 1994 (SAMM-WW-DP-9406).

AT&T TV Information Center

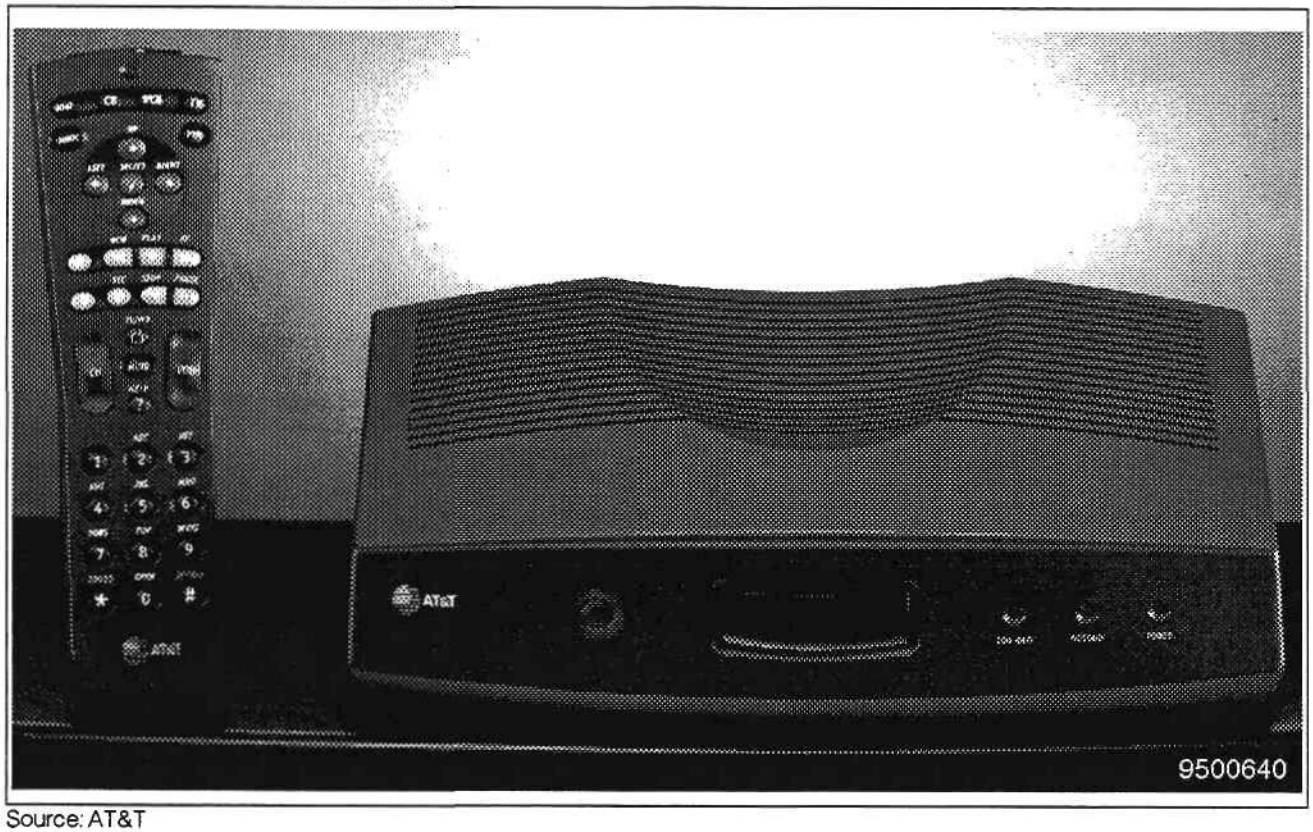
The TV Information Center is one of the first in a family of "intelligent devices" introduced by AT&T Consumer Products in 1995 that takes advantage of ISDN technology. It combines the functionality of a digital answering machine and a set-top box that enables delivery of basic electronic services to the home. This is the first device that allows information delivered over regular telephone lines to be displayed on the home TV screen. A consumer can use a handheld remote control unit to choose from an on-screen menu of information and telephone-answering services. The software interface was developed internally by AT&T, and software updates can be downloaded over the telephone line.

As an answering machine, the TV Information Center provides "caller ID" functionality with on-screen display of a caller's name and number in addition to other standard digital answering machine features. (The caller ID function only works if the caller identification service is provided by the local telephone company.) The system also allows access to subscription services such as electronic banking and bill paying, topic-specific news delivery, local traffic and weather updates, and stock portfolio updates. A basic service subscription package will be available in the spring for about $10.

The modular design of the TV Information Center allows AT&T to enter the set-top box market with a basic set of services at a "low" price point. This design will permit expansion of the system through hardware upgrades that will open the door to future enhanced services. At the core of the system is an AT&T digital signal processor (DSP) and an AMD 29XXX RISC processor. The first systems will be available in the Northeast in the second quarter of 1995, with introductory pricing of $329. Figure 1 shows a photo of the system. Full product rollout to the rest of the United States will occur

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Figure 1
AT&T TV Information Center



Source: AT&T

later in 1995. Zenith Electronics plans to integrate the technology into its television sets and set-top boxes beginning in 1996.

Sun Microsystems and TCE Open TV Interactive System

Sun Microsystems and TCE announced their alliance to develop interactive TV products in July 1994. At the Winter CES they introduced their jointly designed digital interactive TV system, which uses a Sun server to deliver a stream of interactive MPEG 2 compressed video signals and data to a Thomson set-top box. The interoperability of the components in this system is ensured by the Open TV operating environment, a software framework developed by TCE, residing both in the media server and the receiver. A number of sample applications were demonstrated, including a scalable video-on-demand (VOD) system with full VCR control such as fast-forward, rewind, and pause. Also shown was a ticket-ordering application for consumers and an application that allows the TV viewer to respond to commercials.

The alliance, which has yet to be named, places emphasis on the claim that this is the first working system based on commercially available products and technologies. Although the actual demonstration used individual servers sitting behind each set-top box, it was explained that this is a scalable solution that can run on existing broadcast networks for near video-on-demand (NVOD) services today and that will support full-service point-to-point networks for true VOD over an ATM switch. In this system, the for-

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ward channel provides 4-Mbps video delivery, while the back channel employs a 1200-baud modem running on a phone line for interactivity. A movie would be delivered using five encoded streams of data: play, 7X fast-forward, 7X rewind, 21X fast-forward, and 21X rewind. The Sun server could support delivery of a 4-Mbps video to 100 set-top boxes. As an alternative, 15 2.5-hour movies could be stored on the server for delivery in an NVOD system. The claim is that the economics of this system represents a major step in reducing the cost for delivering true VOD to the consumer.

This interactive system leverages Thomson's experience in developing and manufacturing digital decoders. With the introduction of the RCA brand Digital Satellite System (DSS), Thomson became the first consumer electronics company to develop and implement a digital delivery system for video reception to the home. Sales of DSS in the United States have been overwhelming since its introduction. The alliance has been able to leverage the digital video compression technology developed by Thomson and to adapt the DSS set-top box for use in this new system. The decoder box uses an 8-bit processor, 4-bit MPEG 2 graphics processor, 128K DRAM, and 256K flash/EPROM. The Open TV operating environment has been ported to three different MPUs and will soon be running on a total of six popular MPUs. The alliance is advocating Open TV as an open standard and will be attempting to license it. It expects to have products available for system deployment by the second half of 1995.

Interactive Multiplayer News

A large section of the Winter CES was dedicated to interactive games. Major exhibits focused principally on 32-bit systems were presented by Sega, Nintendo, Atari, Panasonic, and Goldstar. Sony showed its PlayStation only by special appointment. Although the 32-bit games dominated the floor, much of the talk revolved around the 64-bit systems planned to hit the market in time for the 1995 holiday season.

Sega Genesis 32X and Saturn

Sega announced plans at the show to launch a standalone unit that combines its 16-bit system, Sega Genesis, with its 32-bit add-on component, Genesis 32X. This new product will be named Genesis 32X System (code-named Neptune) and will be available for less than $200. Consumers will be able to play all of Sega's 16- and 32-bit games on this new system. With Sega CD, they also can play all Sega CD titles. Nationwide shipments of this system are planned for early fall 1995. It was also announced that Sega will begin selling its 64-bit Sega Saturn system in the United States beginning in late 1995. This system was introduced in Japan in November 1994, and Sega claims that 500,000 units have been sold since its launch. Pricing for this system will be $300 to $500 when it is introduced in the United States.

At the heart of these Sega interactive games are two to three Hitachi SH-2 32-bit MPUs, two ASIC graphics processors, a Yamaha DSP for sound management, a system control unit, and 4MB DRAM. The memory is a key cost driver in these systems. The design of the Saturn leaves a slot available for incorporating an MPEG module if price/performance factors justify it. So far, Sega has been successful with software decompression solutions such as CinePak and Duck.

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Nintendo Virtual Boy and Ultra 64

Nintendo's new Virtual Boy was the centerpiece of its exhibit at the show. Virtual Boy is a RISC-based, 32-bit system running at 20 MHz that uses two high-resolution, mirror-scanning LED displays to produce a 3-D experience not possible on conventional television or LCD screens. The design employs a headset viewing system resembling a pair of goggles that sit on a tabletop and are connected to a double-grip controller (see Figure 2). A

Figure 2
Nintendo Virtual Boy



Source: Nintendo

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player can use the headset to eliminate external stimuli and view a high-resolution, red, 3-D image set against a deep black background. Stereophonic sound also is incorporated in the headset. Introduction of this system has been bumped from spring to summer 1995. With suggested retail pricing of $200, Nintendo hopes to sell 2 million systems by March 1996.

Nintendo also announced progress on the 64-bit Ultra 64 game system. Launch of the Ultra 64 is scheduled for fall 1995. This system employs "Reality Immersion Technology" that, according to Nintendo, will allow a player to enter a real-time, 3-D world. Key suppliers of semiconductor technology for this product are Silicon Graphics and Rambus. Silicon Graphics has developed a 64-bit RISC processor using its MIPS technology for use in the game. It claims that the design of the processor is complete and that it would be moving to silicon in January 1995. The Ultra 64 will also use the 500-MHz memory technology from Rambus. This high-speed memory will be key in making fluid 3-D imagery possible.

Panasonic 3DO Multiplayer

Panasonic announced its next-generation 3DO multiplayer, the FZ-10 REAL 3DO Interactive Multiplayer, at a $399.95 list price. The FZ-10 will eventually replace the FZ-1 model, which the company is phasing out. The new model features a new memory management system for saving games in progress. Panasonic has also announced that it will release its MPEG 1 adapter in the first quarter of 1995 at a $249.95 suggested retail price. The adapter will allow users to watch movies and music videos conforming to the Video CD format standards. Also planned for late 1995 is the M2 Accelerator, a PowerPC-based upgrade for 3DO players that will boost performance to 64-bit levels.

Next-Generation Video CD Players

Although a number of manufacturers were displaying first-generation Video CD players that can play up to 74 minutes of full-motion video, the hot topic at the Winter CES was the joint announcement several weeks earlier by Philips and Sony of a Video CD standard that would allow a full-length movie to be stored on one side of a 5-inch CD and produce pictures of better-than-VHS quality. This announcement sets up a rival to the Digital Videodisc (DVD) standard promoted by the Toshiba-Time Warner alliance. The Toshiba-Time Warner standard uses both sides of the disc to store data, and with the backing of major Hollywood studios it was considered the front-runner in the race to be selected as the industry standard. The Toshiba-Time Warner alliance claims that its standard, which has a storage capacity of 4.8Gb per side, offers superior picture and sound quality and would remain a viable technology into the 21st century. The Sony-Philips team claims that CDs following its format would be more economical to manufacture, with only minor modifications to existing CD factories. However, there is industry dispute about whether the dual-depth discs used in the Sony-Philips standard can be mastered and pressed by the CD equipment in use today. Many major manufacturers are evaluating the dispute and are waiting to announce support for one standard or the other. However, the Toshiba-Time Warner alliance received a big boost shortly after the Winter CES when three of the largest consumer electronics companies—Matsushita, Pioneer, and Thomson—announced they would support their standard. The Toshiba-Time Warner group claims that it will provide

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demonstrations for reporters in early 1995. Digital players conforming to the DVD standard are expected to be available in the United States by the end of 1995 at a retail price from $500 to $600. Sony used the Winter CES to present demonstrations of its new Video CD standard.

Sony's Digital Videodisc Player

The Sony-Philips disc can hold 135 minutes of MPEG 2 compressed video, along with CD-quality digital audio for three different languages and extra tracks for subtitles in five other languages. To achieve a high recording density on a single side of a CD, information is stored at two different levels, which the laser reads by changing focus. The system supports a data rate that is variable from 1 to 10 Mbps and averages 3 Mbps. The picture quality of the Sony system was extremely impressive when demonstrated side by side with uncompressed video. The alliance is working to bring systems to market by 1996. Because of the dispute over standards, Dataquest expects volume shipments of DVD players to start in 1997 and approach 2 million unit shipments annually by 1999.

Other Eye-Catching Products

In addition to the major product announcements described, there were a number of other intriguing product introductions at the Winter CES. Because the products ranged from advanced car navigation systems to Microsoft's new "consumer" interface, Bob, it is difficult to discuss all of the innovative products presented. However, a brief description of three notable products demonstrated at the show will round out this report.

Sharp Viewcamteleport

If for nothing else, the Sharp Viewcamteleport deserves mention for its name! As its name not so subtly indicates, it can be used with Sharp's Viewcam to send still video images across standard telephone lines. Three types of images can be sent using the Sharp Viewcam and this new product: a selected scene from the playback of a prerecorded video, an image recorded using the digital still/snap function, or a still image created by rotating the lens toward the user or a group of people. Up to 10 images can be stored for transmission during one phone call. The Viewcamteleport uses compression algorithms that conform to the JPEG standards and Adaptive Discrete Cosine Transform (ADCT) plus variable-length symbol encoding. Compression ratios used for transmitting the image are 1/20, 1/15, and 1/8 and take 8 seconds, 11 seconds, and 20 seconds, respectively, to send. Image transmission speeds of 2400-, 4800-, 7200-, and 9600-baud can be used. The Viewcamteleport can also act as a video/audio answering machine and play a prerecorded message to prompt a caller to leave a message or transmit a video image after a tone.

MiniDisc (MD) Products

New product announcements at Winter CES provide evidence of the continuing commitment of companies such as Sony and Sharp to this class of products. Sony displayed a number of MD products in its exhibit, including a new portable headphone with up to 10 hours of playback time (compared with the predecessor's 7 hours), an in-dash MD-receiver with a 50 percent price reduction, an MD speech recorder, and an MD portable stereo player. Sony even introduced an MD product targeted at storage applications for mobile PCs. Other companies with MD products on display included

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Sanyo with an MD boom box and Aiwa and Sharp with replacement portables. Joining Sony in supplying MD players for automotive sound applications are Clarion, Sanyo, and Kenwood. A number of other companies are waiting for the market to ramp up before introducing MD products. Suppliers estimate total factory shipments of MD in the United States last year at 150,000, but only about 100,000 to 125,000 of those sold through to consumers. Factory shipments in 1995 are expected to remain flat, but retail sales are expected to climb slightly to 150,000 units. One of the key dampers on the MD market is the limited supply of software selections. According to Sony, slightly more than 400 MD titles were available in the United States in about 1,200 stores at the end of 1994. Developers of MD products are still optimistic because of the popularity and strong sales of MD players in Japan. These products represent a triumph in miniaturization in both the mechanical components and the semiconductor packaging.

Timex Data Link Watch

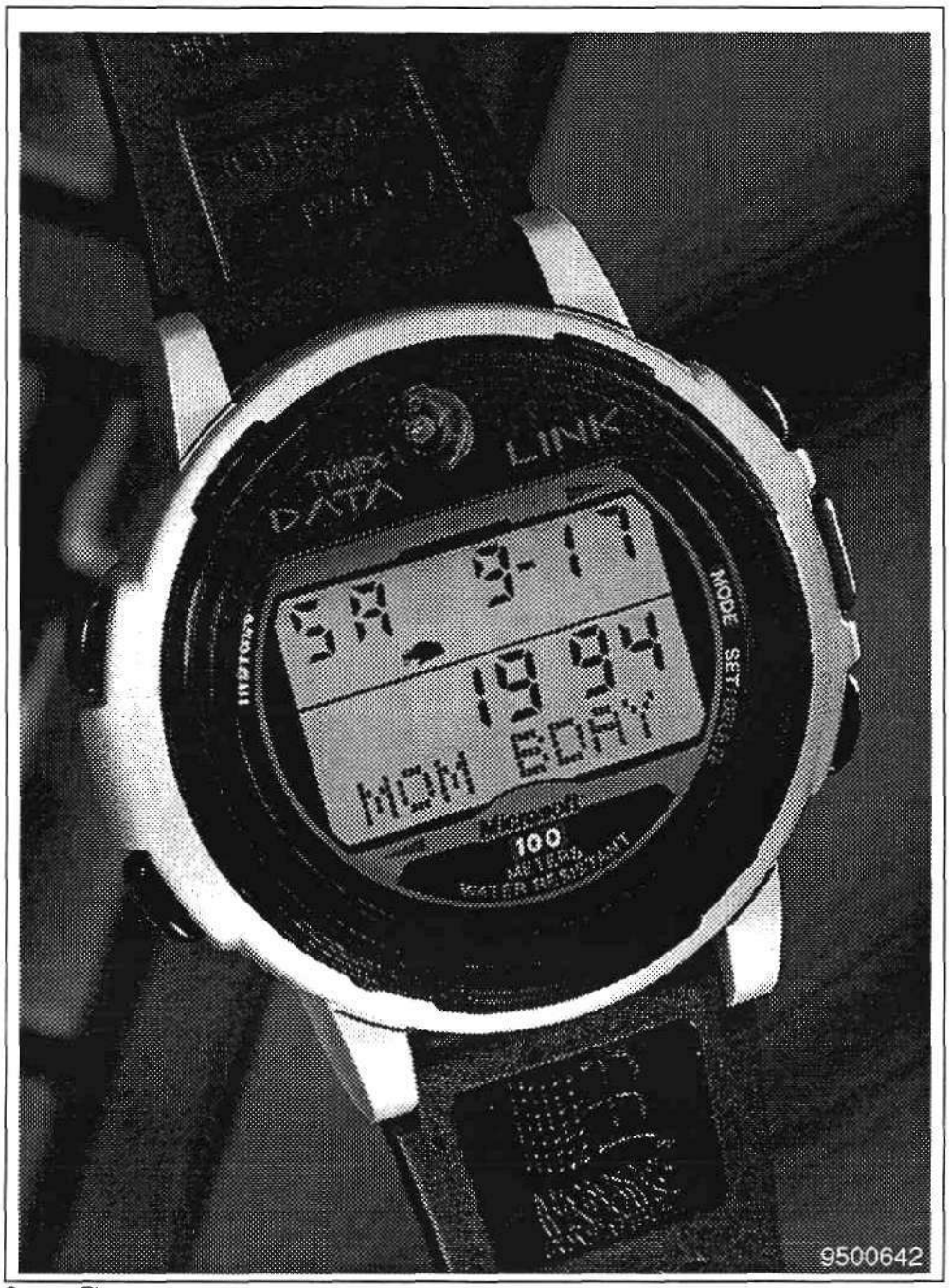
Although Dataquest rarely provides in-depth coverage of watches, this innovative product cannot go without mention. Timex is calling its new watch a "personal information manager (PIM) on your wrist." The watch comes with a simple scheduling software program developed by Timex but can also be used with time management software such as Microsoft Schedule+ for Windows. Items such as appointments, anniversaries, phone numbers, time settings, alarms, and to-do lists can be entered in the program on the PC, or entries can be imported from other PIM software. After selecting the entries to download to the watch, the user hits a send button and holds the watch in front of the PC monitor for a few seconds while five white bars flash on the screen. The entries are downloaded to the watch through a small sensor and can be viewed on an alphanumeric "INDIGLO" light-illuminated display. The watch stores up to 70 entries, and a fuel gauge icon shows how much information has been selected to be sent. These stylish watches that work with a PC have received numerous awards for design excellence. The Timex Data Link watches shown in Figure 3 are available now. Just where you least expect it come opportunities to supply ASIC-embedded microcontrollers, memory, and sensors in a new application.

Dataquest Perspective

This report has focused on recent product introductions and statistics for the U.S. consumer electronics market. The United States is the largest market for consumer electronics, and early trends can provide indicators for future worldwide developments. Although the EIA industry forecast for consumer electronics products shows a slowing in growth for the market, semiconductor opportunities should remain strong. New consumer products, such as those described in this newsletter, are placing greater demands for power and performance on the semiconductors driving them. This trend toward the use of more powerful processors and expanded memory, among others, should drive a robust semiconductor market for consumer products over the coming year.

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Figure 3
Timex Data Link Watch



Source: Timex

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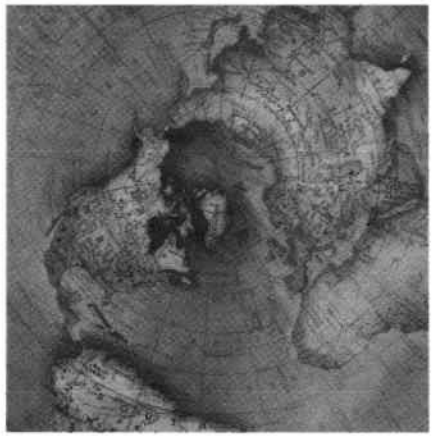
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Worldwide Semiconductor Consumption by Application Market



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Worldwide Semiconductor Consumption by Application Market



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Note: All tables show estimated data.

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Worldwide Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of worldwide semiconductor consumption in electronic equipment. Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

The tables in this document present data to answer the following types of questions:

- What general electronic equipment areas are driving semiconductor demand?
- What is the semiconductor-value composition of various categories of electronic equipment?
- What is the use of particular semiconductor categories such as MOS memory across the various electronic equipment areas?

The electronic equipment forecast contained in this document may be found in its entirety and in detail down to the level of specific equipment system groups in the Market Statistics 1995 document titled *Worldwide and North American Electronic Equipment Production Forecast* (SAMM-WW-MS-9501, published April 24, 1995).

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety in the Market Trends 1995 document titled *Semiconductor Five-Year Forecast Trends—Spring 1995* (SCND-WW-MT-9501, published May 15, 1995). Estimates in this document may differ slightly from estimates in the two aforementioned documents because of rounding.

The tables in this document are organized as follows:

- Tables 1 to 28 cover semiconductor consumption of the six broad application markets, by major semiconductor device group.
- Tables 29 to 56 cover consumption of the major semiconductor device category, by the six broad application markets.
- Tables 57 to 60 cover total semiconductor consumption by each electronic equipment system group.

The following four tables are associated with each application market or semiconductor device category:

- Revenue levels, 1990-1994
- Revenue levels, 1995-1999
- Revenue growth, 1990-1994
- Revenue growth, 1995-1999

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Segmentation

The following two sections outline market segments specific to this document. The first section outlines the electronic equipment segments. The second section outlines the semiconductor device segments. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the 1994 Dataquest Guide titled *Semiconductor Market Definitions* (SCND-WW-GU-9401, published October 3, 1994).

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For purposes of semiconductor consumption analysis, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecom
  - Public telecom
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments
  - Medical equipment
  - Other industrial equipment

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- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Semiconductor Device Segmentation

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optical semiconductor devices.

For purposes of semiconductor consumption analysis, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

Total semiconductor
  Total integrated circuit
    Bipolar digital
    MOS digital
      MOS memory
      MOS microcomponents
      MOS logic
    Analog (monolithic plus hybrid)
  Total discrete
  Total optical semiconductor

Definitions

The following three sections list the definitions used by Dataquest to present the data in this document. The first section gives the electronic equipment definitions. The second section gives the semiconductor device definitions. The third section gives the definition of the worldwide regions. Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the *Dataquest High-Technology Guide: Segmentation and Glossary.* Definitions for semiconductor devices also can be found in the *Dataquest Semiconductor Market Definitions Guide.*

Electronic Equipment Definitions

Application markets are disaggregated into electronic equipment system groups, which are further disaggregated into specific types of electronic equipment systems. The electronic equipment hierarchy is described in the following sections.

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Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data Storage[2]: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. Also, includes semiconductor shipments to U.S. PC marketers for postproduction use.

[2]Worldwide mass storage production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of all equipment categories including rigid disk drive, flexible disk drive, optical disk drive, and tape drive, as estimated by the Dataquest Computer Systems and Peripherals Worldwide group. Also, Dataquest now includes solid-state storage such as flash memory cards in this category. Because most production of these cards is in Japan and Asia/Pacific, we do not include this subcategory in the North American forecast.

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- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing Systems/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

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Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace[3]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Semiconductor Device Definitions

Semiconductor device categories comprise specific types of semiconductor devices, as follows:

Total semiconductor (total integrated circuit + total discrete + total optical semiconductor): Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total integrated circuit (digital monolithic bipolar IC + digital monolithic MOS IC + analog IC): An IC is defined as a large number of passive

[3]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics. Also includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

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and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die, while a hybrid IC is one in which discrete circuits are integrated onto a small number of dice.

Bipolar digital IC (bipolar digital memory IC + bipolar digital logic IC): A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

MOS digital IC (MOS digital memory IC + MOS digital microcomponent IC + MOS digital logic IC): Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed-technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

MOS digital memory IC (DRAM + SRAM + EPROM + EEPROM + flash memory + mask ROM + other MOS digital memory IC): Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS digital microcomponent IC (MOS digital microprocessor + MOS digital microcontroller + MOS digital microperipheral + MOS digital signal processor + programmable digital signal processor): Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS digital logic IC (MOS digital application-specific IC + MOS digital standard logic IC + other MOS logic IC): Defined as a MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC (monolithic analog IC + hybrid IC): A monolithic analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package. A hybrid IC is defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

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Total discrete (transistor + diode + thyristor + other discrete): A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total optical semiconductor (LED lamp/display + optocoupler + CCD + laser diode + photosensor + other optical semiconductor): Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).
  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).
- Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The following two sections discuss definitions of the table line items specific to this document. The first section defines the line items associated with electronic equipment; the second section defines the line items associated with the semiconductor devices.

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Electronic Equipment Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of electronic equipment production is estimated as factory revenue. For purposes of this document, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the money exchange value of the transaction between the North American company's Singaporean operation (which is factory revenue) and the European distributor or final user.

Semiconductor Device Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at the market price rather than at the transfer or factory price.

Data Sources

The historical electronic equipment production estimates presented in this document have been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce (DOC) estimates of manufacturers' shipments
- Trade associations

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- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today.

Forecast and Input/Output Ratio Methodology

The following three sections discuss the forecast methodology used by Dataquest in this document. The first section gives the electronic equipment forecast methodology. The second section gives the semiconductor forecast methodology. The third section discusses the interpretation of I/O ratios and the methodology of the allocation of the aggregate semiconductor forecast across specific electronic equipment markets.

Electronic Equipment Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This establishes a five-year trend growth path or "envelope" for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general comprises annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

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Aggregate Semiconductor Consumption Forecast Methodology

Dataquest publishes a five-year forecast of semiconductor device revenue twice a year, in April and October. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a three-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronic equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest's Semiconductors Worldwide service and its Semiconductor Equipment, Materials, and Manufacturing Worldwide service, in conjunction with various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The I/O ratio reflects the relationship between the dollar value of semiconductors in a type of electronic system and the revenue generated by that system. The ratio is typically expressed as a percentage.

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For example, if a piece of electronic equipment (such as a personal computer) sells for $1,000 and has $100 worth of semiconductors in it, the I/O ratio is expressed as:

$$\text{I/O ratio} = \frac{\text{Semiconductor Value—(Dollars In)}}{\text{Equipment Revenue (Dollars Out)}} = \frac{\$100}{\$1{,}000} = 0.10 \text{ or } 10 \text{ percent}$$

Dataquest estimates semiconductor consumption by electronic equipment segment by combining sample information from electronic system semiconductor content analyses, and surveys of electronic manufacturers' semiconductor procurement and semiconductor manufacturers' shipments by application market with modeled semiconductor consumption. The semiconductor content analyses typically are performed on equipment that sell in high volume or otherwise significantly impact the semiconductor market. These analyses include personal computers, rigid disk drives, and cellular telephones.

The semiconductor consumption model makes use of the following inputs:

- Historical electronic equipment production and the current electronic equipment production forecast
- Historical semiconductor consumption (both aggregate and by electronic equipment segment) and the current semiconductor device revenue forecast
- Information about long-run market trends or long-term systems technology trends

Given these inputs, semiconductor consumption by equipment segment is estimated in an iterative procedure subject to the following constraints and conditions:

- The sum of semiconductor consumption across all equipment markets fully exhausts aggregate semiconductor consumption.
- Market fluctuations in the aggregate semiconductor consumption forecast are realistically and appropriately mapped into the individual equipment segments' semiconductor consumption forecasts.

The procedure is iterative in the respect that modeled results are checked against prior beliefs, expectations, and sample information about each equipment segment's semiconductor consumption, and that this prior information is then used to tune the model such that modeled consumption estimates converge to their respective expected values.

The model combines two important sources of market variation: variation because of nonperiodic market fluctuations about the market's long-run trend growth path; and variation because of shifts in the market's long-run trend growth path.

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It is necessarily the case that nonperiodic fluctuation in the aggregate semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Furthermore, because of a variety of factors, some device markets are relatively more volatile than other device markets. It is an observed fact that there is relatively more volatility in the MOS memory market—owing to price volatility—than in the analog market. Therefore, fluctuation in the MOS memory market "explains" more fluctuation in the aggregate semiconductor market than does fluctuation in the analog market. The model takes given inputs and assumptions and proportionally distributes fluctuations in the aggregate semiconductor market according to the equipment markets' respective long-run semiconductor device composition trends.

For example, because the data processing application market in general—and the computer equipment segment in particular—consumes proportionally more MOS memory devices than does equipment in the industrial market, other things being equal, it is reasonable to expect total semiconductor consumption to be more volatile in the data processing market than in the industrial market.

Semiconductor markets, in general, are relatively more volatile than are the electronic equipment markets. By construction, then, the I/O ratios tend to reflect this difference in volatility. Users of the I/O ratios, therefore, are cautioned to focus on long-run trends in the I/O ratios and growth rates rather than on the year-to-year movement in their values.

Production and I/O Ratio Re-Estimation and Revaluation

The historical and forecast electronic equipment production and semiconductor consumption by application market estimates contained in this book have undergone a thorough audit and review and have been re-estimated and restated to reflect primary or secondary information previously unavailable. Please note the following:

- Computer systems production has been re-estimated and revalued to equal the value of the worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. Also, computer systems' semiconductor consumption includes semiconductor shipments to U.S. PC marketers for postproduction use.
- Communications, industrial, consumer, and transportation production have been re-estimated and revalued to reflect revisions made by the Dataquest Telecommunications group, or secondary-sources estimates.
- Military/civil aerospace production has been re-estimated and revalued to reflect U.S. DOC estimates of U.S. defense and civil (aerospace) electronics. Also, spending on items such as nonrecurring engineering expenses (NRE), R&D, and testing have been eliminated to arrive at a more accurate equipment production estimate.

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Economic Assumptions

Worldwide Business Outlook Points to Continued Strength and Moderate Growth as Expectations for Higher Prices and Profits Edge Up to Six-Year Peaks

The worldwide business outlook for higher sales, prices, profits, and employment levels edged higher during the first quarter of 1995, according to Dun & Bradstreet's most recent quarterly survey of more than 11,000 executives in 16 countries.

Although there has been recent volatility in some markets in response to proposed U.S. trade sanctions against China and the recent depreciation of the Mexican peso, the strength of the (survey) responses indicates that the current global economic expansion will be able to overcome setbacks without a broad negative impact. Long-term experience with business optimism surveys shows a strong correlation with real economic activity, even when the financial markets have signaled uncertainty.

Sales Prices Expected to Rise in All Regions except Pacific

Expectations of worldwide selling prices for the first quarter gained 8 points to an index level of 32, up from 24 during the fourth quarter of 1994. The global price increase reflects strong gains in North America and Europe, rising 9 and 11 points, respectively, to index levels of 40 and 30. The Pacific Selling Price Index dropped 1 point to 12.

The first-quarter survey suggests that executives in Europe and North America believe their economies' respective expansions are nearing their peaks, and that inflationary pressures will grow stronger as idle production capacity is exhausted. As the second quarter approaches, prices will merit closer inspection in order to gauge the impact of recent interest rate hikes in the United States, as well as possible increases in Europe.

North America: Sharp Declines in Value of Peso Could Undermine Expected Gains in Mexican Sales, Profits, Inventories, and Prices

Prior to the sharp decline in the value of the peso, executives in Mexico had reported expectations for record growth in sales, prices, profits, and inventories as businesses in the region prepared for unprecedented expansion under the North American Free Trade Agreement (NAFTA). Despite an expected inventory growth of 25 points—from a fourth-quarter index level of 32 to a first-quarter index level of 57—the Mexican indexes for sales, selling prices, and profits set record highs of 91, 95, and 91, respectively.

Executives, both in Mexico and abroad, were enormously optimistic for that country's performance during the first quarter of 1995 as business hired the labor and invested the capital equipment necessary to capitalize on NAFTA.

Unfortunately, the recession that has gripped Mexico in the wake of the collapsing peso changes everything. Although there is still tremendous promise in the region, little of the previously expected growth will be realized until the peso stabilizes.

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Mexico is one of the United States' largest trading partners, and also is a critical export market for Canada, and volatility there will doubtless have some damping impact on expected growth across North America. However, business expectations in the region are sufficiently strong, and so the impact should be short-term and marginal at worst; aggregate business conditions will likely be mixed, as the survey indicates. Overall, U.S. indexes point to continued positive business conditions. However, the Canadian indexes for sales and profits declined, suggesting that that country's economic recovery could be more shallow and more brief than the U.S. expansion.

The index for net sales in the United States climbed to 62, a gain of 4 points over the previous quarter. However, executives in Canada reported an 8-point drop from 56 to 48. The U.S. Net Profit Index gained 5 points to 56, while the Canadian index dropped 8 points to 42. Highlights of the regional forecast are as follows:

- U.S. real gross domestic product (GDP) is forecast to grow 2.9 percent in 1995, decelerating from 4.0 percent in 1994, and to accelerate slightly to 3.0 percent in 1996.
- Canadian real GDP is forecast to grow 3.7 percent in 1995, decelerating from 4.2 percent in 1994, and to further decelerate to 3.2 percent in 1996.
- Mexican real GDP is forecast to contract 2.0 percent in 1995, following 2.8 percent growth in 1994, and to rebound with 2.5 percent growth in 1996.

Europe: Continued Expansion Anticipated in Europe as Executives Predict Higher Sales and Profits

European executives expect growth in their regions through the end of the first quarter of 1995. The European Sales Index edged upward by 1 point from the previous quarter to reach a six-year high of 47. The European Profits Index jumped 6 points to 31, the Employment Index remained unchanged at 11, and inventories gained 3 points to 7.

Europe is enjoying the benefits of a mature economic expansion, and most indexes are positive for the duration of the first quarter. The region has expanded continuously from the first quarter of 1993. European manufacturers have made significant productivity gains in 1994, but continued expansion could increase pressure on central banks in the region to raise interest rates. Highlights of the regional forecast are as follows:

- France's real GDP is forecast to grow 3.2 percent in 1995, accelerating from 2.4 percent growth in 1994, and to decelerate to 2.9 percent growth in 1996.
- Germany's real GDP is forecast to grow 3.1 percent in 1995, accelerating from 2.8 percent growth in 1994, and to further accelerate to 3.5 percent growth in 1996.

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- Italy's real GDP is forecast to grow 2.9 percent in 1995, accelerating from 2.3 percent growth in 1994, and to further accelerate to 3.2 percent growth in 1996.
- The United Kingdom's real GDP is forecast to grow 3.2 percent in 1995, decelerating from 4.0 percent growth in 1994, and to further decelerate to 3.0 percent growth in 1996.

Japan and Pacific Rim: Weak Growth in Japan Offsets Deteriorating Conditions in the Pacific Region

In contrast with steady growth in Japan during the past three quarters, Japanese executives predict that business conditions will improve only marginally through the first quarter of 1995. Strong gains in expected sales and employment levels were offset by slightly lower expectations for net profits. Overall, results were mixed in the Pacific region, as executives in New Zealand and Australia grew more pessimistic.

Given the gains reported during the fourth quarter of 1994 and throughout 1994, the responses from the region were disappointing but not a complete surprise. The yen's appreciation against Western currencies proved a hindrance to exports and has frustrated Japan's nascent recovery, at least for the first quarter of the year.

The Pacific Sales Index dropped 5 points to 49 as deteriorating conditions in Australia and New Zealand offset a 6-point gain among Japanese executives. The index for expected net profits for the Pacific region fell from 44 to 38, reflecting a loss of 10 points in the Australian index and a 3-point drop in New Zealand. The Pacific Selling Prices Index also fell 1 point to 12, driven by expected price reductions in Japan and New Zealand. Japan reported an expected increase in employment as its index rose from minus 8 to 0, compared to the Pacific region's overall decline from 20 to 17.

Japan's real GDP is forecast to grow 2.0 percent in 1995, accelerating from 0.8 percent growth in 1994, and to further accelerate to 3.5 percent in 1996.

The quarterly International Survey of Business Expectations is modeled on D&B's quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. The survey participants are asked if they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven to be highly accurate, with quarterly forecasts closely paralleling actual performance.

(The current surveys, completed in December 1994, use similar sampling and interviewing procedures in all countries. Hence, the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The D&B index figures used here represent the net percentage of survey respondents expecting higher sales and profits, among others. The indexes are calculated by subtracting the percentage of

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respondents expecting decreases from those expecting increases. Unless otherwise noted, the increases and decreases in indexes represent changes from the previous quarter.)

Regional Electronic Equipment Production

North America

North American electronic equipment production is forecast to grow 5.7 percent in 1995 to $220.4 billion, decelerating from 6.8 percent growth in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1994 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP) over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.
- The mainframe computer market performed better than was previously forecast. Although the market did contract, the rate of contraction was significantly less than previously forecast.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecast for 1994. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market that will increase competition with existing wireless communications services is expected to fuel even greater growth. However, PCS is a very cost-conscious market and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, North America and the worldwide region will see strong growth for mobile equipment.

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- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets.
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets also have continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecommunications hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode (ATM) technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecommunications and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- Industrial electronics production is being fueled by broad-based growth of business' spending on capital equipment. Recent-past increases in interest rates have lowered the current outlook for growth slightly below what it otherwise would have been.
- Consumer electronic production growth stems from growth in households' personal disposable income. Recent-past increases in interest rates will lead to some mild substitution from consumer durables to nondurables, away from new homes (and the associated outfitting with appliances and consumer electronics) and automobiles.
- Military spending cuts are expected to level out after several years of deep cuts. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.

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- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems.

The most significant downside risk to the forecast is the possibility that monetary policy implemented in 1994 will, instead of gently slowing the rapid rate of real GDP growth (also realized in 1994), precipitate a greater-than-desired period of deceleration. The most significant upside risk to the forecast is a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

Japan

Japanese electronic equipment production is forecast to experience 0.9 percent dollar-based growth (1.6 percent yen-based contraction) in 1995 to $191.6 billion, following 9.0 percent dollar-based growth (0.2 percent yen-based contraction) in 1994. (The U.S. dollar depreciated 8.4 percent against the yen in 1994.) Overall, Japanese production will be governed by two forces during the forecast period:

- Production shifting offshore—Two trends are at work here:
  - Japanese companies' electronics production bound for export will shift to the export-bound market, particularly in Asia and Europe.
  - Japanese companies' low-end electronics production will migrate to lower-cost-of-production areas in Asia.
- Yen appreciation—Recent strengthening of the yen against the U.S. dollar in the short term will squeeze the margin of profitability of Japan's electronics exports to the United States. Also, a permanently strong yen in the long term will tend to reinforce the offshore migration of production.

The Japanese forecast is predicated on the following specific assumptions:

- PC unit production growth is positive, but sharp ASP declines are placing contractionary pressure on revenue growth. Mainframe and midrange computer production is suffering from downsizing as companies shift to distributed/networked processing solutions.
- Unit production of flexible disk drives and rigid disk drives will decline sharply because of shift to offshore production to Asia.
- Single in-line memory module (SIMM) production will experience growth in proportion to the PC growth.
- Long-term growth of data processing is positive because of rise in mobile computer production, stemming from personal digital assistant (PDA) production ramp-up.

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- Wireless communications market growth (leading to commensurate production growth) should be stimulated by aggressive ASP reduction of cellular phones in the short term, accompanied by competition between personal handy-phone service (PHS) in equipment price and service fees.
- Production of cellular phones and PHS equipment is spurring infrastructure investment increases for that equipment.
- Industrial electronics should benefit from a resumption of capital spending by Japan's manufacturing industries, in keeping with Japan's overall economic recovery.
- Industrial electronics growth is being particularly spurred by record investment spending in the semiconductor industry on manufacturing equipment, and test and measurement equipment.
- Consumer electronics is particularly subject to the shift offshore, as a means of remaining competitive in the presence of the strengthening yen.
- Automobile electronics is being driven by navigation systems and safety equipment such as antilock braking systems and air bags, and, in the long term, comprehensive driver information systems.

Overall, the downside risks to the Japanese forecast include:

- Greater and faster than expected appreciation of the yen
- More rapid migration of production offshore
- Stalling of the Japanese economic recovery and/or unexpected emergence of recession in major export markets' economies

Upside risks include these events and trends, only in the opposite direction.

Europe

European electronic equipment production is forecast to experience 6.5 percent dollar-based growth (3.3 percent ECU-based growth) in 1995 to $166.8 billion, following 5.3 percent dollar-based growth (3.6 percent ECU-based growth) in 1994. (The U.S. dollar depreciated 1.6 percent against the ECU in 1994.) The European forecast assumptions are as follows:

- Growth of premise communications equipment will be driven by upgrades of PBX equipment to support both voice and data, with the trend toward voice traffic moving digitally and increasing use of cordless telephones.
- The European public telecom market is experiencing very little growth, but European telecom manufacturing companies' significant presence in the global market is benefiting from the superlative growth occurring in Asia/Pacific.
- The central office switching market will decline in Europe during the rest of the forecast period, but production will be bolstered by exports

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to the fast-growing Asia/Pacific market. The European transmission market is set for slow, steady growth, but again there will be significant export opportunities outside western Europe.

- GSM cellular telephones will drive a huge market in Europe as penetration rates approach those in the United States and the continued success of GSM in non-European companies.
- During the initial period of the globalization of the GSM cellular standard, most production of handsets will take place in Europe, for export to other markets.
- Broadcast and studio equipment growth will be helped by investment upgrades to digital broadcast equipment.
- Most audio equipment production in Europe is for the high-end specialist market segment. The most important long-term growth opportunity in consumer audio is forecast to come from digital compact cassette (DCC) equipment and stereo high-fidelity equipment. Volume manufacturers are the major Japanese brand leaders. Overall, the European audio market is supported by imports from Japan and the Far East.
- Color televisions dominate consumer video production. Long-term growth will be attributed to digital transmission, gaining momentum for satellite by 1997 and cable shortly thereafter.
- Wide-screen TV growth will be strongest in France and Germany. Emerging digital satellite and cable services are expected to boost sales of wide-screen TVs toward the end of the decade.
- Camcorder production is expected to expand during the forecast period. Sony is the only camcorder manufacturer in Europe with a full assembly plant in France.
- Satellite TV receiver production continues to show strong growth in Europe as the competition from cable TV operators increases. TV sets with built-in analog CATV and DTH satellite receivers also are gaining popularity across Europe.
- Strong market growth and production is forecast for dishwashers and microwave ovens and air-conditioning toward the end of the forecast period. This is largely influenced by changing European demographics affected by changing patterns in marital status and family structures.

The most significant downside risks to the European forecast include:

- In general, that adoption of cellular telephone equipment is slower than expected.
- GSM success outside Europe does not proceed to volume handset use.
- GSM handset production for non-European markets migrates to non-European manufacturing centers.

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- The forecast assumes there will be no changes in tariffs other than those already announced after the General Agreement on Tariffs and Trade (GATT) negotiations. More restrictive trade could diminish production opportunities.
- Eastern Europe is the volatile area of Europe; political and economic instability is an everyday fact of life. A marked increase of instability, however, could have a detrimental effect on investment in productive capacity.

The most significant upside risks to the European forecast include:

- Cellular handset penetration rates exceed expected future levels at every point in time.
- A strong Japanese economy and currency may accelerate a shift of production from Japan to Europe. (Already some Japanese car manufacturers are exporting their own cars assembled in Europe to Japan.)
- There is a remote possibility that interactive digital services will occur sooner than expected, but this is not very likely.
- Stronger-than-expected economic growth in eastern Europe and the CIS markets would boost western European production above forecast levels.

Asia/Pacific-Rest of World

Asia/Pacific-Rest of World electronic equipment production is forecast to grow 15.4 percent in 1995 to $155.4 billion, decelerating from 17.6 percent growth in 1994. The following factors influence the outlook in regional production:

- Growth in the East Asia PC markets' indigenous demand should help counter the negative effects of expected ASP erosion and Intel's recent entry into the board business on local production.
- Accelerated demand for Pentium machines in 1996 will boost revenue growth; but pricing pressure at the low end of the 486-class systems will tend to diminish average growth.
- OEM business from Japan and continued demand from the United States and Europe has factories in Taiwan running at near full capacity. PC manufacturers in Taiwan after 1995 will have in place everything necessary to ship finished systems, and perhaps to re-enter the brand-name business, at least in Asia.
- Long-term Asian production prospects should be helped by high expectations for Asia's PC markets.
- There will be full participation in the mobile communications revolution.
- Asian communications markets are burgeoning, but production of public switching equipment is not as robust because of the need to import finished systems from Europe and the United States.

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- The settlement of trade differences between China and the United States helps manufacturers to encourage business formation.

Regional Semiconductor Consumption

North America

North American semiconductor device revenue is forecast to grow 26.1 percent in 1995 to $45.3 billion, decelerating from 28.7 percent growth in 1994, and to grow at a 18.3 percent compound annual growth rate (CAGR) from 1994 to 1999, to $83.2 billion in 1999. The North American market forecast is predicated on the following assumptions:

- Data processing will remain the dominant market for semiconductors in North America. PC unit sales in North America will continue along the path of doubling over five years. North America will continue to grow correspondingly as a consumer of ICs, even as motherboards and peripherals are manufactured elsewhere.
- High-ASP semiconductors, such as the x86 processors and memory SIMMs, will continue to have strong consumption in North America and be added to a PC or motherboard manufactured in the Asia/Pacific region.
- Besides PC consumption, resource-hungry software upgrades such as Windows 95, OS-2 Warp, and software "suites" will continue to drive semiconductor consumption toward higher-performance MPUs and wide-word DRAM configurations.
- Because of the strong computer market, microcomponent and memory ICs cornered 59 percent of the semiconductors shipped to North America in 1993 and more than 61 percent in 1994. We expect this share to exceed 64 percent in 1995 because microcomponent and memory ICs will lead all other product types in growth, at 30 percent and 32 percent, respectively, within the North American market. Microcomponent and memory ICs will account for more than 68 percent of semiconductor revenue in North America by 1999, more than two-thirds of the market.
- MOS memory will enjoy a third year of stable prices into 1995 with the continuing tight supply of 4Mb and 16Mb DRAM. Although the DRAM boom will continue into the first half of 1996, strong capital spending in 1994 by Japanese and Korean DRAM suppliers will show up as excess supply and a decline in ASPs in the second half of 1996. Despite falling ASPs, DRAM revenue will be supported by increasing unit shipments as the PC market moves toward higher levels of DRAM use.
- The 4Mb DRAM demand is showing continued strength through 1995, a break from past DRAM life cycles. This extended life has been attributed to limited acceptance of the x1 and x4 configurations of 16Mb DRAMs and the inability of vendors to supply the preferred x16 configuration. This has further limited the price-per-bit decline that was anticipated.

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- MPUs will show a decelerating rate of growth toward the end of the forecast period as increased competition to the x86 family brings ASPs down.
- Discrete device growth (21.9 percent in 1994 and 16.4 percent forecast for 1995) increasingly comes from the use of power MOSFETs and IGBTs in switching power supplies and as peripherals drivers and RF devices. MOSFETS and IGBTs showed 30 percent and 100 percent growth in 1994, respectively, growth rates that will not dissipate by much in 1995.

Japan

Japan's semiconductor device revenue is forecast to grow 15.8 percent in 1995 to $35.9 billion, decelerating from 25.8 percent growth in 1994, and to grow at a 10.0 percent CAGR from 1994 to 1999, to $49.9 billion in 1999. The Japanese market forecast is predicated on the following assumptions:

- Following two years of growth of more than 19 percent, a precipitous decline in growth for 1995 is not anticipated. Although the past two years have had dollar revenue enhancements of 12 percent and 8 percent for 1993 and 1994, respectively, because of yen-to-dollar exchange rate changes, the Japanese market appears more fundamentally sound than expected. The migration of electronic equipment manufacturing to Asia/Pacific sites will tend to create lower revenue growth over the forecast period. The result of this migration is that the Japanese market will drop from 28 percent of worldwide shipments in 1994 to slightly more than 21 percent in 1999.
- MCU, analog IC, and optical semiconductor growth in Japan will be reduced by the offshore production shift of consumer electronics, the biggest application for these devices in Japan.
- As in other regions, MOS memory will enjoy a third year of strong growth in 1995, with continuing tight supply of 4Mb and 16Mb DRAMs. A substantial decline in DRAM growth is expected in 1996 as declining ASPs meet with slowing demand.
- The 4Mb DRAM demand is showing continued strength through 1995, a break from past DRAM life cycles. This extended life has been attributed to limited acceptance of the x1 and x4 configurations of 16Mb DRAMs and the inability of vendors to supply the preferred x16 configuration. This has further limited the price-per-bit decline that was anticipated.
- SRAMs had only 7 percent growth in 1994 and will see no growth in 1995 as DRAMs and synchronous DRAMs provide increasing competition in hard disk drives and other applications.
- MOS ASICs will continue to show low-double-digit growth rates.
- Discrete devices will grow at a modest 6.5 percent CAGR. Power devices such as MOSFETs and IGBTs are providing strong growth but are offset by lower growth in small-signal devices, devices that move offshore as consumer equipment production moves.

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- Optical semiconductors showed a 21 percent growth in 1994, fueled by the growth burst of CD-ROM players. This growth will be blunted in 1995, going to 12 percent because this initial growth burst cannot be sustained and because consumer and computer electronics using laser diodes increasingly are being manufactured in Asia/Pacific nations.

Europe

Europe's semiconductor device revenue is forecast to grow 25.3 percent in 1995 to $26.1 billion, decelerating from 34.7 percent growth in 1994, and to grow at a 15.4 percent CAGR from 1994 to 1999, to $42.6 billion in 1999. The European market forecast is predicated on the following assumptions:

- With 35 percent growth in 1994 following 27 percent growth in 1993, the European market has shown considerably more strength than in previous forecasts. This growth, based on PC and personal communications booms, will be moderated somewhat after 1995.
- MPR consumption has been falling off because of the practice of purchasing Asia-built motherboards preloaded with MPRs.
- Strong MCU unit growth will continue, as the 33 percent growth in 1994 attests. ASP erosion, expected to limit the revenue growth, has been subdued by product shortage. However, revenue growth can be expected to decline as supply catches up with demand by late 1995.
- pDSP use, nearly 40 percent in 1994, continues to be driven by the growth of GSM digital cellular in Europe. Our recent forecasts have favored pDSP solutions for digital cellular over fixed-function DSP in the near term.
- MOS memory will enjoy a third year of stable prices into 1995 with the continuing tight supply of 4Mb and 16Mb DRAMs. Although the DRAM boom will continue into the first half of 1996, we expect supply to meet demand and that ASPs will decline in the second half of 1996. Despite falling ASPs, DRAM revenue will be supported by increasing unit shipments as the PC market moves toward higher levels of DRAM use.
- Communications will continue to drive ASIC demand, particularly in the area of mixed-signal ASIC and CBIC.
- Shortages in discrete products enhanced the market in 1994 as ASPs were kept high. The 19.2 percent growth in 1994 will extend to 1995 with a 19.4 percent annual growth. Power MOSFET and IGBT demand has ramped up strongly. Discretes will return to lower but more stable growth over the longer term.
- As in Japan, optical semiconductor growth in Europe was spectacular at better than 50 percent in 1994. This growth is expected to decline greatly in 1995 because 1994's growth was considered to be a growth spurt rather than sustainable growth.

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Asia/Pacific-ROW

Asia/Pacific-ROW's semiconductor device revenue is forecast to grow 25.0 percent in 1995 to $28.5 billion, decelerating from 30.5 percent growth in 1994, and to grow at a 20.7 percent CAGR from 1994 to 1999, to $58.5 billion in 1999. The Asia/Pacific-ROW market forecast is predicated on the following assumptions:

- The strong yen will accelerate the movement of electronic equipment production out of Japan and into the Asia/Pacific region because the region offers not only lower production costs but also growing markets. The positive note for Japanese semiconductor suppliers is that Asian consumer equipment production depends on Japanese ICs.
- Japan will continue to invest in Asia and China. Because of the significant expansion and investment by Japanese electronic equipment divisions in Asia/Pacific, the Asia/Pacific market is the recipient of the decline of the Japanese semiconductor market, a decline that represents more than 1 percent of the worldwide semiconductor total available market per year.
- Asia/Pacific will become the second-largest equipment manufacturing region by 1998.
- China's economy will continue to grow, attracting computer, telecommunications, and consumer equipment manufacturers. High-end telecommunications equipment is being built in China, which is one aspect of the telecommunications boom.
- MOS memory shipments to Asia/Pacific will enjoy a third year of strong and stable prices into 1995. Despite an excess of supply that will cause falling ASPs in late 1996, DRAM revenue will continue to grow with an increasing Asia/Pacific PC market and higher levels of DRAM use.
- Asia/Pacific dominates in PC motherboard manufacturing. Because motherboards are loaded with logic, ASIC, and MPR chips in Asia/Pacific, while the MPU and memories often are added later, this skews the forecast growth rates toward logic.
- Intel's dominance of the 486 and Pentium MPU markets and the lack of any significant competition in 1994 are expected to continue into 1995, contributing to high ASPs. Increasing competition for the x86 family by 1997 will bring MPU revenue growth back down.
- Led by telecommunications and PC peripherals applications, pDSP revenue in Asia/Pacific has doubled annually during the past two years. We expect pDSP growth to settle into a more sustainable 32 percent growth in 1995.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates for 1994.

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Table 1
Exchange Rates

Country	1994	1995-1999	1994-1995 U.S.$ Appreciation versus Foreign Currency (%)
Japan (Yen/U.S.$1)	101.81	99.25	-2.51
Europe (ECU/U.S.$1)	0.844	0.819	-2.96
France (Franc/U.S.$1)	5.5367	5.3621	-3.15
Germany (Deutsche Mark/U.S.$1)	1.6203	1.5601	-3.72
Great Britain (Pound Sterling/U.S.$1)	0.6536	0.6391	-2.22
Italy (Lira/U.S.$1)	1,609.34	1,620.40	0.69
Korea (Won/U.S.$1)	802.84	791.63	-1.40
Taiwan (NT$1/U.S.$1)	26.45	26.29	-0.60
Hong Kong (HK$1/U.S.$1)	7.7276	7.7357	0.10
Singapore (S$1/U.S.$1)	1.5263	1.4612	-4.27
China (Renminbi/U.S.$1)	8.5384	8.5610	0.26

Source: Dataquest (June 1995)

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Table 2
Revenue from Worldwide Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	560,300	592,967	594,265	632,565	689,668
Total Semiconductor	54,545	59,694	65,261	85,518	110,580
Total IC	44,459	48,855	54,418	73,429	95,928
Bipolar Digital	4,173	3,628	3,193	3,079	2,906
MOS Digital	30,152	34,315	39,710	56,374	75,951
MOS Memory	12,128	12,841	15,308	23,306	33,481
MOS Microcomponent	9,584	11,774	14,359	19,947	25,868
MOS Logic	8,440	9,700	10,043	13,121	16,602
Analog (Monolithic + Hybrid)	10,134	10,912	11,515	13,976	17,071
Total Discrete	7,674	8,035	8,155	9,083	10,758
Total Optical Semiconductor	2,412	2,804	2,688	3,006	3,894

Source: Dataquest (June 1995)

Table 3
Revenue from Worldwide Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	734,265	777,018	829,250	892,901	967,058
Total Semiconductor	135,817	155,980	176,056	202,844	234,246
Total IC	119,071	137,776	156,701	181,595	210,863
Bipolar Digital	2,561	2,210	1,911	1,654	1,416
MOS Digital	96,602	113,371	130,382	151,923	177,295
MOS Memory	44,493	51,415	58,379	67,251	77,890
MOS Microcomponent	32,392	39,298	46,622	55,150	64,994
MOS Logic	19,717	22,658	25,381	29,522	34,411
Analog (Monolithic + Hybrid)	19,908	22,195	24,408	28,018	32,152
Total Discrete	12,288	13,496	14,388	15,850	17,465
Total Optical Semiconductor	4,458	4,708	4,967	5,399	5,918

Source: Dataquest (June 1995)

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Table 4
Revenue Growth from Worldwide Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	8.0	5.8	0.2	6.4	9.0
Total Semiconductor	0.4	9.4	9.3	31.0	29.3
Total IC	-0.3	9.9	11.4	34.9	30.6
Bipolar Digital	-3.3	-13.1	-12.0	-3.6	-5.6
MOS Digital	-3.2	13.8	15.7	42.0	34.7
MOS Memory	-21.3	5.9	19.2	52.2	43.7
MOS Microcomponent	22.7	22.9	22.0	38.9	29.7
MOS Logic	6.5	14.9	3.5	30.6	26.5
Analog (Monolithic + Hybrid)	10.6	7.7	5.5	21.4	22.1
Total Discrete	4.8	4.7	1.5	11.4	18.4
Total Optical Semiconductor	0.2	16.3	-4.1	11.8	29.5

Source: Dataquest (June 1995)

Table 5
Revenue Growth from Worldiwde Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	6.5	5.8	6.7	7.7	8.3	7.0
Total Semiconductor	22.8	14.8	12.9	15.2	15.5	16.2
Total IC	24.1	15.7	13.7	15.9	16.1	17.1
Bipolar Digital	-11.9	-13.7	-13.5	-13.4	-14.4	-13.4
MOS Digital	27.2	17.4	15.0	16.5	16.7	18.5
MOS Memory	32.9	15.6	13.5	15.2	15.8	18.4
MOS Microcomponent	25.2	21.3	18.6	18.3	17.8	20.2
MOS Logic	18.8	14.9	12.0	16.3	16.6	15.7
Analog (Monolithic + Hybrid)	16.6	11.5	10.0	14.8	14.8	13.5
Total Discrete	14.2	9.8	6.6	10.2	10.2	10.2
Total Optical Semiconductor	14.5	5.6	5.5	8.7	9.6	8.7

Source: Dataquest (June 1995)

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Table 6
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Data Processing	175,685	184,139	181,439	192,684	214,463
Total Semiconductor	20,678	23,402	26,577	38,339	52,071
Total IC	19,576	22,100	25,231	36,657	49,808
Bipolar Digital	2,309	2,052	1,819	1,809	1,757
MOS Digital	15,609	18,186	21,466	32,549	45,295
MOS Memory	7,847	8,551	10,185	15,952	23,737
MOS Microcomponent	4,501	5,832	7,307	11,082	14,426
MOS Logic	3,260	3,803	3,974	5,515	7,132
Analog (Monolithic + Hybrid)	1,658	1,861	1,946	2,300	2,757
Total Discrete	777	930	948	1,178	1,510
Total Optical Semiconductor	325	373	398	503	753

Source: Dataquest (June 1995)

Table 7
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Data Processing	230,160	241,836	256,463	277,593	303,587
Total Semiconductor	66,761	77,618	86,929	99,840	115,772
Total IC	64,030	74,702	83,861	96,437	111,942
Bipolar Digital	1,533	1,306	1,099	928	774
MOS Digital	59,368	70,070	79,456	91,934	107,204
MOS Memory	32,372	37,865	42,680	49,161	57,028
MOS Microcomponent	18,461	22,497	26,209	30,590	35,860
MOS Logic	8,536	9,708	10,567	12,183	14,317
Analog (Monolithic + Hybrid)	3,129	3,325	3,305	3,575	3,964
Total Discrete	1,848	1,996	2,106	2,355	2,669
Total Optical Semiconductor	882	919	963	1,048	1,161

Source: Dataquest (June 1995)

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Table 8
Revenue Growth from Worldwide Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Data Processing	9.7	4.8	-1.5	6.2	11.3
Total Semiconductor	-3.7	13.2	13.6	44.3	35.8
Total IC	-4.1	12.9	14.2	45.3	35.9
Bipolar Digital	-1.6	-11.1	-11.3	-0.6	-2.9
MOS Digital	-5.8	16.5	18.0	51.6	39.2
MOS Memory	-22.4	9.0	19.1	56.6	48.8
MOS Microcomponent	29.3	29.6	25.3	51.7	30.2
MOS Logic	9.8	16.7	4.5	38.8	29.3
Analog (Monolithic + Hybrid)	10.6	12.3	4.5	18.2	19.9
Total Discrete	10.1	19.6	1.9	24.3	28.1
Total Optical Semiconductor	-5.4	14.8	6.8	26.4	49.6

Source: Dataquest (June 1995)

Table 9
Revenue Growth from Worldwide Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Data Processing	7.3	5.1	6.0	8.2	9.4	7.2
Total Semiconductor	28.2	16.3	12.0	14.9	16.0	17.3
Total IC	28.6	16.7	12.3	15.0	16.1	17.6
Bipolar Digital	-12.7	-14.8	-15.8	-15.6	-16.6	-15.1
MOS Digital	31.1	18.0	13.4	15.7	16.6	18.8
MOS Memory	36.4	17.0	12.7	15.2	16.0	19.2
MOS Microcomponent	28.0	21.9	16.5	16.7	17.2	20.0
MOS Logic	19.7	13.7	8.9	15.3	17.5	15.0
Analog (Monolithic + Hybrid)	13.5	6.3	-0.6	8.2	10.9	7.5
Total Discrete	22.4	8.0	5.5	11.8	13.3	12.1
Total Optical Semiconductor	17.2	4.2	4.7	8.8	10.8	9.0

Source: Dataquest (June 1995)

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Table 10
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Communications	87,922	94,550	101,662	114,287	127,356
Total Semiconductor	8,418	8,785	10,130	13,916	18,584
Total IC	6,694	6,991	8,290	11,900	15,791
Bipolar Digital	680	546	500	444	397
MOS Digital	4,341	4,672	5,772	8,675	11,814
MOS Memory	1,452	1,413	1,849	2,844	4,095
MOS Microcomponent	1,219	1,419	1,864	2,763	3,616
MOS Logic	1,670	1,840	2,058	3,068	4,102
Analog (Monolithic + Hybrid)	1,673	1,773	2,018	2,781	3,580
Total Discrete	1,264	1,284	1,323	1,454	1,973
Total Optical Semiconductor	459	511	517	561	820

Source: Dataquest (June 1995)

Table 11
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Communications	138,663	150,522	162,152	174,464	187,651
Total Semiconductor	23,661	27,910	32,109	37,734	43,266
Total IC	20,225	24,032	27,892	32,971	37,972
Bipolar Digital	359	313	276	240	205
MOS Digital	15,316	18,378	21,576	25,535	29,395
MOS Memory	5,562	6,385	7,328	8,471	9,618
MOS Microcomponent	4,640	5,925	7,334	8,896	10,333
MOS Logic	5,115	6,068	6,915	8,169	9,444
Analog (Monolithic + Hybrid)	4,550	5,341	6,040	7,196	8,372
Total Discrete	2,457	2,834	3,104	3,534	3,956
Total Optical Semiconductor	978	1,044	1,113	1,229	1,338

Source: Dataquest (June 1995)

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Table 12
Revenue Growth from Worldwide Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Communications	11.3	7.5	7.5	12.4	11.4
Total Semiconductor	6.4	4.4	15.3	37.4	33.5
Total IC	4.8	4.4	18.6	43.5	32.7
Bipolar Digital	-2.4	-19.8	-8.3	-11.1	-10.6
MOS Digital	-0.3	7.6	23.5	50.3	36.2
MOS Memory	-20.7	-2.7	30.9	53.8	44.0
MOS Microcomponent	24.8	16.4	31.4	48.2	30.9
MOS Logic	8.0	10.1	11.9	49.0	33.7
Analog (Monolithic + Hybrid)	25.2	6.0	13.8	37.8	28.7
Total Discrete	15.1	1.5	3.0	10.0	35.7
Total Optical Semiconductor	8.4	11.2	1.2	8.6	46.0

Source: Dataquest (June 1995)

Table 13
Revenue Growth from Worldwide Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Communications	8.9	8.6	7.7	7.6	7.6	8.1
Total Semiconductor	27.3	18.0	15.0	17.5	14.7	18.4
Total IC	28.1	18.8	16.1	18.2	15.2	19.2
Bipolar Digital	-9.7	-12.7	-11.9	-13.2	-14.4	-12.4
MOS Digital	29.6	20.0	17.4	18.3	15.1	20.0
MOS Memory	35.8	14.8	14.8	15.6	13.5	18.6
MOS Microcomponent	28.3	27.7	23.8	21.3	16.2	23.4
MOS Logic	24.7	18.6	14.0	18.1	15.6	18.1
Analog (Monolithic + Hybrid)	27.1	17.4	13.1	19.1	16.3	18.5
Total Discrete	24.5	15.3	9.5	13.9	11.9	14.9
Total Optical Semiconductor	19.3	6.8	6.6	10.4	8.9	10.3

Source: Dataquest (June 1995)

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Table 14
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Industrial	92,350	96,298	94,586	97,843	105,189
Total Semiconductor	6,447	6,656	7,163	8,605	10,090
Total IC	4,240	4,406	4,960	6,191	7,382
Bipolar Digital	482	385	334	284	260
MOS Digital	2,381	2,576	3,125	4,226	5,138
MOS Memory	769	781	946	1,348	1,612
MOS Microcomponent	848	956	1,278	1,642	2,065
MOS Logic	764	839	901	1,235	1,461
Analog (Monolithic + Hybrid)	1,377	1,445	1,502	1,681	1,984
Total Discrete	1,753	1,740	1,714	1,962	2,156
Total Optical Semiconductor	454	510	488	452	552

Source: Dataquest (June 1995)

Table 15
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Industrial	111,498	118,066	126,396	136,393	148,156
Total Semiconductor	11,386	12,728	14,659	16,767	19,199
Total IC	8,428	9,577	11,329	13,168	15,366
Bipolar Digital	231	203	190	172	152
MOS Digital	5,950	6,828	8,265	9,684	11,409
MOS Memory	1,839	1,992	2,470	2,938	3,507
MOS Microcomponent	2,483	3,004	3,688	4,329	5,107
MOS Logic	1,628	1,832	2,107	2,417	2,794
Analog (Monolithic + Hybrid)	2,248	2,546	2,874	3,312	3,805
Total Discrete	2,346	2,519	2,669	2,889	3,067
Total Optical Semiconductor	611	631	661	710	766

Source: Dataquest (June 1995)

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Table 16
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Industrial	10.2	4.3	-1.8	3.4	7.5
Total Semiconductor	4.6	3.2	7.6	20.1	17.3
Total IC	4.5	3.9	12.6	24.8	19.2
Bipolar Digital	-6.5	-20.0	-13.4	-14.9	-8.5
MOS Digital	0.4	8.2	21.3	35.2	21.6
MOS Memory	-18.3	1.6	21.1	42.5	19.6
MOS Microcomponent	16.0	12.8	33.7	28.5	25.8
MOS Logic	9.3	9.8	7.3	37.2	18.2
Analog (Monolithic + Hybrid)	17.5	4.9	4.0	11.9	18.0
Total Discrete	5.9	-0.7	-1.5	14.4	9.9
Total Optical Semiconductor	0.5	12.3	-4.3	-7.3	22.0

Source: Dataquest (June 1995)

Table 17
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Industrial	6.0	5.9	7.1	7.9	8.6	7.1
Total Semiconductor	12.8	11.8	15.2	14.4	14.5	13.7
Total IC	14.2	13.6	18.3	16.2	16.7	15.8
Bipolar Digital	-11.3	-11.7	-6.6	-9.5	-11.7	-10.2
MOS Digital	15.8	14.8	21.0	17.2	17.8	17.3
MOS Memory	14.0	8.3	24.0	19.0	19.4	16.8
MOS Microcomponent	20.2	21.0	22.8	17.4	18.0	19.8
MOS Logic	11.5	12.5	15.0	14.7	15.6	13.9
Analog (Monolithic + Hybrid)	13.3	13.2	12.9	15.2	14.9	13.9
Total Discrete	8.8	7.4	6.0	8.2	6.2	7.3
Total Optical Semiconductor	10.8	3.3	4.7	7.4	7.8	6.8

Source: Dataquest (June 1995)

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Table 18
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Consumer Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Consumer	120,422	133,190	132,142	141,081	154,677
Total Semiconductor	12,996	14,693	14,964	17,406	21,471
Total IC	9,349	10,625	10,962	13,034	16,423
Bipolar Digital	214	217	170	173	161
MOS Digital	5,177	6,061	6,256	7,375	9,517
MOS Memory	1,507	1,544	1,747	2,337	3,048
MOS Microcomponent	1,915	2,328	2,471	2,908	3,879
MOS Logic	1,755	2,188	2,038	2,130	2,590
Analog (Monolithic + Hybrid)	3,958	4,348	4,536	5,486	6,744
Total Discrete	2,724	2,925	2,996	3,186	3,639
Total Optical Semiconductor	923	1,143	1,007	1,185	1,409

Source: Dataquest (June 1995)

Table 19
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to to the World for Use in Consumer Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Consumer	164,032	173,560	186,965	201,995	219,725
Total Semiconductor	24,622	27,688	31,386	36,226	42,406
Total IC	19,061	21,635	24,963	29,254	34,650
Bipolar Digital	142	122	105	97	88
MOS Digital	11,182	12,907	15,216	18,009	21,576
MOS Memory	3,540	3,926	4,529	5,185	6,116
MOS Microcomponent	4,659	5,507	6,652	8,073	9,860
MOS Logic	2,983	3,474	4,035	4,751	5,600
Analog (Monolithic + Hybrid)	7,737	8,606	9,642	11,147	12,986
Total Discrete	3,986	4,371	4,649	5,065	5,659
Total Optical Semiconductor	1,575	1,682	1,774	1,907	2,097

Source: Dataquest (June 1995)

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Table 20
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Consumer	5.6	10.6	-0.8	6.8	9.6
Total Semiconductor	0.9	13.1	1.8	16.3	23.4
Total IC	1.2	13.7	3.2	18.9	26.0
Bipolar Digital	-9.2	1.3	-21.6	1.9	-6.7
MOS Digital	-1.5	17.1	3.2	17.9	29.0
MOS Memory	-19.5	2.5	13.1	33.7	30.5
MOS Microcomponent	17.5	21.6	6.1	17.7	33.4
MOS Logic	0.2	24.6	-6.9	4.6	21.6
Analog (Monolithic + Hybrid)	5.6	9.9	4.3	20.9	22.9
Total Discrete	0.5	7.4	2.4	6.4	14.2
Total Optical Semiconductor	-1.0	23.8	-11.9	17.7	18.8

Source: Dataquest (June 1995)

Table 21
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Consumer	6.0	5.8	7.7	8.0	8.8	7.3
Total Semiconductor	14.7	12.5	13.4	15.4	17.1	14.6
Total IC	16.1	13.5	15.4	17.2	18.4	16.1
Bipolar Digital	-11.9	-14.1	-14.2	-7.1	-9.7	-11.4
MOS Digital	17.5	15.4	17.9	18.4	19.8	17.8
MOS Memory	16.1	10.9	15.4	14.5	18.0	14.9
MOS Microcomponent	20.1	18.2	20.8	21.4	22.1	20.5
MOS Logic	15.2	16.5	16.2	17.7	17.9	16.7
Analog (Monolithic + Hybrid)	14.7	11.2	12.0	15.6	16.5	14.0
Total Discrete	9.5	9.7	6.4	9.0	11.7	9.2
Total Optical Semiconductor	11.8	6.8	5.5	7.5	10.0	8.3

Source: Dataquest (June 1995)

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Table 22
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	62,764	62,245	59,830	59,276	57,729
Total Semiconductor	2,806	2,721	2,664	2,681	2,751
Total IC	2,192	2,126	2,080	2,177	2,230
Bipolar Digital	410	350	294	288	257
MOS Digital	1,187	1,209	1,245	1,335	1,404
MOS Memory	382	372	378	465	509
MOS Microcomponent	335	359	389	345	361
MOS Logic	469	477	478	525	535
Analog (Monolithic + Hybrid)	595	567	541	554	568
Total Discrete	508	486	478	413	421
Total Optical Semiconductor	106	108	105	92	100

Source: Dataquest (June 1995)

Table 23
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Military/Civil Aerospace	57,193	58,045	59,274	60,677	62,145
Total Semiconductor	2,799	2,883	3,034	3,237	3,415
Total IC	2,273	2,339	2,470	2,644	2,802
Bipolar Digital	231	211	194	178	163
MOS Digital	1,469	1,548	1,673	1,824	1,967
MOS Memory	550	570	625	672	711
MOS Microcomponent	376	406	449	507	561
MOS Logic	543	572	599	646	696
Analog (Monolithic + Hybrid)	573	579	604	642	672
Total Discrete	423	437	449	465	474
Total Optical Semiconductor	103	107	115	128	140

Source: Dataquest (June 1995)

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Table 24
Revenue Growth from Worldwide Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	1.7	-0.8	-3.9	-0.9	-2.6
Total Semiconductor	-2.9	-3.0	-2.1	0.6	2.6
Total IC	-2.5	-3.0	-2.1	4.6	2.4
Bipolar Digital	-9.9	-14.5	-16.0	-2.1	-10.7
MOS Digital	-3.0	1.9	3.0	7.2	5.2
MOS Memory	-13.2	-2.6	1.5	23.1	9.4
MOS Microcomponent	4.0	7.2	8.2	-11.4	4.6
MOS Logic	2.0	1.7	0.2	9.8	1.9
Analog (Monolithic + Hybrid)	4.6	-4.8	-4.5	2.3	2.6
Total Discrete	-4.5	-4.3	-1.6	-13.7	2.1
Total Optical Semiconductor	-4.9	2.3	-2.8	-12.8	8.6

Source: Dataquest (June 1995)

Table 25
Revenue Growth from Worldwide Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Military/Civil Aerospace	-0.9	1.5	2.1	2.4	2.4	1.5
Total Semiconductor	1.8	3.0	5.2	6.7	5.5	4.4
Total IC	2.0	2.9	5.6	7.0	6.0	4.7
Bipolar Digital	-10.2	-8.5	-8.2	-8.4	-8.3	-8.7
MOS Digital	4.6	5.4	8.1	9.1	7.8	7.0
MOS Memory	8.1	3.6	9.5	7.6	5.7	6.9
MOS Microcomponent	4.3	7.9	10.5	12.9	10.7	9.2
MOS Logic	1.5	5.3	4.8	7.7	7.7	5.4
Analog (Monolithic + Hybrid)	0.9	1.1	4.2	6.3	4.7	3.4
Total Discrete	0.4	3.3	2.6	3.7	1.8	2.4
Total Optical Semiconductor	3.0	4.2	7.3	11.2	9.4	7.0

Source: Dataquest (June 1995)

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Table 26
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Transportation	21,158	22,544	24,607	27,394	30,255
Total Semiconductor	3,200	3,437	3,763	4,571	5,613
Total IC	2,409	2,607	2,894	3,470	4,293
Bipolar Digital	79	78	76	81	73
MOS Digital	1,457	1,611	1,847	2,214	2,782
MOS Memory	170	179	202	360	480
MOS Microcomponent	766	879	1,050	1,207	1,520
MOS Logic	521	553	595	647	782
Analog (Monolithic + Hybrid)	873	918	971	1,175	1,438
Total Discrete	647	670	696	890	1,058
Total Optical Semiconductor	145	159	173	212	261

Source: Dataquest (June 1995)

Table 27
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Transportation	32,719	34,989	37,999	41,779	45,793
Total Semiconductor	6,588	7,154	7,939	9,040	10,188
Total IC	5,052	5,491	6,186	7,122	8,131
Bipolar Digital	65	53	47	39	34
MOS Digital	3,316	3,640	4,196	4,937	5,744
MOS Memory	630	677	748	824	909
MOS Microcomponent	1,774	1,959	2,291	2,756	3,274
MOS Logic	912	1,004	1,156	1,357	1,561
Analog (Monolithic + Hybrid)	1,671	1,798	1,943	2,146	2,353
Total Discrete	1,227	1,339	1,411	1,541	1,640
Total Optical Semiconductor	309	324	342	378	416

Source: Dataquest (June 1995)

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Table 28
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Transportation	6.2	6.6	9.2	11.3	10.4
Total Semiconductor	5.6	7.4	9.5	21.5	22.8
Total IC	6.1	8.2	11.0	19.9	23.7
Bipolar Digital	19.8	-0.8	-2.9	6.7	-9.5
MOS Digital	6.5	10.5	14.6	19.9	25.7
MOS Memory	-16.5	5.0	12.7	78.6	33.2
MOS Microcomponent	15.0	14.8	19.5	14.9	26.0
MOS Logic	4.6	6.2	7.6	8.8	20.8
Analog (Monolithic + Hybrid)	4.4	5.2	5.8	20.9	22.4
Total Discrete	5.0	3.6	3.9	27.8	19.0
Total Optical Semiconductor	0.8	10.2	8.5	22.5	23.3

Source: Dataquest (June 1995)

Table 29
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Transportation	8.1	6.9	8.6	9.9	9.6	8.6
Total Semiconductor	17.4	8.6	11.0	13.9	12.7	12.7
Total IC	17.7	8.7	12.6	15.1	14.2	13.6
Bipolar Digital	-11.2	-17.9	-12.8	-15.6	-13.0	-14.1
MOS Digital	19.2	9.8	15.3	17.7	16.4	15.6
MOS Memory	31.3	7.4	10.5	10.1	10.4	13.6
MOS Microcomponent	16.7	10.5	17.0	20.3	18.8	16.6
MOS Logic	16.7	10.0	15.2	17.4	15.0	14.8
Analog (Monolithic + Hybrid)	16.2	7.6	8.1	10.4	9.7	10.4
Total Discrete	15.9	9.1	5.4	9.2	6.5	9.2
Total Optical Semiconductor	18.2	4.9	5.5	10.6	10.2	9.8

Source: Dataquest (June 1995)

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Table 30
Revenue from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4,173	3,628	3,193	3,079	2,906
Data Processing	2,309	2,052	1,819	1,809	1,757
Communications	680	546	500	444	397
Industrial	482	385	334	284	260
Consumer	214	217	170	173	161
Military/Civil Aerospace	410	350	294	288	257
Transportation	79	78	76	81	73

Source: Dataquest (June 1995)

Table 31
Revenue from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	2,561	2,210	1,911	1,654	1,416
Data Processing	1,533	1,306	1,099	928	774
Communications	359	313	276	240	205
Industrial	231	203	190	172	152
Consumer	142	122	105	97	88
Military/Civil Aerospace	231	211	194	178	163
Transportation	65	53	47	39	34

Source: Dataquest (June 1995)

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Table 32
Revenue Growth from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-3.3	-13.1	-12.0	-3.6	-5.6
Data Processing	-1.6	-11.1	-11.3	-0.6	-2.9
Communications	-2.4	-19.8	-8.3	-11.1	-10.6
Industrial	-6.5	-20.0	-13.4	-14.9	-8.5
Consumer	-9.2	1.3	-21.6	1.9	-6.7
Military/Civil Aerospace	-9.9	-14.5	-16.0	-2.1	-10.7
Transportation	19.8	-0.8	-2.9	6.7	-9.5

Source: Dataquest (June 1995)

Table 33
Revenue Growth from Shipments of Bipolar Digital Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	-11.9	-13.7	-13.5	-13.4	-14.4	-13.4
Data Processing	-12.7	-14.8	-15.8	-15.6	-16.6	-15.1
Communications	-9.7	-12.7	-11.9	-13.2	-14.4	-12.4
Industrial	-11.3	-11.7	-6.6	-9.5	-11.7	-10.2
Consumer	-11.9	-14.1	-14.2	-7.1	-9.7	-11.4
Military/Civil Aerospace	-10.2	-8.5	-8.2	-8.4	-8.3	-8.7
Transportation	-11.2	-17.9	-12.8	-15.6	-13.0	-14.1

Source: Dataquest (June 1995)

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Table 34
Revenue from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	12,128	12,841	15,308	23,306	33,481
Data Processing	7,847	8,551	10,185	15,952	23,737
Communications	1,452	1,413	1,849	2,844	4,095
Industrial	769	781	946	1,348	1,612
Consumer	1,507	1,544	1,747	2,337	3,048
Military/Civil Aerospace	382	372	378	465	509
Transportation	170	179	202	360	480

Source: Dataquest (June 1995)

Table 35
Revenue from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	44,493	51,415	58,379	67,251	77,890
Data Processing	32,372	37,865	42,680	49,161	57,028
Communications	5,562	6,385	7,328	8,471	9,618
Industrial	1,839	1,992	2,470	2,938	3,507
Consumer	3,540	3,926	4,529	5,185	6,116
Military/Civil Aerospace	550	570	625	672	711
Transportation	630	677	748	824	909

Source: Dataquest (June 1995)

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Table 36
Revenue Growth from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-21.3	5.9	19.2	52.2	43.7
Data Processing	-22.4	9.0	19.1	56.6	48.8
Communications	-20.7	-2.7	30.9	53.8	44.0
Industrial	-18.3	1.6	21.1	42.5	19.6
Consumer	-19.5	2.5	13.1	33.7	30.5
Military/Civil Aerospace	-13.2	-2.6	1.5	23.1	9.4
Transportation	-16.5	5.0	12.7	78.6	33.2

Source: Dataquest (June 1995)

Table 37
Revenue Growth from Shipments of MOS Memory Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	32.9	15.6	13.5	15.2	15.8	18.4
Data Processing	36.4	17.0	12.7	15.2	16.0	19.2
Communications	35.8	14.8	14.8	15.6	13.5	18.6
Industrial	14.0	8.3	24.0	19.0	19.4	16.8
Consumer	16.1	10.9	15.4	14.5	18.0	14.9
Military/Civil Aerospace	8.1	3.6	9.5	7.6	5.7	6.9
Transportation	31.3	7.4	10.5	10.1	10.4	13.6

Source: Dataquest (June 1995)

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Table 38
Revenue from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	9,584	11,774	14,359	19,947	25,868
Data Processing	4,501	5,832	7,307	11,082	14,426
Communications	1,219	1,419	1,864	2,763	3,616
Industrial	848	956	1,278	1,642	2,065
Consumer	1,915	2,328	2,471	2,908	3,879
Military/Civil Aerospace	335	359	389	345	361
Transportation	766	879	1,050	1,207	1,520

Source: Dataquest (June 1995)

Table 39
Revenue from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	32,392	39,298	46,622	55,150	64,994
Data Processing	18,461	22,497	26,209	30,590	35,860
Communications	4,640	5,925	7,334	8,896	10,333
Industrial	2,483	3,004	3,688	4,329	5,107
Consumer	4,659	5,507	6,652	8,073	9,860
Military/Civil Aerospace	376	406	449	507	561
Transportation	1,774	1,959	2,291	2,756	3,274

Source: Dataquest (June 1995)

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Table 40
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	22.7	22.9	22.0	38.9	29.7
Data Processing	29.3	29.6	25.3	51.7	30.2
Communications	24.8	16.4	31.4	48.2	30.9
Industrial	16.0	12.8	33.7	28.5	25.8
Consumer	17.5	21.6	6.1	17.7	33.4
Military/Civil Aerospace	4.0	7.2	8.2	-11.4	4.6
Transportation	15.0	14.8	19.5	14.9	26.0

Source: Dataquest (June 1995)

Table 41
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	25.2	21.3	18.6	18.3	17.8	20.2
Data Processing	28.0	21.9	16.5	16.7	17.2	20.0
Communications	28.3	27.7	23.8	21.3	16.2	23.4
Industrial	20.2	21.0	22.8	17.4	18.0	19.8
Consumer	20.1	18.2	20.8	21.4	22.1	20.5
Military/Civil Aerospace	4.3	7.9	10.5	12.9	10.7	9.2
Transportation	16.7	10.5	17.0	20.3	18.8	16.6

Source: Dataquest (June 1995)

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Table 42
Revenue from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	8,440	9,700	10,043	13,121	16,602
Data Processing	3,260	3,803	3,974	5,515	7,132
Communications	1,670	1,840	2,058	3,068	4,102
Industrial	764	839	901	1,235	1,461
Consumer	1,755	2,188	2,038	2,130	2,590
Military/Civil Aerospace	469	477	478	525	535
Transportation	521	553	595	647	782

Source: Dataquest (June 1995)

Table 43
Revenue from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	19,717	22,658	25,381	29,522	34,411
Data Processing	8,536	9,708	10,567	12,183	14,317
Communications	5,115	6,068	6,915	8,169	9,444
Industrial	1,628	1,832	2,107	2,417	2,794
Consumer	2,983	3,474	4,035	4,751	5,600
Military/Civil Aerospace	543	572	599	646	696
Transportation	912	1,004	1,156	1,357	1,561

Source: Dataquest (June 1995)

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Table 44
Revenue Growth from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	6.5	14.9	3.5	30.6	26.5
Data Processing	9.8	16.7	4.5	38.8	29.3
Communications	8.0	10.1	11.9	49.0	33.7
Industrial	9.3	9.8	7.3	37.2	18.2
Consumer	0.2	24.6	-6.9	4.6	21.6
Military/Civil Aerospace	2.0	1.7	0.2	9.8	1.9
Transportation	4.6	6.2	7.6	8.8	20.8

Source: Dataquest (June 1995)

Table 45
Revenue Growth from Shipments of MOS Logic Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	18.8	14.9	12.0	16.3	16.6	15.7
Data Processing	19.7	13.7	8.9	15.3	17.5	15.0
Communications	24.7	18.6	14.0	18.1	15.6	18.1
Industrial	11.5	12.5	15.0	14.7	15.6	13.9
Consumer	15.2	16.5	16.2	17.7	17.9	16.7
Military/Civil Aerospace	1.5	5.3	4.8	7.7	7.7	5.4
Transportation	16.7	10.0	15.2	17.4	15.0	14.8

Source: Dataquest (June 1995)

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Table 46
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10,134	10,912	11,515	13,976	17,071
Data Processing	1,658	1,861	1,946	2,300	2,757
Communications	1,673	1,773	2,018	2,781	3,580
Industrial	1,377	1,445	1,502	1,681	1,984
Consumer	3,958	4,348	4,536	5,486	6,744
Military/Civil Aerospace	595	567	541	554	568
Transportation	873	918	971	1,175	1,438

Source: Dataquest (June 1995)

Table 47
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	19,908	22,195	24,408	28,018	32,152
Data Processing	3,129	3,325	3,305	3,575	3,964
Communications	4,550	5,341	6,040	7,196	8,372
Industrial	2,248	2,546	2,874	3,312	3,805
Consumer	7,737	8,606	9,642	11,147	12,986
Military/Civil Aerospace	573	579	604	642	672
Transportation	1,671	1,798	1,943	2,146	2,353

Source: Dataquest (June 1995)

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Table 48
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10.6	7.7	5.5	21.4	22.1
Data Processing	10.6	12.3	4.5	18.2	19.9
Communications	25.2	6.0	13.8	37.8	28.7
Industrial	17.5	4.9	4.0	11.9	18.0
Consumer	5.6	9.9	4.3	20.9	22.9
Military/Civil Aerospace	4.6	-4.8	-4.5	2.3	2.6
Transportation	4.4	5.2	5.8	20.9	22.4

Source: Dataquest (June 1995)

Table 49
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	16.6	11.5	10.0	14.8	14.8	13.5
Data Processing	13.5	6.3	-0.6	8.2	10.9	7.5
Communications	27.1	17.4	13.1	19.1	16.3	18.5
Industrial	13.3	13.2	12.9	15.2	14.9	13.9
Consumer	14.7	11.2	12.0	15.6	16.5	14.0
Military/Civil Aerospace	0.9	1.1	4.2	6.3	4.7	3.4
Transportation	16.2	7.6	8.1	10.4	9.7	10.4

Source: Dataquest (June 1995)

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Table 50
Revenue from Shipments of Discrete Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	7,172	7,524	7,632	8,405	9,961
Data Processing	777	930	948	1,178	1,510
Communications	1,264	1,284	1,323	1,454	1,973
Industrial	1,753	1,740	1,714	1,962	2,156
Consumer	2,724	2,925	2,996	3,186	3,639
Military/Civil Aerospace	508	486	478	413	421
Transportation	145	159	173	212	261

Source: Dataquest (June 1995)

Table 51
Revenue from Shipments of Discrete Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	11,370	12,481	13,318	14,687	16,241
Data Processing	1,848	1,996	2,106	2,355	2,669
Communications	2,457	2,834	3,104	3,534	3,956
Industrial	2,346	2,519	2,669	2,889	3,067
Consumer	3,986	4,371	4,649	5,065	5,659
Military/Civil Aerospace	423	437	449	465	474
Transportation	309	324	342	378	416

Source: Dataquest (June 1995)

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Table 52
Revenue Growth from Shipments of Discrete Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.7	4.9	1.4	10.1	18.5
Data Processing	10.1	19.6	1.9	24.3	28.1
Communications	15.1	1.5	3.0	10.0	35.7
Industrial	5.9	-0.7	-1.5	14.4	9.9
Consumer	0.5	7.4	2.4	6.4	14.2
Military/Civil Aerospace	-4.5	-4.3	-1.6	-13.7	2.1
Transportation	0.8	10.2	8.5	22.5	23.3

Source: Dataquest (June 1995)

Table 53
Revenue Growth from Shipments of Discrete Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	14.1	9.8	6.7	10.3	10.6	10.3
Data Processing	22.4	8.0	5.5	11.8	13.3	12.1
Communications	24.5	15.3	9.5	13.9	11.9	14.9
Industrial	8.8	7.4	6.0	8.2	6.2	7.3
Consumer	9.5	9.7	6.4	9.0	11.7	9.2
Military/Civil Aerospace	0.4	3.3	2.6	3.7	1.8	2.4
Transportation	18.2	4.9	5.5	10.6	10.2	9.8

Source: Dataquest (June 1995)

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Table 54
Revenue from Shipments of Optical Semiconductors to the World, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,412	2,804	2,688	3,006	3,894
Data Processing	325	373	398	503	753
Communications	459	511	517	561	820
Industrial	454	510	488	452	552
Consumer	923	1,143	1,007	1,185	1,409
Military/Civil Aerospace	106	108	105	92	100
Transportation	145	159	173	212	261

Source: Dataquest (June 1995)

Table 55
Revenue from Shipments of Optical Semiconductors to the World, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	4,458	4,708	4,967	5,399	5,918
Data Processing	882	919	963	1,048	1,161
Communications	978	1,044	1,113	1,229	1,338
Industrial	611	631	661	710	766
Consumer	1,575	1,682	1,774	1,907	2,097
Military/Civil Aerospace	103	107	115	128	140
Transportation	309	324	342	378	416

Source: Dataquest (June 1995)

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Table 56
Revenue Growth from Shipments of Optical Semiconductors to the World, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	0.2	16.3	-4.1	11.8	29.5
Data Processing	-5.4	14.8	6.8	26.4	49.6
Communications	8.4	11.2	1.2	8.6	46.0
Industrial	0.5	12.3	-4.3	-7.3	22.0
Consumer	-1.0	23.8	-11.9	17.7	18.8
Military/Civil Aerospace	-4.9	2.3	-2.8	-12.8	8.6
Transportation	0.8	10.2	8.5	22.5	23.3

Source: Dataquest (June 1995)

Table 57
Revenue Growth from Shipments of Optical Semiconductors to the World, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	14.5	5.6	5.5	8.7	9.6	8.7
Data Processing	17.2	4.2	4.7	8.8	10.8	9.0
Communications	19.3	6.8	6.6	10.4	8.9	10.3
Industrial	10.8	3.3	4.7	7.4	7.8	6.8
Consumer	11.8	6.8	5.5	7.5	10.0	8.3
Military/Civil Aerospace	3.0	4.2	7.3	11.2	9.4	7.0
Transportation	18.2	4.9	5.5	10.6	10.2	9.8

Source: Dataquest (June 1995)

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Table 58
Revenue from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	54,545	59,694	65,261	85,518	110,580
Data Processing	20,678	23,402	26,577	38,339	52,071
Computers	12,281	13,711	16,574	25,323	35,414
Data Storage	2,832	3,086	3,072	3,841	4,999
Input/Output	3,610	4,210	4,307	5,442	6,903
Dedicated System	1,417	1,676	1,736	2,402	2,885
Other Data Processing	538	719	888	1,331	1,871
Communications	8,418	8,785	10,130	13,916	18,584
Premise Telecommunications	3,444	3,462	4,104	5,671	7,269
Public Telecommunications	2,165	2,234	2,268	2,920	3,586
Mobile Communications	1,522	1,837	2,373	3,526	5,392
Broadcast and Studio	319	303	340	474	650
Other Communications	968	950	1,045	1,326	1,687
Industrial	6,447	6,656	7,163	8,605	10,090
Security and Energy Management	592	669	743	899	1,069
Manufacturing Systems/Instruments	4,223	4,359	4,568	5,649	6,613
Medical Equipment	843	834	971	1,125	1,287
Other Industrial	789	794	880	932	1,121
Consumer	12,996	14,693	14,964	17,406	21,471
Audio	2,340	2,710	2,813	3,168	4,019
Video	6,296	7,157	6,756	7,541	8,875
Personal Electronics	1,987	2,159	2,393	2,907	3,809
Appliances	1,715	1,891	2,178	2,744	3,506
Other Consumer	659	776	825	1,046	1,262
Military/Civil Aerospace	2,806	2,721	2,664	2,681	2,751
Transportation	3,200	3,437	3,763	4,571	5,613

Source: Dataquest (June 1995)

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Table 59
Revenue from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Semiconductor	135,817	155,980	176,056	202,844	234,246
Data Processing	66,761	77,618	86,929	99,840	115,772
Computers	46,471	53,955	60,977	70,535	82,631
Data Storage	5,798	6,771	7,350	8,013	9,015
Input/Output	8,567	9,994	11,077	12,545	14,410
Dedicated System	3,402	4,023	4,417	5,356	6,004
Other Data Processing	2,523	2,876	3,108	3,392	3,711
Communications	23,661	27,910	32,109	37,734	43,266
Premise Telecommunications	9,305	10,957	12,485	14,605	16,731
Public Telecommunications	4,346	4,872	5,278	5,806	6,225
Mobile Communications	7,005	8,482	10,123	12,210	14,363
Broadcast and Studio	898	1,125	1,380	1,782	2,200
Other Communications	2,106	2,474	2,842	3,331	3,748
Industrial	11,386	12,728	14,659	16,767	19,199
Security and Energy Management	1,231	1,403	1,658	1,956	2,311
Manufacturing Systems/Instruments	7,422	8,279	9,548	10,956	12,587
Medical Equipment	1,438	1,596	1,829	2,077	2,357
Other Industrial	1,294	1,450	1,625	1,779	1,943
Consumer	24,622	27,688	31,386	36,226	42,406
Audio	4,714	5,460	6,356	7,500	8,714
Video	10,118	11,221	12,335	13,669	15,351
Personal Electronics	4,380	4,877	5,582	6,865	8,823
Appliances	3,994	4,570	5,378	6,238	7,324
Other Consumer	1,416	1,560	1,735	1,954	2,194
Military/Civil Aerospace	2,799	2,883	3,034	3,237	3,415
Transportation	6,588	7,154	7,939	9,040	10,188

Source: Dataquest (June 1995)

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Table 60
Revenue Growth from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Semiconductor	0.4	9.4	9.3	31.0	29.3
Data Processing	-3.7	13.2	13.6	44.3	35.8
Computers	-7.9	11.6	20.9	52.8	39.8
Data Storage	9.5	9.0	-0.5	25.0	30.2
Input/Output	1.0	16.6	2.3	26.3	26.8
Dedicated System	-5.0	18.3	3.6	38.4	20.1
Other Data Processing	13.2	33.5	23.6	49.8	40.6
Communications	6.4	4.4	15.3	37.4	33.5
Premise Telecommunications	-1.5	0.5	18.5	38.2	28.2
Public Telecommunications	12.0	3.2	1.5	28.7	22.8
Mobile Communications	16.1	20.7	29.2	48.6	52.9
Broadcast and Studio	12.3	-5.0	12.2	39.5	37.0
Other Communications	9.0	-1.9	10.1	26.9	27.3
Industrial	4.6	3.2	7.6	20.1	17.3
Security and Energy Management	5.3	13.1	11.1	20.9	18.9
Manufacturing Systems/Instruments	5.5	3.2	4.8	23.7	17.1
Medical Equipment	5.8	-1.1	16.5	15.9	14.4
Other Industrial	-1.7	0.7	10.8	5.8	20.3
Consumer	0.9	13.1	1.8	16.3	23.4
Audio	1.8	15.8	3.8	12.6	26.8
Video	-0.6	13.7	-5.6	11.6	17.7
Personal Electronics	6.3	8.7	10.8	21.5	31.0
Appliances	0.4	10.3	15.2	26.0	27.8
Other Consumer	-1.6	17.9	6.2	26.8	20.7
Military/Civil Aerospace	-2.9	-3.0	-2.1	0.6	2.6
Transportation	5.6	7.4	9.5	21.5	22.8

Source: Dataquest (June 1995)

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Table 61
Revenue Growth from Total Semiconductors Shipped to the World for Use in Each Electronic Equipment Group, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	22.8	14.8	12.9	15.2	15.5	16.2
Data Processing	28.2	16.3	12.0	14.9	16.0	17.3
Computers	31.2	16.1	13.0	15.7	17.2	18.5
Data Storage	16.0	16.8	8.5	9.0	12.5	12.5
Input/Output	24.1	16.7	10.8	13.2	14.9	15.9
Dedicated System	17.9	18.3	9.8	21.3	12.1	15.8
Other Data Processing	34.8	14.0	8.1	9.1	9.4	14.7
Communications	27.3	18.0	15.0	17.5	14.7	18.4
Premise Telecommunications	28.0	17.7	14.0	17.0	14.6	18.1
Public Telecommunications	21.2	12.1	8.3	10.0	7.2	11.7
Mobile Communications	29.9	21.1	19.3	20.6	17.6	21.6
Broadcast and Studio	38.2	25.2	22.8	29.1	23.5	27.6
Other Communications	24.8	17.5	14.9	17.2	12.5	17.3
Industrial	12.8	11.8	15.2	14.4	14.5	13.7
Security and Energy Management	15.2	14.0	18.2	18.0	18.2	16.7
Manufacturing Systems/Instruments	12.2	11.5	15.3	14.7	14.9	13.7
Medical Equipment	11.8	11.0	14.6	13.5	13.5	12.9
Other Industrial	15.5	12.0	12.1	9.5	9.3	11.6
Consumer	14.7	12.5	13.4	15.4	17.1	14.6
Audio	17.3	15.8	16.4	18.0	16.2	16.7
Video	14.0	10.9	9.9	10.8	12.3	11.6
Personal Electronics	15.0	11.3	14.5	23.0	28.5	18.3
Appliances	13.9	14.4	17.7	16.0	17.4	15.9
Other Consumer	12.2	10.2	11.2	12.6	12.3	11.7
Military/Civil Aerospace	1.8	3.0	5.2	6.7	5.5	4.4
Transportation	17.4	8.6	11.0	13.9	12.7	12.7

Source: Dataquest (June 1995)

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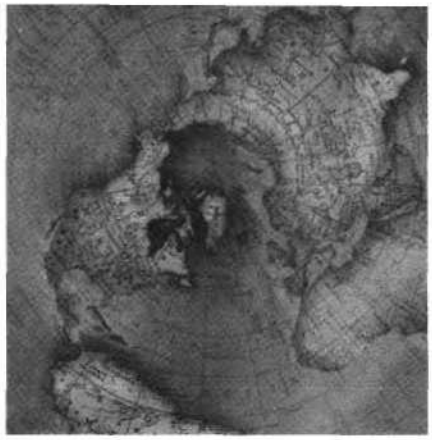
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North American Semiconductor Consumption by Application Market



Market Statistics

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North American Semiconductor Consumption by Application Market



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North American Semiconductor Consumption by Application Market

Introduction

This document contains detailed information on Dataquest's view of North American semiconductor consumption in electronic equipment. Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

The tables in this document present data to answer the following types of questions:

- What general electronic equipment areas are driving semiconductor demand?
- What is the semiconductor-value composition of various categories of electronic equipment?
- What is the use of particular semiconductor categories such as MOS memory across the various electronic equipment areas?

The electronic equipment forecast contained in this document may be found in its entirety and in detail down to the level of specific equipment system groups in the Market Statistics 1995 document titled *Worldwide and North American Electronic Equipment Production Forecast* (SAMM-WW-MS-9501, published April 24, 1995).

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety in the Market Trends 1995 document titled *Semiconductor Five-Year Forecast Trends—Spring 1995* (SCND-WW-MT-9501, published May 15, 1995). Estimates in this document may differ slightly from estimates in the two aforementioned documents because of rounding.

The tables in this document are organized as follows:

- Tables 1 to 28 cover semiconductor consumption of the six broad application markets, by major semiconductor device group.
- Tables 29 to 56 cover consumption of the major semiconductor device category, by the six broad application markets.
- Tables 57 to 60 cover total semiconductor consumption by each electronic equipment system group.

The following four tables are associated with each application market or semiconductor device category:

- Revenue levels, 1990-1994
- Revenue levels, 1995-1999

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- Revenue growth, 1990-1994
- Revenue growth, 1995-1999

Segmentation

The following two sections outline market segments specific to this document. The first section outlines the electronic equipment segments. The second section outlines the semiconductor device segments. Dataquest's objective is to provide data along lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the 1994 Dataquest Guide titled *Semiconductor Market Definitions* (SCND-WW-GU-9401, published October 3, 1994).

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For purposes of semiconductor consumption analysis, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data processing
  - Computers
  - Data storage
  - Input/output devices
  - Dedicated systems
  - Other data processing
- Communications
  - Premise telecom
  - Public telecom
  - Mobile communications
  - Broadcast and studio equipment
  - Other communications
- Industrial
  - Security and energy management systems
  - Manufacturing systems and instruments

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- Medical equipment
- Other industrial equipment

- Consumer
  - Audio
  - Video
  - Personal electronics
  - Appliances
  - Other consumer equipment
- Military/civilian aerospace
- Transportation

Semiconductor Device Segmentation

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optical semiconductor devices.

For purposes of semiconductor consumption analysis, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

Total semiconductor
  Total integrated circuit
    Bipolar digital
    MOS digital
      MOS memory
      MOS microcomponents
      MOS logic
    Analog (monolithic plus hybrid)
  Total discrete
  Total optical semiconductor

Definitions

The following three sections list the definitions used by Dataquest to present the data in this document. The first section gives the electronic equipment definitions. The second section gives the semiconductor device definitions. The third section gives the definition of the North American region. Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the *Dataquest High-Technology Guide: Segmentation and Glossary.* Definitions for semiconductor devices also can be found in the *Dataquest Semiconductor Market Definitions Guide.*

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Electronic Equipment Definitions

Application markets are disaggregated into electronic equipment system groups, which are further disaggregated into specific types of electronic equipment systems. The electronic equipment hierarchy is described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data Storage[2]: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.
- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. Also, includes semiconductor shipments to U.S. PC marketers for postproduction use.

[2]Worldwide mass storage production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of all equipment categories including rigid disk drive, flexible disk drive, optical disk drive, and tape drive, as estimated by the Dataquest Computer Systems and Peripherals Worldwide group. Also, Dataquest now includes solid-state storage such as flash memory cards in this category. Because most production of these cards is in Japan and Asia/Pacific, we do not include this subcategory in the North American forecast.

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hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.

- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (headend) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing Systems/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.
- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.

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- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace[3]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Semiconductor Device Definitions

Semiconductor device categories comprise specific types of semiconductor devices, as follows:

Total semiconductor (total integrated circuit + total discrete + total optical semiconductor): Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or

[3]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics. Also includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

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gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total integrated circuit (digital monolithic bipolar IC + digital monolithic MOS IC + analog IC): An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die, while a hybrid IC is one in which discrete circuits are integrated onto a small number of dice.

Bipolar digital IC (bipolar digital memory IC + bipolar digital logic IC): A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

MOS digital IC (MOS digital memory IC + MOS digital microcomponent IC + MOS digital logic IC): Defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed-technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.

MOS digital memory IC (DRAM + SRAM + EPROM + EEPROM + flash memory + mask ROM + other MOS digital memory IC): Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS digital microcomponent IC (MOS digital microprocessor + MOS digital microcontroller + MOS digital microperipheral + MOS digital signal processor + programmable digital signal processor): Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS digital logic IC (MOS digital application-specific IC + MOS digital standard logic IC + other MOS logic IC): Defined as a MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC (monolithic analog IC + hybrid IC): A monolithic analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS

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technologies. A monolithic IC is a single die contained in a single package. A hybrid IC is defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total discrete (transistor + diode + thyristor + other discrete): A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total optical semiconductor (LED lamp/display + optocoupler + CCD + laser diode + photosensor + other optical semiconductor): Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definitions

North America: Includes Canada, Mexico, and the United States (50 states).

Line Item Definitions

The following two sections discuss definitions of the table line items specific to this document. The first section defines the line items associated with electronic equipment; the second section defines the line items associated with the semiconductor devices.

Electronic Equipment Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

The value of electronic equipment production is estimated as factory revenue. For purposes of this document, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would

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classify this as Asia/Pacific-Rest of World (A/P-ROW) data storage device production because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the money exchange value of the transaction between the North American company's Singaporean operation (which is factory revenue) and the European distributor or final user.

Semiconductor Device Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at the market price rather than at the transfer or factory price.

Data Sources

The historical electronic equipment production estimates presented in this document have been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce (DOC) estimates of manufacturers' shipments
- Trade associations
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today.

Forecast and Input/Output Ratio Methodology

The following three sections discuss the forecast methodology used by Dataquest in this document. The first section gives the electronic equipment forecast methodology. The second section gives the semiconductor forecast methodology. The third section discusses the interpretation of I/O ratios and the methodology of the allocation of the aggregate semiconductor forecast across specific electronic equipment markets.

Electronic Equipment Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

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Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This establishes a five-year trend growth path or "envelope" for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general comprises annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Aggregate Semiconductor Consumption Forecast Methodology

Dataquest publishes a five-year forecast of semiconductor device revenue twice a year, in April and October. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a three-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronic equipment

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market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest's Semiconductors Worldwide service and its Semiconductor Equipment, Materials, and Manufacturing Worldwide service, in conjunction with various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The I/O ratio reflects the relationship between the dollar value of semiconductors in a type of electronic system and the revenue generated by that system. The ratio is typically expressed as a percentage.

For example, if a piece of electronic equipment (such as a personal computer) sells for $1,000 and has $100 worth of semiconductors in it, the I/O ratio is expressed as:

$$\text{I/O ratio} = \frac{\text{Semiconductor Value—(Dollars In)}}{\text{Equipment Revenue (Dollars Out)}} = \frac{\$100}{\$1{,}000} = 0.10 \text{ or } 10 \text{ percent}$$

Dataquest estimates semiconductor consumption by electronic equipment segment by combining sample information from electronic system semiconductor content analyses, and surveys of electronic manufacturers' semiconductor procurement and semiconductor manufacturers' shipments by application market with modeled semiconductor consumption. The semiconductor content analyses typically are performed on equipment that sell in high volume or otherwise significantly impact the semiconductor market. These analyses include personal computers, rigid disk drives, and cellular telephones.

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The semiconductor consumption model makes use of the following inputs:

- Historical electronic equipment production and the current electronic equipment production forecast
- Historical semiconductor consumption (both aggregate and by electronic equipment segment) and the current semiconductor device revenue forecast
- Information about long-run market trends or long-term systems technology trends

Given these inputs, semiconductor consumption by equipment segment is estimated in an iterative procedure subject to the following constraints and conditions:

- The sum of semiconductor consumption across all equipment markets fully exhausts aggregate semiconductor consumption.
- Market fluctuations in the aggregate semiconductor consumption forecast are realistically and appropriately mapped into the individual equipment segments' semiconductor consumption forecasts.

The procedure is iterative in the respect that modeled results are checked against prior beliefs, expectations, and sample information about each equipment segment's semiconductor consumption, and that this prior information is then used to tune the model such that modeled consumption estimates converge to their respective expected values.

The model combines two important sources of market variation: variation because of nonperiodic market fluctuations about the market's long-run trend growth path; and variation because of shifts in the market's long-run trend growth path.

It is necessarily the case that nonperiodic fluctuation in the aggregate semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Furthermore, because of a variety of factors, some device markets are relatively more volatile than other device markets. It is an observed fact that there is relatively more volatility in the MOS memory market—owing to price volatility—than in the analog market. Therefore, fluctuation in the MOS memory market "explains" more fluctuation in the aggregate semiconductor market than does fluctuation in the analog market. The model takes given inputs and assumptions and proportionally distributes fluctuations in the aggregate semiconductor market according to the equipment markets' respective long-run semiconductor device composition trends.

For example, because the data processing application market in general—and the computer equipment segment in particular—consumes proportionally more MOS memory devices than does equipment in the industrial market, other things being equal, it is reasonable to expect total semiconductor consumption to be more volatile in the data processing market than in the industrial market.

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Semiconductor markets, in general, are relatively more volatile than are the electronic equipment markets. By construction, then, the I/O ratios tend to reflect this difference in volatility. Users of the I/O ratios, therefore, are cautioned to focus on long-run trends in the I/O ratios and growth rates rather than on the year-to-year movement in their values.

Production and I/O Ratio Re-Estimation and Revaluation

The historical and forecast electronic equipment production and semiconductor consumption by application market estimates contained in this book have undergone a thorough audit and review and have been re-estimated and restated to reflect primary or secondary information previously unavailable. Please note the following:

- Computer systems production has been re-estimated and revalued to equal the value of the worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays. Also, computer systems' semiconductor consumption includes semiconductor shipments to U.S. PC marketers for postproduction use.
- Communications, industrial, consumer, and transportation production have been re-estimated and revalued to reflect revisions made by the Dataquest Telecommunications group, or secondary-sources estimates.
- Military/civil aerospace production has been re-estimated and revalued to reflect U.S. DOC estimates of U.S. defense and civil (aerospace) electronics. Also, spending on items such as nonrecurring engineering expenses (NRE), R&D, and testing have been eliminated to arrive at a more accurate equipment production estimate.

Economic Assumptions

Worldwide Business Outlook Points to Continued Strength and Moderate Growth as Expectations for Higher Prices and Profits Edge Up to Six-Year Peaks

The worldwide business outlook for higher sales, prices, profits, and employment levels edged higher during the first quarter of 1995, according to Dun & Bradstreet's most recent quarterly survey of more than 11,000 executives in 16 countries.

Although there has been recent volatility in some markets in response to proposed U.S. trade sanctions against China and the recent depreciation of the Mexican peso, the strength of the (survey) responses indicates that the current global economic expansion will be able to overcome setbacks without a broad negative impact. Long-term experience with business optimism surveys shows a strong correlation with real economic activity, even when the financial markets have signaled uncertainty.

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Sales Prices Expected to Rise in All Regions except Pacific

Expectations of worldwide selling prices for the first quarter gained 8 points to an index level of 32, up from 24 during the fourth quarter of 1994. The global price increase reflects strong gains in North America and Europe, rising 9 and 11 points, respectively, to index levels of 40 and 30. The Pacific Selling Price Index dropped 1 point to 12.

The first-quarter survey suggests that executives in Europe and North America believe their economies' respective expansions are nearing their peaks, and that inflationary pressures will grow stronger as idle production capacity is exhausted. As the second quarter approaches, prices will merit closer inspection in order to gauge the impact of recent interest rate hikes in the United States, as well as possible increases in Europe.

North America: Sharp Declines in Value of Peso Could Undermine Expected Gains in Mexican Sales, Profits, Inventories, and Prices

Prior to the sharp decline in the value of the peso, executives in Mexico had reported expectations for record growth in sales, prices, profits, and inventories as businesses in the region prepared for unprecedented expansion under the North American Free Trade Agreement (NAFTA). Despite an expected inventory growth of 25 points—from a fourth-quarter index level of 32 to a first-quarter index level of 57—the Mexican indexes for sales, selling prices, and profits set record highs of 91, 95, and 91, respectively.

Executives, both in Mexico and abroad, were enormously optimistic for that country's performance during the first quarter of 1995 as business hired the labor and invested the capital equipment necessary to capitalize on NAFTA.

Unfortunately, the recession that has gripped Mexico in the wake of the collapsing peso changes everything. Although there is still tremendous promise in the region, little of the previously expected growth will be realized until the peso stabilizes.

Mexico is one of the United States' largest trading partners, and also is a critical export market for Canada, and volatility there will doubtless have some damping impact on expected growth across North America. However, business expectations in the region are sufficiently strong, and so the impact should be short-term and marginal at worst; aggregate business conditions will likely be mixed, as the survey indicates. Overall, U.S. indexes point to continued positive business conditions. However, the Canadian indexes for sales and profits declined, suggesting that that country's economic recovery could be more shallow and more brief than the U.S. expansion.

The index for net sales in the United States climbed to 62, a gain of 4 points over the previous quarter. However, executives in Canada reported an 8-point drop from 56 to 48. The U.S. Net Profit Index gained

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5 points to 56, while the Canadian index dropped 8 points to 42. Highlights of the regional forecast are as follows:

- U.S. real gross domestic product (GDP) is forecast to grow 2.9 percent in 1995, decelerating from 4.0 percent in 1994, and to accelerate slightly to 3.0 percent in 1996.
- Canadian real GDP is forecast to grow 3.7 percent in 1995, decelerating from 4.2 percent in 1994, and to further decelerate to 3.2 percent in 1996.
- Mexican real GDP is forecast to contract 2.0 percent in 1995, following 2.8 percent growth in 1994, and to rebound with 2.5 percent growth in 1996.

North American Electronic Equipment Production Assumptions

North American electronic equipment production is forecast to grow 5.7 percent in 1995 to $220.4 billion, decelerating from 6.8 percent growth in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1994 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP)over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.
- The mainframe computer market performed better than was previously forecast. Although the market did contract, the rate of contraction was significantly less than previously forecast.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecast for 1994. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market that will increase competition with existing wireless

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communications services is expected to fuel even greater growth. However, PCS is a very cost-conscious market and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, North America and the worldwide region will see strong growth for mobile equipment.

- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets.
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets also have continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecommunications hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode (ATM) technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.
- Public telecommunications and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- Industrial electronics production is being fueled by broad-based growth of business' spending on capital equipment. Recent-past increases in interest rates have lowered the current outlook for growth slightly below what it otherwise would have been.
- Consumer electronic production growth stems from growth in households' personal disposable income. Recent-past increases in interest rates will lead to some mild substitution from consumer durables to nondurables, away from new homes (and the associated outfitting with appliances and consumer electronics) and automobiles.

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- Military spending cuts are expected to level out after several years of deep cuts. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.
- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems.

The most significant downside risk to the forecast is the possibility that monetary policy implemented in 1994 will, instead of gently slowing the rapid rate of real GDP growth (also realized in 1994), precipitate a greater-than-desired period of deceleration. The most significant upside risk to the forecast is a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

North American Semiconductor Consumption

North American semiconductor device revenue is forecast to grow 26.1 percent in 1995 to $45.3 billion, decelerating from 28.7 percent growth in 1994, and to grow at a 18.3 percent compound annual growth rate (CAGR) from 1994 to 1999, to $83.2 billion in 1999. The North American market forecast is predicated on the following assumptions:

- Data processing will remain the dominant market for semiconductors in North America. PC unit sales in North America will continue along the path of doubling over five years. North America will continue to grow correspondingly as a consumer of ICs, even as motherboards and peripherals are manufactured elsewhere.
- High-ASP semiconductors, such as the x86 processors and memory SIMMs, will continue to have strong consumption in North America and be added to a PC or motherboard manufactured in the Asia/Pacific region.
- Besides PC consumption, resource-hungry software upgrades such as Windows 95, OS-2 Warp, and software "suites" will continue to drive semiconductor consumption toward higher-performance MPUs and wide-word DRAM configurations.
- Because of the strong computer market, microcomponent and memory ICs cornered 59 percent of the semiconductors shipped to North America in 1993 and more than 61 percent in 1994. We expect this share to exceed 64 percent in 1995 because microcomponent and memory ICs will lead all other product types in growth, at 30 percent and 32 percent, respectively, within the North American market. Microcomponent and memory ICs will account for more than 68 percent of semiconductor revenue in North America by 1999, more than two-thirds of the market.

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- MOS memory will enjoy a third year of stable prices into 1995 with the continuing tight supply of 4Mb and 16Mb DRAM. Although the DRAM boom will continue into the first half of 1996, strong capital spending in 1994 by Japanese and Korean DRAM suppliers will show up as excess supply and a decline in ASPs in the second half of 1996. Despite falling ASPs, DRAM revenue will be supported by increasing unit shipments as the PC market moves toward higher levels of DRAM use.
- The 4Mb DRAM demand is showing continued strength through 1995, a break from past DRAM life cycles. This extended life has been attributed to limited acceptance of the x1 and x4 configurations of 16Mb DRAMs and the inability of vendors to supply the preferred x16 configuration. This has further limited the price-per-bit decline that was anticipated.
- MPUs will show a decelerating rate of growth toward the end of the forecast period as increased competition to the x86 family brings ASPs down.
- Discrete device growth (21.9 percent in 1994 and 16.4 percent forecast for 1995) increasingly comes from the use of power MOSFETs and IGBTs in switching power supplies and as peripherals drivers and RF devices. MOSFETS and IGBTs showed 30 percent and 100 percent growth in 1994, respectively, growth rates that will not dissipate by much in 1995.

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Table 1
Revenue from North American Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	187,909	187,889	186,492	195,149	208,500
Total Semiconductor	16,540	16,990	20,430	27,926	35,939
Total IC	14,616	15,269	18,404	25,629	33,032
Bipolar Digital	1,577	1,331	1,232	1,173	967
MOS Digital	10,390	11,296	14,174	20,864	27,861
MOS Memory	4,325	4,510	5,707	8,785	12,458
MOS Microcomponent	3,381	3,916	5,282	7,620	9,657
MOS Logic	2,684	2,870	3,185	4,459	5,746
Analog (Monolithic + Hybrid)	2,649	2,642	2,998	3,592	4,204
Total Discrete	1,611	1,389	1,603	1,811	2,208
Total Optical Semiconductor	313	332	423	486	699

Source: Dataquest (June 1995)

Table 2
Revenue from North American Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	220,425	229,933	240,437	252,320	265,836
Total Semiconductor	45,307	53,570	61,770	72,163	83,191
Total IC	41,917	49,930	57,840	67,783	78,246
Bipolar Digital	862	740	635	533	444
MOS Digital	36,110	43,645	50,995	60,055	69,452
MOS Memory	16,535	19,080	21,355	25,235	29,375
MOS Microcomponent	12,515	16,380	20,395	24,090	27,730
MOS Logic	7,060	8,185	9,245	10,730	12,347
Analog (Monolithic + Hybrid)	4,945	5,545	6,210	7,195	8,350
Total Discrete	2,570	2,770	2,970	3,305	3,750
Total Optical Semiconductor	820	870	960	1,075	1,195

Source: Dataquest (June 1995)

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Table 3
Revenue Growth from North American Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.8	0	-0.7	4.6	6.8
Total Semiconductor	-3.1	2.7	20.2	36.7	28.7
Total IC	-3.2	4.5	20.5	39.3	28.9
Bipolar Digital	-3.6	-15.6	-7.4	-4.8	-17.6
MOS Digital	-5.4	8.7	25.5	47.2	33.5
MOS Memory	-25.1	4.3	26.5	53.9	41.8
MOS Microcomponent	20.9	15.8	34.9	44.3	26.7
MOS Logic	10.9	6.9	11.0	40.0	28.9
Analog (Monolithic + Hybrid)	6.9	-0.3	13.5	19.8	17.0
Total Discrete	-1.7	-13.8	15.4	13.0	21.9
Total Optical Semiconductor	-4.9	6.1	27.4	14.9	43.8

Source: Dataquest (June 1995)

Table 4
Revenue Growth from North American Total Electronic Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in All Electronic Equipment Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	5.7	4.3	4.6	4.9	5.4	5.0
Total Semiconductor	26.1	18.2	15.3	16.8	15.3	18.3
Total IC	26.9	19.1	15.8	17.2	15.4	18.8
Bipolar Digital	-10.9	-14.2	-14.2	-16.1	-16.7	-14.4
MOS Digital	29.6	20.9	16.8	17.8	15.6	20.0
MOS Memory	32.7	15.4	11.9	18.2	16.4	18.7
MOS Microcomponent	29.6	30.9	24.5	18.1	15.1	23.5
MOS Logic	22.9	15.9	13.0	16.1	15.1	16.5
Analog (Monolithic + Hybrid)	17.6	12.1	12.0	15.9	16.1	14.7
Total Discrete	16.4	7.8	7.2	11.3	13.5	11.2
Total Optical Semiconductor	17.3	6.1	10.3	12.0	11.2	11.3

Source: Dataquest (June 1995)

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Table 5
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Data Processing	66,664	65,314	61,037	60,617	64,098
Total Semiconductor	7,305	8,214	9,603	13,573	18,115
Total IC	7,085	7,996	9,353	13,296	17,701
Bipolar Digital	752	686	634	611	494
MOS Digital	5,929	6,900	8,311	12,250	16,778
MOS Memory	2,787	3,123	3,755	5,748	8,411
MOS Microcomponent	1,926	2,384	3,087	4,439	5,613
MOS Logic	1,216	1,393	1,469	2,062	2,754
Analog (Monolithic + Hybrid)	404	410	408	435	429
Total Discrete	149	132	150	163	220
Total Optical Semiconductor	71	86	100	114	195

Source: Dataquest (June 1995)

Table 6
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Data Processing	67,605	69,036	70,684	73,212	76,584
Total Semiconductor	24,062	29,163	33,584	39,520	45,482
Total IC	23,556	28,645	33,047	38,929	44,820
Bipolar Digital	451	383	322	263	209
MOS Digital	22,622	27,784	32,296	38,208	44,145
MOS Memory	11,669	13,638	15,069	17,809	20,675
MOS Microcomponent	7,443	10,023	12,587	14,985	17,215
MOS Logic	3,509	4,123	4,639	5,414	6,255
Analog (Monolithic + Hybrid)	483	479	429	458	466
Total Discrete	272	279	281	309	358
Total Optical Semiconductor	234	239	257	282	304

Source: Dataquest (June 1995)

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Table 7
Revenue Growth from North American Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Data Processing	5.8	-2.0	-6.5	-0.7	5.7
Total Semiconductor	-3.7	12.4	16.9	41.3	33.5
Total IC	-3.8	12.9	17.0	42.2	33.1
Bipolar Digital	-0.2	-8.8	-7.6	-3.6	-19.2
MOS Digital	-4.7	16.4	20.4	47.4	37.0
MOS Memory	-23.6	12.1	20.3	53.1	46.3
MOS Microcomponent	28.9	23.8	29.5	43.8	26.4
MOS Logic	12.4	14.5	5.5	40.4	33.6
Analog (Monolithic + Hybrid)	3.6	1.5	-0.6	6.7	-1.4
Total Discrete	0.5	-11.2	13.3	8.6	35.0
Total Optical Semiconductor	-6.6	21.1	16.8	14.3	70.3

Source: Dataquest (June 1995)

Table 8
Revenue Growth from North American Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Data Processing	5.5	2.1	2.4	3.6	4.6	3.6
Total Semiconductor	32.8	21.2	15.2	17.7	15.1	20.2
Total IC	33.1	21.6	15.4	17.8	15.1	20.4
Bipolar Digital	-8.8	-15.1	-15.7	-18.4	-20.4	-15.8
MOS Digital	34.8	22.8	16.2	18.3	15.5	21.3
MOS Memory	38.7	16.9	10.5	18.2	16.1	19.7
MOS Microcomponent	32.6	34.7	25.6	19.0	14.9	25.1
MOS Logic	27.4	17.5	12.5	16.7	15.5	17.8
Analog (Monolithic + Hybrid)	12.8	-1.0	-10.4	6.9	1.7	1.7
Total Discrete	23.7	2.4	0.8	10.1	15.7	10.2
Total Optical Semiconductor	20.3	2.2	7.2	9.9	7.8	9.3

Source: Dataquest (June 1995)

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Table 9
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Communications	27,471	29,126	33,035	38,615	44,037
Total Semiconductor	2,982	2,768	3,810	5,697	7,509
Total IC	2,607	2,446	3,391	5,177	6,703
Bipolar Digital	273	197	195	199	150
MOS Digital	1,783	1,712	2,493	4,065	5,443
MOS Memory	704	614	937	1,554	2,194
MOS Microcomponent	506	528	837	1,339	1,684
MOS Logic	573	570	719	1,171	1,565
Analog (Monolithic + Hybrid)	550	537	703	913	1,111
Total Discrete	316	260	320	394	578
Total Optical Semiconductor	60	62	98	127	228

Source: Dataquest (June 1995)

Table 10
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Communications	48,224	52,265	55,817	59,677	63,206
Total Semiconductor	9,845	11,754	13,426	15,808	18,305
Total IC	8,792	10,581	12,129	14,274	16,468
Bipolar Digital	124	98	75	56	41
MOS Digital	7,157	8,650	9,924	11,593	13,186
MOS Memory	2,941	3,322	3,546	4,050	4,567
MOS Microcomponent	2,219	2,971	3,713	4,408	4,986
MOS Logic	1,996	2,358	2,665	3,135	3,634
Analog (Monolithic + Hybrid)	1,511	1,833	2,130	2,626	3,241
Total Discrete	762	857	934	1,109	1,349
Total Optical Semiconductor	290	316	363	425	488

Source: Dataquest (June 1995)

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Table 11
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Communications	8.6	6.0	13.4	16.9	14.0
Total Semiconductor	-5.6	-7.2	37.6	49.5	31.8
Total IC	-6.6	-6.2	38.6	52.7	29.5
Bipolar Digital	-8.6	-28.1	-0.9	2.3	-24.9
MOS Digital	-11.5	-4.0	45.6	63.0	33.9
MOS Memory	-33.6	-12.8	52.7	65.8	41.2
MOS Microcomponent	19.8	4.4	58.5	60.0	25.8
MOS Logic	8.0	-0.5	26.1	62.9	33.6
Analog (Monolithic + Hybrid)	15.5	-2.4	30.9	29.8	21.6
Total Discrete	2.7	-17.6	23.2	22.9	46.9
Total Optical Semiconductor	-5.3	3.6	58.6	28.7	80.3

Source: Dataquest (June 1995)

Table 12
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Communications	9.5	8.4	6.8	6.9	5.9	7.5
Total Semiconductor	31.1	19.4	14.2	17.7	15.8	19.5
Total IC	31.2	20.3	14.6	17.7	15.4	19.7
Bipolar Digital	-16.9	-21.1	-23.4	-26.0	-26.5	-22.9
MOS Digital	31.5	20.9	14.7	16.8	13.7	19.4
MOS Memory	34.0	12.9	6.8	14.2	12.8	15.8
MOS Microcomponent	31.8	33.9	25.0	18.7	13.1	24.2
MOS Logic	27.6	18.1	13.0	17.7	15.9	18.4
Analog (Monolithic + Hybrid)	36.1	21.3	16.2	23.3	23.4	23.9
Total Discrete	31.8	12.4	9.0	18.7	21.6	18.5
Total Optical Semiconductor	27.2	9.0	14.7	17.0	15.0	16.4

Source: Dataquest (June 1995)

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Table 13
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Industrial	36,628	37,702	37,844	40,410	43,881
Total Semiconductor	2,194	2,101	2,761	3,617	4,467
Total IC	1,608	1,601	2,150	2,946	3,697
Bipolar Digital	157	112	119	108	91
MOS Digital	972	1,000	1,441	2,126	2,742
MOS Memory	263	248	392	622	795
MOS Microcomponent	365	398	623	908	1,214
MOS Logic	343	355	426	595	733
Analog (Monolithic + Hybrid)	480	488	590	712	864
Total Discrete	506	418	499	544	620
Total Optical Semiconductor	80	82	113	127	150

Source: Dataquest (June 1995)

Table 14
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Industrial	47,192	50,270	53,438	57,204	61,564
Total Semiconductor	5,053	5,823	7,024	8,243	9,795
Total IC	4,201	4,899	6,018	7,140	8,571
Bipolar Digital	75	63	55	46	38
MOS Digital	3,152	3,715	4,651	5,543	6,683
MOS Memory	815	907	1,204	1,519	1,937
MOS Microcomponent	1,525	1,893	2,367	2,784	3,306
MOS Logic	811	914	1,080	1,240	1,440
Analog (Monolithic + Hybrid)	974	1,121	1,312	1,550	1,851
Total Discrete	686	742	804	879	972
Total Optical Semiconductor	166	182	202	224	252

Source: Dataquest (June 1995)

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Table 15
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Industrial	4.8	2.9	0.4	6.8	8.6
Total Semiconductor	0.3	-4.3	31.4	31.0	23.5
Total IC	1.8	-0.5	34.3	37.0	25.5
Bipolar Digital	-6.5	-28.4	6.0	-9.4	-15.8
MOS Digital	-1.6	2.9	44.0	47.5	29.0
MOS Memory	-31.1	-5.8	58.0	58.9	27.8
MOS Microcomponent	14.8	8.8	56.7	45.8	33.7
MOS Logic	19.3	3.5	20.1	39.7	23.2
Analog (Monolithic + Hybrid)	12.9	1.8	20.9	20.6	21.3
Total Discrete	-3.0	-17.4	19.4	9.1	13.9
Total Optical Semiconductor	-5.3	3.0	36.7	12.9	18.1

Source: Dataquest (June 1995)

Table 16
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Industrial	7.5	6.5	6.3	7.0	7.6	7.0
Total Semiconductor	13.1	15.2	20.6	17.4	18.8	17.0
Total IC	13.6	16.6	22.8	18.6	20.1	18.3
Bipolar Digital	-17.6	-16.0	-12.7	-16.3	-17.4	-16.0
MOS Digital	14.9	17.9	25.2	19.2	20.6	19.5
MOS Memory	2.5	11.3	32.7	26.2	27.5	19.5
MOS Microcomponent	25.6	24.1	25.0	17.6	18.8	22.2
MOS Logic	10.7	12.7	18.1	14.8	16.1	14.5
Analog (Monolithic + Hybrid)	12.8	15.1	17.0	18.2	19.4	16.5
Total Discrete	10.7	8.2	8.3	9.4	10.5	9.4
Total Optical Semiconductor	10.7	9.6	11.0	10.9	12.4	10.9

Source: Dataquest (June 1995)

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Table 17
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Consumer	17,005	16,616	17,804	19,582	21,279
Total Semiconductor	1,116	1,066	1,424	2,027	2,559
Total IC	919	899	1,216	1,780	2,269
Bipolar Digital	10	7	7	6	5
MOS Digital	461	436	651	1,071	1,428
MOS Memory	224	196	300	532	716
MOS Microcomponent	182	187	288	445	594
MOS Logic	54	53	63	95	117
Analog (Monolithic + Hybrid)	447	456	558	702	836
Total Discrete	184	155	193	230	270
Total Optical Semiconductor	13	13	15	17	19

Source: Dataquest (June 1995)

Table 18
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Consumer	22,560	23,072	24,239	24,889	26,138
Total Semiconductor	2,838	3,159	3,821	4,401	5,174
Total IC	2,518	2,821	3,454	4,009	4,744
Bipolar Digital	4	3	3	2	2
MOS Digital	1,610	1,843	2,359	2,801	3,398
MOS Memory	754	843	1,148	1,451	1,773
MOS Microcomponent	728	861	1,049	1,173	1,423
MOS Logic	128	139	161	177	201
Analog (Monolithic + Hybrid)	904	975	1,093	1,206	1,344
Total Discrete	300	319	348	373	410
Total Optical Semiconductor	19	19	20	20	20

Source: Dataquest (June 1995)

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Table 19
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Consumer	-1.0	-2.3	7.1	10.0	8.7
Total Semiconductor	-3.7	-4.4	33.5	42.4	26.2
Total IC	-3.8	-2.2	35.3	46.4	27.5
Bipolar Digital	-26.4	-35.8	0.5	-5.5	-16.5
MOS Digital	-10.0	-5.4	49.2	64.6	33.3
MOS Memory	-23.9	-12.7	53.1	77.4	34.6
MOS Microcomponent	10.4	2.6	53.8	54.5	33.6
MOS Logic	3.9	-1.7	19.0	49.5	24.3
Analog (Monolithic + Hybrid)	4.4	1.9	22.5	25.8	19.1
Total Discrete	-3.2	-16.1	24.7	19.4	17.4
Total Optical Semiconductor	-8.5	4.0	15.8	13.4	11.5

Source: Dataquest (June 1995)

Table 20
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Consumer	6.0	2.3	5.1	2.7	5.0	4.2
Total Semiconductor	10.9	11.3	20.9	15.2	17.6	15.1
Total IC	11.0	12.0	22.4	16.1	18.3	15.9
Bipolar Digital	-21.2	-21.4	-15.3	-22.8	-19.5	-20.1
MOS Digital	12.8	14.5	28.0	18.7	21.3	18.9
MOS Memory	5.3	11.7	36.2	26.3	22.2	19.9
MOS Microcomponent	22.5	18.3	21.8	11.8	21.4	19.1
MOS Logic	8.8	8.5	16.1	10.2	13.4	11.4
Analog (Monolithic + Hybrid)	8.1	7.8	12.1	10.4	11.4	10.0
Total Discrete	11.1	6.3	8.9	7.2	10.1	8.7
Total Optical Semiconductor	1.8	-1.2	1.9	-0.2	2.7	1.0

Source: Dataquest (June 1995)

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Table 21
Revenue from North American Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	36,603	35,577	32,861	31,284	29,668
Total Semiconductor	1,991	1,870	1,762	1,712	1,692
Total IC	1,610	1,509	1,407	1,364	1,348
Bipolar Digital	353	301	249	219	198
MOS Digital	846	827	804	799	809
MOS Memory	292	279	269	268	273
MOS Microcomponent	199	199	193	193	197
MOS Logic	355	349	343	338	339
Analog (Monolithic + Hybrid)	411	381	354	346	341
Total Discrete	313	295	291	285	280
Total Optical Semiconductor	68	66	64	63	64

Source: Dataquest (June 1995)

Table 22
Revenue from North American Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Military/Civil Aerospace	28,698	28,932	29,466	30,018	30,585
Total Semiconductor	1,681	1,736	1,806	1,882	1,958
Total IC	1,342	1,387	1,446	1,509	1,572
Bipolar Digital	180	166	155	144	134
MOS Digital	827	877	929	985	1,042
MOS Memory	283	300	319	340	359
MOS Microcomponent	202	215	228	241	254
MOS Logic	342	362	382	405	429
Analog (Monolithic + Hybrid)	335	344	363	380	396
Total Discrete	275	283	291	300	309
Total Optical Semiconductor	64	66	69	73	77

Source: Dataquest (June 1995)

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Table 23
Revenue Growth from North American Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1990-1994
(Percentage Change)

	1990	1991	1992	1993	1994
Total Military/Civil Aerospace	4.9	-2.8	-7.6	-4.8	-5.2
Total Semiconductor	-1.6	-6.1	-5.7	-2.9	-1.2
Total IC	-1.0	-6.3	-6.7	-3.1	-1.2
Bipolar Digital	-8.1	-14.7	-17.3	-12.0	-9.6
MOS Digital	-0.1	-2.3	-2.7	-0.7	1.3
MOS Memory	-10.9	-4.6	-3.5	-0.3	1.9
MOS Microcomponent	5.9	0	-3.3	0.3	2.1
MOS Logic	7.3	-1.7	-1.7	-1.5	0.3
Analog (Monolithic + Hybrid)	4.1	-7.3	-7.1	-2.3	-1.4
Total Discrete	-4.3	-5.8	-1.4	-2.1	-1.8
Total Optical Semiconductor	-4.2	-2.9	-3.0	-1.6	1.6

Source: Dataquest (June 1995)

Table 24
Revenue Growth from North American Military/Civil Aerospace Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1995-1999
(Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Military/Civil Aerospace	-3.3	0.8	1.8	1.9	1.9	0.6
Total Semiconductor	-0.7	3.3	4.1	4.2	4.0	3.0
Total IC	-0.5	3.3	4.3	4.4	4.1	3.1
Bipolar Digital	-9.1	-7.7	-6.9	-6.7	-7.1	-7.5
MOS Digital	2.2	6.0	5.9	6.1	5.7	5.2
MOS Memory	3.7	6.0	6.3	6.6	5.6	5.6
MOS Microcomponent	2.5	6.2	6.3	5.5	5.6	5.2
MOS Logic	0.9	5.8	5.4	6.0	5.9	4.8
Analog (Monolithic + Hybrid)	-1.8	2.7	5.5	4.7	4.2	3.0
Total Discrete	-1.8	2.9	2.8	3.1	3.0	2.0
Total Optical Semiconductor	0	3.1	4.5	5.8	5.5	3.8

Source: Dataquest (June 1995)

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Table 25
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Transportation	3,537	3,554	3,911	4,641	5,537
Total Semiconductor	952	971	1,069	1,299	1,597
Total IC	787	819	886	1,066	1,314
Bipolar Digital	31	28	28	29	29
MOS Digital	399	421	474	554	662
MOS Memory	54	51	54	60	69
MOS Microcomponent	202	220	255	296	355
MOS Logic	143	150	165	198	238
Analog (Monolithic + Hybrid)	357	370	384	484	623
Total Discrete	143	129	150	195	239
Total Optical Semiconductor	22	23	33	38	43

Source: Dataquest (June 1995)

Table 26
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Transportation	6,145	6,357	6,793	7,321	7,758
Total Semiconductor	1,828	1,935	2,109	2,308	2,478
Total IC	1,508	1,598	1,747	1,922	2,072
Bipolar Digital	28	27	25	22	20
MOS Digital	743	777	837	925	999
MOS Memory	72	70	68	66	65
MOS Microcomponent	398	417	451	500	546
MOS Logic	273	290	319	358	389
Analog (Monolithic + Hybrid)	737	794	884	975	1,052
Total Discrete	274	290	312	335	352
Total Optical Semiconductor	46	47	50	52	54

Source: Dataquest (June 1995)

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Table 27
Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Transportation Applications, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Transportation	-9.3	0.5	10.0	18.7	19.3
Total Semiconductor	0	2.0	10.1	21.5	22.9
Total IC	0.1	4.1	8.2	20.3	23.2
Bipolar Digital	89.7	-9.7	0	3.6	0
MOS Digital	-1.7	5.5	12.6	16.8	19.5
MOS Memory	-11.3	-5.6	5.9	11.1	15.0
MOS Microcomponent	-2.8	8.9	15.9	16.0	20.0
MOS Logic	4.4	4.9	10.0	20.0	20.0
Analog (Monolithic + Hybrid)	-2.0	3.6	3.9	25.8	28.9
Total Discrete	-0.7	-9.8	16.3	29.9	22.9
Total Optical Semiconductor	4.6	4.5	43.5	15.2	13.2

Source: Dataquest (June 1995)

Table 28
Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Transportation Applications, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Transportation	11.0	3.4	6.9	7.8	6.0	7.0
Total Semiconductor	14.5	5.9	9.0	9.5	7.3	9.2
Total IC	14.7	6.0	9.3	10.0	7.8	9.5
Bipolar Digital	-3.4	-3.6	-7.4	-12.0	-9.1	-7.2
MOS Digital	12.3	4.6	7.8	10.4	8.1	8.6
MOS Memory	4.4	-2.8	-2.9	-2.9	-1.5	-1.2
MOS Microcomponent	12.0	5.0	8.0	11.0	9.0	9.0
MOS Logic	15.0	6.0	10.0	12.5	8.5	10.4
Analog (Monolithic + Hybrid)	18.2	7.7	11.4	10.3	8.0	11.0
Total Discrete	14.5	5.8	7.5	7.2	5.1	8.0
Total Optical Semiconductor	7.0	2.2	6.4	4.0	3.8	4.7

Source: Dataquest (June 1995)

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Table 29
Revenue from Shipments of Bipolar Digital Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	1,577	1,331	1,232	1,173	967
Data Processing	752	686	634	611	494
Communications	273	197	195	199	150
Industrial	157	112	119	108	91
Consumer	10	7	7	6	5
Military/Civil Aerospace	353	301	249	219	198
Transportation	31	28	28	29	29

Source: Dataquest (June 1995)

Table 30
Revenue from Shipments of Bipolar Digital Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	862	740	635	533	444
Data Processing	451	383	322	263	209
Communications	124	98	75	56	41
Industrial	75	63	55	46	38
Consumer	4	3	3	2	2
Military/Civil Aerospace	180	166	155	144	134
Transportation	28	27	25	22	20

Source: Dataquest (June 1995)

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Table 31
Revenue Growth from Shipments of Bipolar Digital Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-3.6	-15.6	-7.4	-4.8	-17.6
Data Processing	-0.2	-8.8	-7.6	-3.6	-19.2
Communications	-8.6	-28.1	-0.9	2.3	-24.9
Industrial	-6.5	-28.4	6.0	-9.4	-15.8
Consumer	-26.4	-35.8	0.5	-5.5	-16.5
Military/Civil Aerospace	-8.1	-14.7	-17.3	-12.0	-9.6
Transportation	89.7	-9.7	0	3.6	0

Source: Dataquest (June 1995)

Table 32
Revenue Growth from Shipments of Bipolar Digital Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	-10.9	-14.2	-14.2	-16.1	-16.7	-14.4
Data Processing	-8.8	-15.1	-15.7	-18.4	-20.4	-15.8
Communications	-16.9	-21.1	-23.4	-26.0	-26.5	-22.9
Industrial	-17.6	-16.0	-12.7	-16.3	-17.4	-16.0
Consumer	-21.2	-21.4	-15.3	-22.8	-19.5	-20.1
Military/Civil Aerospace	-9.1	-7.7	-6.9	-6.7	-7.1	-7.5
Transportation	-3.4	-3.6	-7.4	-12.0	-9.1	-7.2

Source: Dataquest (June 1995)

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Table 33
Revenue from Shipments of MOS Memory Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4,325	4,510	5,707	8,785	12,458
Data Processing	2,787	3,123	3,755	5,748	8,411
Communications	704	614	937	1,554	2,194
Industrial	263	248	392	622	795
Consumer	224	196	300	532	716
Military/Civil Aerospace	292	279	269	268	273
Transportation	54	51	54	60	69

Source: Dataquest (June 1995)

Table 34
Revenue from Shipments of MOS Memory Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	16,535	19,080	21,355	25,235	29,375
Data Processing	11,669	13,638	15,069	17,809	20,675
Communications	2,941	3,322	3,546	4,050	4,567
Industrial	815	907	1,204	1,519	1,937
Consumer	754	843	1,148	1,451	1,773
Military/Civil Aerospace	283	300	319	340	359
Transportation	72	70	68	66	65

Source: Dataquest (June 1995)

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Table 35
Revenue Growth from Shipments of MOS Memory Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-25.1	4.3	26.5	53.9	41.8
Data Processing	-23.6	12.1	20.3	53.1	46.3
Communications	-33.6	-12.8	52.7	65.8	41.2
Industrial	-31.1	-5.8	58.0	58.9	27.8
Consumer	-23.9	-12.7	53.1	77.4	34.6
Military/Civil Aerospace	-10.9	-4.6	-3.5	-0.3	1.9
Transportation	-11.3	-5.6	5.9	11.1	15.0

Source: Dataquest (June 1995)

Table 36
Revenue Growth from Shipments of MOS Memory Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	32.7	15.4	11.9	18.2	16.4	18.7
Data Processing	38.7	16.9	10.5	18.2	16.1	19.7
Communications	34.0	12.9	6.8	14.2	12.8	15.8
Industrial	2.5	11.3	32.7	26.2	27.5	19.5
Consumer	5.3	11.7	36.2	26.3	22.2	19.9
Military/Civil Aerospace	3.7	6.0	6.3	6.6	5.6	5.6
Transportation	4.4	-2.8	-2.9	-2.9	-1.5	-1.2

Source: Dataquest (June 1995)

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Table 37
Revenue from Shipments of MOS Microcomponent Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	3,381	3,916	5,282	7,620	9,657
Data Processing	1,926	2,384	3,087	4,439	5,613
Communications	506	528	837	1,339	1,684
Industrial	365	398	623	908	1,214
Consumer	182	187	288	445	594
Military/Civil Aerospace	199	199	193	193	197
Transportation	202	220	255	296	355

Source: Dataquest (June 1995)

Table 38
Revenue from Shipments of MOS Microcomponent Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	12,515	16,380	20,395	24,090	27,730
Data Processing	7,443	10,023	12,587	14,985	17,215
Communications	2,219	2,971	3,713	4,408	4,986
Industrial	1,525	1,893	2,367	2,784	3,306
Consumer	728	861	1,049	1,173	1,423
Military/Civil Aerospace	202	215	228	241	254
Transportation	398	417	451	500	546

Source: Dataquest (June 1995)

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Table 39
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	20.9	15.8	34.9	44.3	26.7
Data Processing	28.9	23.8	29.5	43.8	26.4
Communications	19.8	4.4	58.5	60.0	25.8
Industrial	14.8	8.8	56.7	45.8	33.7
Consumer	10.4	2.6	53.8	54.5	33.6
Military/Civil Aerospace	5.9	0	-3.3	0.3	2.1
Transportation	-2.8	8.9	15.9	16.0	20.0

Source: Dataquest (June 1995)

Table 40
Revenue Growth from Shipments of MOS Microcomponent Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	29.6	30.9	24.5	18.1	15.1	23.5
Data Processing	32.6	34.7	25.6	19.0	14.9	25.1
Communications	31.8	33.9	25.0	18.7	13.1	24.2
Industrial	25.6	24.1	25.0	17.6	18.8	22.2
Consumer	22.5	18.3	21.8	11.8	21.4	19.1
Military/Civil Aerospace	2.5	6.2	6.3	5.5	5.6	5.2
Transportation	12.0	5.0	8.0	11.0	9.0	9.0

Source: Dataquest (June 1995)

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Table 41
Revenue from Shipments of MOS Logic Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,684	2,870	3,185	4,459	5,746
Data Processing	1,216	1,393	1,469	2,062	2,754
Communications	573	570	719	1,171	1,565
Industrial	343	355	426	595	733
Consumer	54	53	63	95	117
Military/Civil Aerospace	355	349	343	338	339
Transportation	143	150	165	198	238

Source: Dataquest (June 1995)

Table 42
Revenue from Shipments of MOS Logic Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	7,060	8,185	9,245	10,730	12,347
Data Processing	3,509	4,123	4,639	5,414	6,255
Communications	1,996	2,358	2,665	3,135	3,634
Industrial	811	914	1,080	1,240	1,440
Consumer	128	139	161	177	201
Military/Civil Aerospace	342	362	382	405	429
Transportation	273	290	319	358	389

Source: Dataquest (June 1995)

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Table 43
Revenue Growth from Shipments of MOS Logic Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	10.9	6.9	11.0	40.0	28.9
Data Processing	12.4	14.5	5.5	40.4	33.6
Communications	8.0	-0.5	26.1	62.9	33.6
Industrial	19.3	3.5	20.1	39.7	23.2
Consumer	3.9	-1.7	19.0	49.5	24.3
Military/Civil Aerospace	7.3	-1.7	-1.7	-1.5	0.3
Transportation	4.4	4.9	10.0	20.0	20.0

Source: Dataquest (June 1995)

Table 44
Revenue Growth from Shipments of MOS Logic Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	22.9	15.9	13.0	16.1	15.1	16.5
Data Processing	27.4	17.5	12.5	16.7	15.5	17.8
Communications	27.6	18.1	13.0	17.7	15.9	18.4
Industrial	10.7	12.7	18.1	14.8	16.1	14.5
Consumer	8.8	8.5	16.1	10.2	13.4	11.4
Military/Civil Aerospace	0.9	5.8	5.4	6.0	5.9	4.8
Transportation	15.0	6.0	10.0	12.5	8.5	10.4

Source: Dataquest (June 1995)

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Table 45
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	2,649	2,642	2,998	3,592	4,204
Data Processing	404	410	408	435	429
Communications	550	537	703	913	1,111
Industrial	480	488	590	712	864
Consumer	447	456	558	702	836
Military/Civil Aerospace	411	381	354	346	341
Transportation	357	370	384	484	623

Source: Dataquest (June 1995)

Table 46
Revenue from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	4,945	5,545	6,210	7,195	8,350
Data Processing	483	479	429	458	466
Communications	1,511	1,833	2,130	2,626	3,241
Industrial	974	1,121	1,312	1,550	1,851
Consumer	904	975	1,093	1,206	1,344
Military/Civil Aerospace	335	344	363	380	396
Transportation	737	794	884	975	1,052

Source: Dataquest (June 1995)

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Table 47
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	6.9	-0.3	13.5	19.8	17.0
Data Processing	3.6	1.5	-0.6	6.7	-1.4
Communications	15.5	-2.4	30.9	29.8	21.6
Industrial	12.9	1.8	20.9	20.6	21.3
Consumer	4.4	1.9	22.5	25.8	19.1
Military/Civil Aerospace	4.1	-7.3	-7.1	-2.3	-1.4
Transportation	-2.0	3.6	3.9	25.8	28.9

Source: Dataquest (June 1995)

Table 48
Revenue Growth from Shipments of Analog (Monolithic plus Hybrid) Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	17.6	12.1	12.0	15.9	16.1	14.7
Data Processing	12.8	-1.0	-10.4	6.9	1.7	1.7
Communications	36.1	21.3	16.2	23.3	23.4	23.9
Industrial	12.8	15.1	17.0	18.2	19.4	16.5
Consumer	8.1	7.8	12.1	10.4	11.4	10.0
Military/Civil Aerospace	-1.8	2.7	5.5	4.7	4.2	3.0
Transportation	18.2	7.7	11.4	10.3	8.0	11.0

Source: Dataquest (June 1995)

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Table 49
Revenue from Shipments of Discrete Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	1,490	1,283	1,486	1,654	2,012
Data Processing	149	132	150	163	220
Communications	316	260	320	394	578
Industrial	506	418	499	544	620
Consumer	184	155	193	230	270
Military/Civil Aerospace	313	295	291	285	280
Transportation	22	23	33	38	43

Source: Dataquest (June 1995)

Table 50
Revenue from Shipments of Discrete Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	2,342	2,527	2,708	3,022	3,452
Data Processing	272	279	281	309	358
Communications	762	857	934	1,109	1,349
Industrial	686	742	804	879	972
Consumer	300	319	348	373	410
Military/Civil Aerospace	275	283	291	300	309
Transportation	46	47	50	52	54

Source: Dataquest (June 1995)

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Table 51
Revenue Growth from Shipments of Discrete Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-1.7	-13.9	15.8	11.3	21.6
Data Processing	0.5	-11.2	13.3	8.6	35.0
Communications	2.7	-17.6	23.2	22.9	46.9
Industrial	-3.0	-17.4	19.4	9.1	13.9
Consumer	-3.2	-16.1	24.7	19.4	17.4
Military/Civil Aerospace	-4.3	-5.8	-1.4	-2.1	-1.8
Transportation	4.6	4.5	43.5	15.2	13.2

Source: Dataquest (June 1995)

Table 52
Revenue Growth from Shipments of Discrete Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	16.4	7.9	7.2	11.6	14.2	11.4
Data Processing	23.7	2.4	0.8	10.1	15.7	10.2
Communications	31.8	12.4	9.0	18.7	21.6	18.5
Industrial	10.7	8.2	8.3	9.4	10.5	9.4
Consumer	11.1	6.3	8.9	7.2	10.1	8.7
Military/Civil Aerospace	-1.8	2.9	2.8	3.1	3.0	2.0
Transportation	7.0	2.2	6.4	4.0	3.8	4.7

Source: Dataquest (June 1995)

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Table 53
Revenue from Shipments of Optical Semiconductors to North America, by Application Market, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	313	332	423	486	699
Data Processing	71	86	100	114	195
Communications	60	62	98	127	228
Industrial	80	82	113	127	150
Consumer	13	13	15	17	19
Military/Civil Aerospace	68	66	64	63	64
Transportation	22	23	33	38	43

Source: Dataquest (June 1995)

Table 54
Revenue from Shipments of Optical Semiconductors to North America, by Application Market, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	820	870	960	1,075	1,195
Data Processing	234	239	257	282	304
Communications	290	316	363	425	488
Industrial	166	182	202	224	252
Consumer	19	19	20	20	20
Military/Civil Aerospace	64	66	69	73	77
Transportation	46	47	50	52	54

Source: Dataquest (June 1995)

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Table 55
Revenue Growth from Shipments of Optical Semiconductors to North America, by Application Market, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	-4.9	6.1	27.4	14.9	43.8
Data Processing	-6.6	21.1	16.8	14.3	70.3
Communications	-5.3	3.6	58.6	28.7	80.3
Industrial	-5.3	3.0	36.7	12.9	18.1
Consumer	-8.5	4.0	15.8	13.4	11.5
Military/Civil Aerospace	-4.2	-2.9	-3.0	-1.6	1.6
Transportation	4.6	4.5	43.5	15.2	13.2

Source: Dataquest (June 1995)

Table 56
Revenue Growth from Shipments of Optical Semiconductors to North America, by Application Market, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	17.3	6.1	10.3	12.0	11.2	11.3
Data Processing	20.3	2.2	7.2	9.9	7.8	9.3
Communications	27.2	9.0	14.7	17.0	15.0	16.4
Industrial	10.7	9.6	11.0	10.9	12.4	10.9
Consumer	1.8	-1.2	1.9	-0.2	2.7	1.0
Military/Civil Aerospace	0	3.1	4.5	5.8	5.5	3.8
Transportation	7.0	2.2	6.4	4.0	3.8	4.7

Source: Dataquest (June 1995)

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Table 57
Revenue from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	16,540	16,990	20,430	27,926	35,939
Data Processing	7,305	8,214	9,603	13,573	18,115
Computers	5,203	5,794	7,166	10,355	14,031
Data Storage	737	755	591	606	628
Input/Output	972	1,213	1,346	1,898	2,510
Dedicated System	250	287	291	399	511
Other Data Processing	144	164	208	316	435
Communications	2,982	2,768	3,810	5,697	7,509
Premise Telecom	1,634	1,475	2,037	3,149	4,228
Public Telecom	557	511	628	911	1,157
Mobile Communications	323	368	600	813	1,033
Broadcast & Studio	128	111	147	220	289
Other Communications	340	304	398	605	801
Industrial	2,194	2,101	2,761	3,617	4,467
Security and Energy Management	173	166	210	291	344
Manufacturing Sys/Instruments	1,333	1,283	1,731	2,432	3,051
Medical Equipment	358	336	424	521	630
Other Industrial	329	316	396	373	442
Consumer	1,116	1,066	1,424	2,027	2,559
Audio	40	38	50	67	83
Video	247	232	301	419	520
Personal Electronics	26	25	32	45	55
Appliances	713	685	923	1,325	1,680
Other Consumer	90	86	118	171	221
Military/Civil Aerospace	1,991	1,870	1,762	1,712	1,692
Transportation	952	971	1,069	1,299	1,597

Source: Dataquest (June 1995)

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Table 58
Revenue from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Semiconductor	45,307	53,570	61,770	72,163	83,191
Data Processing	24,062	29,163	33,584	39,520	45,482
Computers	18,876	23,124	26,876	31,879	36,944
Data Storage	646	606	539	489	433
Input/Output	3,296	3,941	4,471	5,176	5,854
Dedicated System	651	754	830	931	1,021
Other Data Processing	593	737	869	1,046	1,229
Communications	9,845	11,754	13,426	15,808	18,305
Premise Telecom	5,644	6,857	7,965	9,532	11,213
Public Telecom	1,461	1,680	1,847	2,092	2,329
Mobile Communications	1,305	1,501	1,650	1,868	2,080
Broadcast & Studio	379	451	513	602	694
Other Communications	1,056	1,266	1,451	1,714	1,990
Industrial	5,053	5,823	7,024	8,243	9,795
Security and Energy Management	382	447	546	641	751
Manufacturing Sys/Instruments	3,472	3,998	4,832	5,685	6,812
Medical Equipment	708	824	1,006	1,191	1,409
Other Industrial	491	554	640	726	823
Consumer	2,838	3,159	3,821	4,401	5,174
Audio	90	98	115	129	148
Video	567	620	737	834	963
Personal Electronics	61	66	79	89	103
Appliances	1,871	2,092	2,540	2,937	3,465
Other Consumer	250	284	351	412	495
Military/Civil Aerospace	1,681	1,736	1,806	1,882	1,958
Transportation	1,828	1,935	2,109	2,308	2,478

Source: Dataquest (June 1995)

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Table 59
Revenue Growth from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Semiconductor	-3.1	2.7	20.2	36.7	28.7
Data Processing	-3.7	12.4	16.9	41.3	33.5
Computers	-5.2	11.4	23.7	44.5	35.5
Data Storage	2.5	2.5	-21.8	2.5	3.7
Input/Output	1.4	24.8	11.0	41.0	32.3
Dedicated System	-6.0	15.2	1.4	36.8	28.2
Other Data Processing	-7.5	14.1	26.7	52.1	37.4
Communications	-5.6	-7.2	37.6	49.5	31.8
Premise Telecom	-5.9	-9.8	38.1	54.6	34.3
Public Telecom	-10.6	-8.2	23.0	44.9	27.1
Mobile Communications	16.4	13.9	63.1	35.5	27.1
Broadcast & Studio	-10.0	-13.3	31.8	50.0	31.6
Other Communications	-10.7	-10.8	31.2	51.9	32.5
Industrial	0.3	-4.3	31.4	31.0	23.5
Security and Energy Management	4.2	-4.4	26.9	38.3	18.3
Manufacturing Sys/Instruments	-0.7	-3.8	34.9	40.5	25.4
Medical Equipment	-1.1	-6.1	26.1	22.9	21.0
Other Industrial	4.2	-4.1	25.4	-5.8	18.6
Consumer	-3.7	-4.4	33.5	42.4	26.2
Audio	2.2	-4.8	29.7	35.1	23.1
Video	-2.0	-6.1	30.0	39.1	24.1
Personal Electronics	1.8	-3.7	31.5	38.2	24.2
Appliances	-4.1	-3.9	34.7	43.6	26.8
Other Consumer	-9.1	-4.0	36.4	45.4	28.9
Military/Civil Aerospace	-1.6	-6.1	-5.7	-2.9	-1.2
Transportation	0	2.0	10.1	21.5	22.9

Source: Dataquest (June 1995)

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Table 60
Revenue Growth from Total Semiconductors Shipped to North America for Use in Each Electronic Equipment Group, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	26.1	18.2	15.3	16.8	15.3	18.3
Data Processing	32.8	21.2	15.2	17.7	15.1	20.2
Computers	34.5	22.5	16.2	18.6	15.9	21.4
Data Storage	2.9	-6.3	-11.1	-9.2	-11.3	-7.1
Input/Output	31.3	19.6	13.4	15.8	13.1	18.5
Dedicated System	27.3	15.9	10.0	12.2	9.7	14.8
Other Data Processing	36.5	24.3	17.9	20.3	17.5	23.1
Communications	31.1	19.4	14.2	17.7	15.8	19.5
Premise Telecom	33.5	21.5	16.2	19.7	17.6	21.5
Public Telecom	26.3	15.0	9.9	13.3	11.3	15.0
Mobile Communications	26.3	15.0	9.9	13.3	11.3	15.0
Broadcast & Studio	30.8	19.1	13.8	17.3	15.3	19.1
Other Communications	31.7	19.9	14.6	18.1	16.1	19.9
Industrial	13.1	15.2	20.6	17.4	18.8	17.0
Security and Energy Management	11.0	17.0	22.1	17.4	17.1	16.9
Manufacturing Sys/Instruments	13.8	15.2	20.9	17.6	19.8	17.4
Medical Equipment	12.4	16.4	22.1	18.4	18.3	17.5
Other Industrial	11.1	12.8	15.5	13.5	13.3	13.2
Consumer	10.9	11.3	20.9	15.2	17.6	15.1
Audio	8.2	8.6	17.9	12.3	14.6	12.3
Video	9.0	9.4	18.8	13.2	15.5	13.1
Personal Electronics	9.1	9.5	18.9	13.3	15.6	13.2
Appliances	11.4	11.8	21.4	15.6	18.0	15.6
Other Consumer	13.3	13.7	23.5	17.6	20.0	17.5
Military/Civil Aerospace	-0.7	3.3	4.1	4.2	4.0	3.0
Transportation	14.5	5.9	9.0	9.5	7.3	9.2

Source: Dataquest (June 1995)

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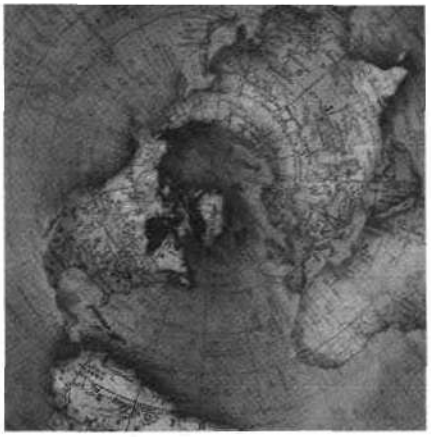
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Worldwide and North American Electronic Equipment Production Forecast

Market Statistics

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Note: All tables show estimated data.

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Worldwide and North American Electronic Equipment Production Forecast

Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets in which semiconductors are used. Included in this document are the following:

- 1990-1994 historical data
- 1995-1999 forecast data

Worldwide production is segmented into four major geographic regions. The list of tables details the type of production data by region, application market, and unit of measure.

Electronic equipment production is an important determinant of semiconductor market activity because semiconductor demand is derived, in part, from the underlying demand for the systems that use semiconductors. Therefore, the forecast of expected future electronics system production is an essential component to assess expected future semiconductor market activity.

Worldwide electronic equipment production estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. factory revenue are based on the average exchange rate for the given year. The section entitled "Exchange Rates" has more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange rate for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year.

Dataquest does not forecast exchange rates per se; however, we do forecast electronic equipment production in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. Specifically, the assumptions of the electronic equipment production forecast are set in the month of January 1995. Therefore, the following should be kept in mind:

- Actual monthly exchange rates are used for all months in the historical interval up through January 1995.

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- The January 1995 exchange rate is assumed to hold for all months in the February-December 1995 period, and throughout all future years.

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of this data is provided in the documents located in the binder of the same name.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to the clients.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civilian aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups, as follows:

- Data Processing
  - Computers
  - Data Storage
  - Input/Output Devices
  - Dedicated Systems
  - Other Data Processing
- Communications
  - Premise Telecom
  - Public Telecom
  - Mobile Communications
  - Broadcast and Studio Equipment
  - Other Communications
- Industrial
  - Security and Energy Management Systems
  - Manufacturing Systems and Instruments

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- Medical Equipment
- Other Industrial Equipment

- Consumer
  - Audio
  - Video
  - Personal Electronics
  - Appliances
  - Other Consumer Equipment
- Military/Civilian Aerospace
- Transportation

Definitions

This section lists the definitions used by Dataquest to present the data in this document.

Electronic system groups comprise the specific electronic equipment types described in the following sections.

Data Processing

Data processing definitions are as follows:

- Computer Systems[1]: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers). Includes the value of central processing units (that is, boxes) only.
- Data Storage[2]: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.
- Input/Output Devices: Includes alphanumeric terminals and graphics terminals (for example, X terminals), monitors, and funds transfer terminals; and printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, and digitizers.

[1]Computer estimate does not include the value of the following systems: rigid disk drive, flexible disk drive, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards. Worldwide computer systems production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of computer systems as estimated by the Dataquest Computer Systems and Peripherals Worldwide group, and to eliminate double counting of system sales of storage devices, keyboards, and displays.

[2]Worldwide mass storage production has been re-estimated and revalued to equal the value of worldwide (factory) revenue and shipments of all equipment categories including rigid disk drive, flexible disk drive, optical disk drive, and tape drive, as estimated by the Dataquest Computer Systems and Peripherals Worldwide group. Also, Dataquest now includes solid-state storage such as flash memory cards in this category. Because most production of these cards is in Japan and Asia/Pacific, we do not include this subcategory in the North American forecast.

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- Dedicated Systems: Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictation/transcribing equipment, electronic typewriters and dedicated word processors, point-of sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other Data Processing: Includes sound/audio boards, digital video boards, accelerator boards, and embedded CPU boards.

Communications

Communications definitions are as follows:

- Premise Telecom Equipment: Includes image and text communication, such as facsimile and facsimile cards, and video teleconferencing; data communications equipment such as modems and modem cards, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, (local area) network interface cards, LAN hubs and internetworking equipment, packet data switching systems; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- Public Telecom Equipment: Includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile Communications Equipment: Includes mobile radio systems such as cellular telephones, microcellular telephones, mobile radios, mobile radio base station equipment and pagers; portable radio receivers and transmitters; and radio checkout equipment.
- Broadcast and Studio Equipment: Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV (head-end) equipment, closed circuit TV equipment, and other equipment, such as studio and theater equipment.
- Other Telecom Equipment: Includes intercom equipment and electrical amplifiers; and communications equipment not elsewhere classified.

Industrial

Industrial definitions are as follows:

- Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems; and energy management systems.
- Manufacturing Systems/Instruments: Includes semiconductor production equipment, controls, process controls, control and processing displays and robots; and test and measuring equipment such as semiconductor-dedicated automatic test equipment (ATE), other test and measurement equipment, and nuclear electronics.

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- Medical Equipment: Includes diagnostic equipment, therapeutic equipment, patient monitoring equipment, surgical support systems, and irradiation equipment.
- Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Consumer definitions are as follows:

- Audio Equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.
- Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, color and monochrome TVs, and cable/satellite set-top decoders.
- Personal Electronics: Includes electronic games and toys (systems and cartridges), cameras, watches, and clocks.
- Appliances: Includes air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other Consumer Equipment: Includes automatic garage door openers, and consumer equipment not elsewhere classified.

Military/Civil Aerospace

Military/civil aerospace definitions are as follows:

- Military/Civil Aerospace[3]: Includes radar/sonar/reconnaissance systems, missile/space-related electronics, navigation equipment, electronic warfare, aircraft flight systems, and command and control systems.

Transportation

Transportation definitions are as follows:

- Transportation Electronics: Includes in-car entertainment systems such as AM/FM radios, cassette and compact disc players, and radio/cassette combination systems; body control electronics such as four-wheel steering control, 2WD/4WD control; multiplex systems such as driver's door, door locks, windshield wipers, heated rear windows, memory seats, memory steering wheel, remote security systems, and suspension control and traction control systems; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls; driver information systems including electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and

[3]North American military/civil aerospace production has been re-estimated and revalued to reflect U.S. Department of Commerce estimates of U.S. defense and civil (aerospace) electronics.

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clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computers; powertrain systems including engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, wheel speed sensors, and transmission control; and safety and convenience systems including climate control systems (air conditioning/heating), air purifier systems, air bag control systems, antilock braking systems, collision warning systems, and cruise control.

Regional Definitions

- North America: Includes Canada, Mexico, and the United States (50 states).
- Japan: Japan is the only single-country region.
- Europe:
  - Western Europe: Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and rest of western Europe (Andorra, Cypress, Gibraltar, Iceland, Liechtenstein, Malta, Monaco, San Marino, Turkey, and Vatican City).
  - Eastern Europe: Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan).
- Asia/Pacific: Includes Asia/Pacific's Newly Industrialized Economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Bangladesh, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.
- Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

The objective of analyzing electronic systems production is to estimate its important implications for semiconductor consumption. Therefore, general economic concepts such as production and consumption are tailored to best isolate these implications.

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The value of production is estimated as factory revenue. For the purposes of this report, Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes.

Production is the value-adding process by which the factors of production (labor and capital) and material inputs are transformed into the finished goods that are desired for consumption and investment. As such, production can and increasingly does span both time and geography. For example, a North America-owned disk drive company may minimize its cost of production by manufacturing (that is, consuming chips) its products in Singapore, for eventual sale in Europe. We would classify this as Asia/Pacific-Rest of World data storage device production, because we are interested in that stage of the production process that relates particularly to semiconductor consumption. Production would be valued as the exchange value of the transaction between the North American company's Singapore operation (which is factory revenue) and the European distributor or final user.

Data Sources

The historical information presented in the production data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- Dataquest's estimates of systems manufacturers' factory revenue
- U.S. Department of Commerce estimates of manufacturers' shipments
- Japanese production statistics compiled and published by the Ministry of International Trade and Industry
- Various European and Asian nations' government agency statistics
- Trade associations
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices

Dataquest believes that the estimates presented here represent the most accurate and meaningful generally available today.

Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the Dataquest Research Methodology document.

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. The Dun & Bradstreet

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Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using the forecast in conjunction with input from Dataquest's regional offices, Dataquest estimates the overall business climate in which the electronic systems markets will operate.

Second, Dataquest analyzes and forecasts the significant long-range trends and outlook in the various electronic system groups. This establishes a five-year trend growth path or "envelope" for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about the market trends so that the two do not inexplicably diverge. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time-series data contained in this document in general is composed of annual observations and is sparse in terms of the number of observations, the data generally does not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time-series models. Therefore, in most cases we have used judgmental models (that is, intuitive judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Forecast Assumptions

Economics

Worldwide Business Outlook Points to Continued Strength and Moderate Growth as Expectations for Higher Prices and Profits Edge Up to Six-Year Peaks

The worldwide business outlook for higher sales, prices, profits, and employment levels edged higher during the first quarter of 1995, according to Dun & Bradstreet's most recent quarterly survey of more that 11,000 executives in 16 countries.

Although there has been recent volatility in some markets in response to proposed U.S. trade sanctions against China and the recent depreciation of the Mexican peso, the strength of the (survey) responses indicates that the current global economic expansion will be able to overcome setbacks without a broad negative impact. Long-term experience with business optimism surveys shows a strong correlation with real economic activity, even when the financial markets have signaled uncertainty.

Sales Prices Expected to Rise in All Regions Except Pacific

Expectations of worldwide selling prices for the first quarter gained eight points to an index level of 32, up from 24 during the fourth quarter of 1994. The global price increase reflects strong gains in North America and Europe, rising 9 and 11 points, respectively, to index levels of 40 and 30. The Pacific Selling Price Index dropped one point to 12.

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The first-quarter survey suggests that executives in Europe and North America believe their economies' respective expansions are nearing their peaks, and that inflationary pressures will grow stronger as idle production capacity is exhausted. As the second quarter approaches, prices will merit closer inspection in order to gauge the impact of recent interest rate hikes in the United States and possible increases in Europe.

North America: Sharp Declines in Value of Peso Could Undermine Expected Gains in Mexican Sales, Prices, Profits, and Inventories

Prior to the sharp decline in the value of the peso, executives in Mexico had reported expectations for record growth in sales, prices, profits, and inventories as businesses in the region prepared for unprecedented expansion under the North American Free Trade Agreement (NAFTA). Despite an expected inventory growth of 25 points—from a fourth-quarter index level of 32 to a first-quarter index level of 57—the Mexican indexes for sales, selling prices, and profits set record highs of 91, 95, and 91, respectively.

Executives both in Mexico and abroad were enormously optimistic for that country's performance during the first quarter of 1995 as business hired the labor and invested the capital equipment necessary to capitalize on the NAFTA.

Unfortunately, the recession that has gripped Mexico in the wake of the collapsing peso changes everything. Although there is still tremendous promise in the region, little of the previously expected growth will be realized until the peso stabilizes.

As one of the United States' largest trading partners, and also as a critical export market for Canada, Mexico's volatility will doubtless have some damping impact on expected growth across North America. However, business expectations in the region are sufficiently strong, so the impact should be short-term and marginal at worst; aggregate business conditions likely will be mixed, as the survey indicates. Overall, U.S. indexes point to continued positive business conditions. However, the Canadian indexes for sales and profits declined, suggesting that that country's economic recovery could be more shallow and more brief than the U.S. expansion.

The index for net sales in the United States climbed to 62, a gain of four points over the previous quarter. However, executives in Canada reported an eight-point drop from 56 to 48. The U.S. Net Profit Index gained five points to 56, while the Canadian index dropped eight points to 42. Growth rate forecasts are as follows:

- The United States' real gross domestic product (GDP) is forecast to grow 2.9 percent in 1995, decelerating from 4.0 percent in 1994, and to accelerate slightly to 3. 0 percent in 1996.
- Canada's real GDP is forecast to grow 3.7 percent in 1995, decelerating from 4.2 percent in 1994, and to further decelerate to 3.2 percent in 1996.

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- Mexico's real GDP is forecast to contract 2.0 percent in 1995, following 2.8 percent growth in 1994, and to rebound with 2.5 percent growth in 1996.

Europe: Continued Expansion Anticipated in Europe as Executives Predict Higher Sales and Profits

European executives expected growth in their regions through the end of the first quarter of 1995. The European Sales Index edged upward by one point from the previous quarter to reach a six-year high of 47. The European Profits Index jumped six points to 31, the Employment Index remained unchanged at 11, and inventories gained three points to 7.

Europe is enjoying the benefits of a mature economic expansion, and most indexes are positive for the duration of the first quarter. The region has expanded continuously from the first quarter of 1993. European manufacturers made significant productivity gains in 1994, but continued expansion could increase pressure on central banks in the region to raise interest rates. Growth rate forecasts are as follows:

- France's real GDP is forecast to grow 3.2 percent in 1995, accelerating from 2.4 percent growth in 1994, and to decelerate to 2.9 percent growth in 1996.
- Germany's real GDP is forecast to grow 3.1 percent in 1995, accelerating from 2.8 percent growth in 1994, and to further accelerate to 3.5 percent growth in 1996.
- Italy's real GDP is forecast to grow 2.9 percent in 1995, accelerating from 2.3 percent growth in 1994, and further accelerating to 3.2 percent growth in 1995.
- The United Kingdom's real GDP is forecast to grow 3.2 percent in 1994, decelerating from 4.0 percent growth in 1994, and further decelerating to 3.0 percent growth in 1995.

Japan and Pacific Rim: Weak Growth in Japan Offsets Deteriorating Conditions in the Pacific Region

In contrast with steady growth in Japan during the past three quarters, Japanese executives predicted that business conditions would improve only marginally through the first quarter of 1995. Strong gains in expected sales and employment levels were offset by slightly lower expectations for net profits. Overall, results were mixed in the Pacific region, as executives in New Zealand and Australia grew more pessimistic.

Given the gains reported during the fourth quarter of 1994, and throughout 1994, the responses from the region were disappointing but not a complete surprise. The yen's appreciation against Western currencies proved a hindrance to exports and has frustrated Japan's nascent recovery, at least for the first quarter of the year.

The Pacific Sales Index dropped five points to 49 as deteriorating conditions in Australia and New Zealand offset a six-point gain among Japanese executives. The index for expected net profits for the Pacific

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region fell from 44 to 38, reflecting a loss of 10 points in the Australian index and a three-point drop in New Zealand. The Pacific Selling Prices Index also fell one point to 12, driven by expected price reductions in Japan and New Zealand. Japan reported an expected increase in employment as its index rose from minus 8 to 0, compared to the Pacific region's overall decline from 20 to 17.

Japan's real GDP is forecast to grow 2.0 percent in 1995, accelerating from 0.8 growth in 1994, and to further accelerate to 3.5 percent in 1996.

The quarterly International Survey of Business Expectations is modeled on D&B's quarterly Survey of U.S. Business Expectations, which has been conducted in the United States since 1947. The survey participants are asked if they expect increases, decreases, or no change in their sales, profits, prices, inventories, and employment levels in the upcoming quarter, compared with the same quarter a year ago. Results of the U.S. survey have proven to be highly accurate, with quarterly forecasts closely paralleling actual performance.

(The current surveys, completed in December 1994, use similar sampling and interviewing procedures in all countries. Hence, the results provide unique "apples-to-apples" comparisons of trends in business expectations worldwide. The D&B index figures used here represent the net percentage of survey respondents expecting higher sales and profits, among others. The indexes are calculated by subtracting the percentage of respondents expecting decreases from those expecting increases. Unless otherwise noted, the increases and decreases in indexes represent changes from the previous quarter.)

Regional Electronic Equipment Production

North America

North American electronic equipment production is forecast to grow 5.7 percent in 1995 to $220.4 billion, decelerating from 6.8 percent growth in 1994. The North American forecast is predicated on the following assumptions:

- Intel has become a major producer of PC motherboards using its Pentium chip during 1994. Because of its plans to reduce the time between introductions of new processor families, we expect a higher percentage of these systems to be produced in North America over the forecast period. We have reduced the share of production that will migrate from North America to the Asia/Pacific region.
- The expansion of the home PC market and multimedia PCs has provided added momentum to the PC market, both of which lead to a significant increase in market growth for 1994 (and outlying years) over our previous forecast.
- The introduction of new generations of PCs that offer features with strong market appeal has allowed PCs to maintain a fairly steady average selling price (ASP) over time. This lack of significant price erosion will help support revenue growth over the forecast period as unit shipments increase.

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- The mainframe computer market performed better than was previously forecast. Although the market did contract, the rate of contraction was significantly less than previously forecast.
- Although unit shipments of mass storage equipment have increased dramatically, major price erosion has kept revenue flat or declining in all categories. This trend will likely continue.
- The growth of mobile communications markets throughout the world has exceeded even the most optimistic forecast for 1994. The number of cellular subscribers in the United States grew by more than 40 percent in 1994. We are very optimistic about the continued growth of wireless markets in North America and around the world. In the United States, the creation of a new personal communications services (PCS) market, which will increase competition with existing wireless communications services is expected to fuel even greater growth. However, PCS is a very cost-conscious market, and there will be significant price pressure on end-user equipment. This pressure will be reflected back to the factory, and we expect to see significant ASP erosion over the forecast period. Even with the price pressures, we expect strong growth for mobile equipment in North America and worldwide.
- There is a growing trend for manufacturers to produce cellular handsets near the region where they are purchased by users. This trend is reflected in the growth of production in all regions that more closely matches the local markets.
- The strong subscriber growth in the mobile communications market will act as a driver for new infrastructure equipment and mobile base stations. In addition to serving the needs of their local markets, the United States and Europe are major exporters of mobile communications equipment to other developing regions of the world. For this reason, the growth of base station production will outpace even the growth of the local markets in these areas.
- Pager markets have also continued to expand beyond previous forecasts. The introduction of two-way paging capability will drive this market to higher levels as pagers compete for the cost-conscious market. (Popularity among teenagers has also played a major role in the growth of this market, and fashion trends will play a wild card in this segment.)
- Most consumer, cost-sensitive telecom hardware continues to be manufactured in Asia. Some production is returning to Mexico.
- Increased capital spending is stimulating premise networking equipment production. Near-term demand is for higher-speed networking products such as switched Ethernet and FDDI. Intermediate and long-term production will be carried on for 100-Mbps and Asynchronous Transfer Mode technologies.
- The modem market is being propelled by record subscriptions to online services and the Internet. ISDN and T Carrier equipment production is increasing because of higher-speed WAN requirements.

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- Public telecom and cable infrastructure equipment companies (for example, SONET) are receiving record orders to support the rollout of high-bandwidth interactive video services to the residential market.
- Industrial electronics production is being fueled by broad-based growth of business spending on capital equipment. Recent increases in interest rates have lowered the current outlook for growth slightly below what it otherwise would have been.
- Consumer electronic production growth stems from growth in households' personal disposable income. Recent increases in interest rates will lead to some mild substitution from consumer durables to nondurables, away from new homes (and the associated outfitting with appliances and consumer electronics) and automobiles.
- Military spending cuts are expected to level out after several years of deep cuts. A cyclical upturn is expected in civil aviation avionics production. Civilian space electronic production is expected to remain robust amid a flurry of orders for low-earth-orbit satellite telephone and direct broadcast satellites.
- Automotive production is expected to slow over the next two years as higher interest rates induce a shift of household spending away from new automobiles.
- New automotive electronic systems such as air bags and antilock braking are being complemented by dozens of other new car electronic systems. The most significant downside risk to the forecast is the possibility that monetary policy implemented in 1994 will precipitate a greater-than-desired period of deceleration instead of gently slowing the rapid rate of real GDP growth (also realized in 1994). The most significant upside risk to the forecast is a more durable, longer-duration PC boom, driven by more elastic demand and quicker conversion to newer, more powerful computer models.

Japan

Japanese electronic equipment production is forecast to experience 0.9 percent dollar-based growth (1.6 percent yen-based contraction) in 1995 to $191.6 billion, following 9.0 percent dollar-based growth (0.2 percent yen-based contraction) in 1994. (The U.S. dollar depreciated 8.4 percent against the yen in 1994.) Overall, Japanese production will be governed by the following two forces during the forecast period:

- Production shifting offshore—Two trends are at work:
  - Japanese companies' electronics production bound for export will shift to the export-bound market, particularly in Asia and Europe.
  - Japanese companies' low-end electronics production will migrate to lower-cost-of-production areas in Asia.
- Yen appreciation—Recent strengthening of the yen against the U.S. dollar in the short term will squeeze the margin of profitability of Japan's electronics exports to the United States. Also, a permanently strong yen in the long-term will tend to reinforce the offshore migration of production.

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The Japanese forecast is predicated on the following specific assumptions:

- PC unit production growth is positive, but sharp ASP declines are placing contractionary pressure on revenue growth. Mainframe and midrange computer production is suffering from downsizing as companies shift to distributed/networked processing solutions.
- Unit production of flexible disk drives and rigid disk drives will decline sharply because of a shift of offshore production to Asia.
- Single in-line memory module production will experience growth in proportion to the PC growth.
- Long-term growth of data processing is positive because of a rise in mobile computer production, stemming from a personal digital assistant production ramp-up.
- Wireless communications market growth (leading to commensurate production growth) should be stimulated by aggressive ASP reduction of cellular phones in the short term; it will be accompanied by competition between personal handy-phone service (PHS) in equipment price and service fees.
- Production of cellular phones and PHS equipment is spurring infrastructure investment increases for that equipment.
- Industrial electronics should benefit from a resumption of capital spending by Japan's manufacturing industries, in keeping with Japan's overall economic recovery.
- Industrial electronics growth is being particularly spurred by record investment spending in the semiconductor industry on manufacturing equipment and on test and measurement equipment.
- Consumer electronics is particularly subject to the shift offshore as a means of remaining competitive in the presence of the strengthening yen.
- Automobile electronic is being driven by navigation systems and safety equipment such as antilock braking systems and air bags, and, in the long term, by comprehensive driver information systems.

Overall, the downside risk to the Japanese forecast includes greater- and faster-than-expected appreciation of the yen, more rapid migration of production offshore, and stalling of the Japanese economic recovery and/or unexpected emergence of a recession in major export markets' economies. Upside risks include these events and trends, only in the opposite direction.

Europe

European electronic equipment production is forecast to experience 6.5 percent dollar-based growth (3.3 percent ECU-based growth) in 1995 to $169.1 billion, following 5.3 percent dollar-based growth (3.6 percent ECU-based growth) in 1994. (The U.S. dollar depreciated 1.6 percent

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against the ECU in 1994.) The European forecast assumptions are as follows:

- Growth of premise communications equipment will be driven by upgrades of PBX equipment to support both voice and data, with the trend toward voice traffic moving digitally and increasing use of cordless telephones.
- The European public telecom market is experiencing very little growth, but European telecom manufacturing companies' significant presence in the global market is benefiting from the superlative growth occurring in Asia/Pacific.
- The central office switching market will decline in Europe during the rest of the forecast period, but production will be bolstered by exports to the fast-growing Asia/Pacific market. The European transmission market is set for slow, steady growth, but again there will be significant export opportunities outside western Europe.
- GSM cellular telephones will drive a huge market in Europe as penetration rates approach those of the United States and the continued success of GSM in non-European companies.
- Most production of handsets will take place in Europe during the initial period of the globalization of the GSM cellular standard for export to other markets.
- Broadcast and studio equipment growth will be helped by investment upgrades to digital broadcast equipment.
- Most audio equipment production in Europe is for the high-end specialist market segment. The most important long-term growth opportunity in consumer audio is forecast to come from digital compact cassette equipment and stereo high-fidelity equipment. Volume manufacturers are the major Japanese brand leaders. Overall, the European audio market is supported by imports from Japan and the Far East.
- Color televisions dominate consumer video production. Long-term growth will be attributed to digital transmission, gaining momentum for satellite by 1997 and cable shortly thereafter.
- Wide-screen TV growth is strongest in France and Germany. Emerging digital satellite and cable services are expected to boost sales of wide-screen TVs toward the end of the decade.
- Camcorder production is expected to expand during the forecast period. Sony is the only camcorder manufacturer in Europe with a full assembly plant in France.
- Satellite TV receiver production continues to show strong growth in Europe as the competition from cable TV operators increases. TV sets with built-in analog CATV and DTH satellite receivers also are gaining popularity across Europe.

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- Strong market growth and production is forecast for dishwashers and microwave ovens and air-conditioning toward the end of the forecast period. This is largely influenced by changing European demographics affected by changing patterns in marital status and family structures.

The most significant downside risks to the European forecast include:

- In general, there will be slower-than-expected adoption of cellular telephone equipment.
- GSM success outside Europe does not proceed to volume handset use.
- GSM handset production for non-European markets migrates to non-European manufacturing centers.
- The forecast assumes that there will be no changes in tariffs other than those already announced after the General Agreement on Tariffs and Trade negotiations. More restrictive trade could diminish production opportunities.
- Eastern Europe is the volatile area of Europe; political and economic instability is an everyday fact of life. A marked increase of instability, however, could have a detrimental effect on investment in productive capacity.

The most significant upside risks to the European forecast include:

- Cellular handset penetration rates exceed expected future levels at every point in time.
- A strong Japanese economy and currency may accelerate a shift of production from Japan to Europe. (Already some Japanese car manufacturers are exporting their own cars assembled in Europe to Japan.)
- There is a remote possibility that interactive digital services will occur sooner than expected, but this is not very likely.
- Stronger-than-expected economic growth in eastern Europe and CIS markets would boost western European production above forecast levels.

Asia/Pacific-Rest of World

Asia/Pacific-Rest of World electronic equipment production is forecast to grow 15.4 percent in 1995 to $155.4 billion, decelerating from 17.6 percent growth in 1994. The following factors influence the outlook in regional production:

- Growth in the East Asian PC markets' indigenous demand should help counter the negative effects on local production of expected ASP erosion and Intel's recent entry into the board business.
- Accelerated demand for Pentium machines in 1996 will boost revenue growth, but pricing pressure at the low end of the 486-class systems will tend to diminish average growth.

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- OEM business from Japan and continued demand from the United States and Europe means that factories in Taiwan are running at nearly full capacity. PC manufacturers in Taiwan will (after 1995) have in place everything necessary to ship finished systems and perhaps to re-enter the brand-name business, at least in Asia.
- Long-term Asian production prospects should be helped by high expectations for Asia's PC markets.
- Full participation in the mobile communications revolution.
- Asian communications markets are burgeoning, but production of public switching equipment is not as robust because of the need to import finished systems from Europe and the United States.
- The settlement of trade differences between China and the United States should help reassure manufacturers, thus fostering continued business formation.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates for 1994.

Table 1
Exchange Rates

Country	1994	1995-1999	1994-1995 U.S.$ Appreciation versus Foreign Currency (%)
Japan (Yen/U.S.$1)	101.81	99.25	-2.51
Europe (ECU/U.S.$1)	0.844	0.819	-2.96
France (Franc/U.S.$1)	5.5367	5.3621	-3.15
Germany (Deutsche Mark/U.S.$1)	1.6203	1.5601	-3.72
Great Britain (Pound Sterling/U.S.$1)	0.6536	0.6391	-2.22
Italy (Lira/U.S.$1)	1,609.34	1,620.40	0.69
Korea (Won/U.S.$1)	802.84	791.63	-1.40
Taiwan (NT$/U.S.$1)	26.45	26.29	-0.60
Hong Kong (HK$/U.S.$1)	7.7276	7.7357	0.10
Singapore (S$/U.S.$1)	1.5263	1.4612	-4.27
China (Renminbi/U.S.$1)	8.5384	8.5610	0.26

Source: Dataquest (April 1995)

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Table 2
Worldwide Revenue from Production of Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	560,300	592,967	594,265	632,565	689,668
Data Processing	175,685	184,139	181,439	192,684	214,463
Computers[1]	102,413	105,539	101,397	106,094	118,512
Data Storage	22,040	23,773	23,706	25,675	29,309
Input/Output	31,340	33,778	34,200	35,935	39,164
Dedicated System	17,500	18,639	19,399	21,472	23,001
Other Data Processing	2,392	2,410	2,737	3,507	4,477
Communications	87,922	94,550	101,662	114,287	127,356
Premise Telecom	25,338	27,359	29,467	32,694	35,705
Public Telecom	27,590	29,711	30,532	33,889	36,173
Mobile Communications	17,043	18,928	22,773	29,109	35,512
Broadcast and Studio	3,873	3,797	4,024	4,383	4,829
Other Communications	14,079	14,755	14,865	14,213	15,137
Industrial	92,350	96,298	94,586	97,843	105,189
Security and Energy Management	10,439	11,943	11,867	12,121	13,059
Manufacturing Systems/Instruments	54,650	56,289	54,146	55,492	59,281
Medical Equipment	12,172	13,411	14,126	14,906	15,753
Other Industrial	15,089	14,655	14,447	15,324	17,096
Consumer	120,422	133,190	132,142	141,081	154,677
Audio	16,247	18,963	19,427	20,495	22,842
Video	39,436	44,368	42,478	44,672	47,842
Personal Electronics	16,934	18,104	19,171	20,238	22,453
Appliances	38,282	41,287	40,618	43,411	47,965
Other Consumer	9,523	10,468	10,449	12,265	13,576
Military/Civil Aerospace	62,764	62,245	59,830	59,276	57,729
Transportation	21,158	22,544	24,607	27,394	30,255
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81
ECU/U.S.$ Exchange Rate	0.788	0.811	0.770	0.858	0.844

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 3
Worldwide Revenue from Production of Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	734,265	777,018	829,250	892,901	967,058
Data Processing	230,160	241,836	256,463	277,593	303,587
Computers[1]	128,813	135,836	145,031	159,412	178,941
Data Storage	30,702	32,142	33,228	34,392	35,792
Input/Output	41,598	43,695	46,718	50,283	54,010
Dedicated System	23,801	24,790	25,873	27,675	28,906
Other Data Processing	5,246	5,373	5,613	5,830	5,937
Communications	138,663	150,522	162,152	174,464	187,651
Premise Telecom	39,259	42,292	45,467	48,968	52,511
Public Telecom	37,668	39,585	41,933	44,358	47,106
Mobile Communications	40,617	46,319	50,669	55,010	60,019
Broadcast and Studio	5,310	5,737	6,193	6,717	7,287
Other Communications	15,809	16,589	17,891	19,411	20,728
Industrial	111,498	118,066	126,396	136,393	148,156
Security and Energy Management	13,618	14,389	15,495	16,766	18,244
Manufacturing Systems/Instruments	62,587	65,997	70,574	76,491	83,609
Medical Equipment	16,844	18,017	19,139	20,327	21,677
Other Industrial	18,449	19,662	21,189	22,809	24,626
Consumer	164,032	173,560	186,965	201,995	219,725
Audio	24,943	27,523	30,703	34,398	38,305
Video	51,565	54,930	59,228	64,098	69,762
Personal Electronics	23,435	24,576	26,794	29,905	33,789
Appliances	49,813	51,536	54,359	56,775	60,108
Other Consumer	14,275	14,995	15,881	16,819	17,761
Military/Civil Aerospace	57,193	58,045	59,274	60,677	62,145
Transportation	32,719	34,989	37,999	41,779	45,793
Yen/U.S.$ Exchange Rate	99.25	99.25	99.25	99.25	99.25
ECU/U.S.$ Exchange Rate	0.819	0.819	0.819	0.819	0.819

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 4
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	8.0	5.8	0.2	6.4	9.0
Data Processing	9.7	4.8	-1.5	6.2	11.3
Computers[1]	9.8	3.1	-3.9	4.6	11.7
Data Storage	31.5	7.9	-0.3	8.3	14.2
Input/Output	2.4	7.8	1.3	5.1	9.0
Dedicated System	-2.4	6.5	4.1	10.7	7.1
Other Data Processing	55.0	0.8	13.6	28.1	27.6
Communications	11.3	7.5	7.5	12.4	11.4
Premise Telecom	3.6	8.0	7.7	10.9	9.2
Public Telecom	15.3	7.7	2.8	11.0	6.7
Mobile Communications	16.8	11.1	20.3	27.8	22.0
Broadcast and Studio	11.5	-2.0	6.0	8.9	10.2
Other Communications	12.1	4.8	0.7	-4.4	6.5
Industrial	10.2	4.3	-1.8	3.4	7.5
Security and Energy Management	5.5	14.4	-0.6	2.1	7.7
Manufacturing Systems/Instruments	14.4	3.0	-3.8	2.5	6.8
Medical Equipment	11.6	10.2	5.3	5.5	5.7
Other Industrial	-1.0	-2.9	-1.4	6.1	11.6
Consumer	5.6	10.6	-0.8	6.8	9.6
Audio	6.6	16.7	2.4	5.5	11.4
Video	6.1	12.5	-4.3	5.2	7.1
Personal Electronics	14.7	6.9	5.9	5.6	10.9
Appliances	2.1	7.8	-1.6	6.9	10.5
Other Consumer	2.2	9.9	-0.2	17.4	10.7
Military/Civil Aerospace	1.7	-0.8	-3.9	-0.9	-2.6
Transportation	6.2	6.6	9.2	11.3	10.4
U.S.$ Appreciation versus Yen	4.3	-5.6	-7.0	-12.1	-8.4
U.S.$ Appreciation versus ECU	-13.2	2.9	-5.1	11.4	-1.6

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 5
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	6.5	5.8	6.7	7.7	8.3	7.0
Data Processing	7.3	5.1	6.0	8.2	9.4	7.2
Computers[1]	8.7	5.5	6.8	9.9	12.3	8.6
Data Storage	4.8	4.7	3.4	3.5	4.1	4.1
Input/Output	6.2	5.0	6.9	7.6	7.4	6.6
Dedicated System	3.5	4.2	4.4	7.0	4.4	4.7
Other Data Processing	17.2	2.4	4.5	3.9	1.8	5.8
Communications	8.9	8.6	7.7	7.6	7.6	8.1
Premise Telecom	10.0	7.7	7.5	7.7	7.2	8.0
Public Telecom	4.1	5.1	5.9	5.8	6.2	5.4
Mobile Communications	14.4	14.0	9.4	8.6	9.1	11.1
Broadcast and Studio	10.0	8.0	8.0	8.5	8.5	8.6
Other Communications	4.4	4.9	7.8	8.5	6.8	6.5
Industrial	6.0	5.9	7.1	7.9	8.6	7.1
Security and Energy Management	4.3	5.7	7.7	8.2	8.8	6.9
Manufacturing Systems/Instruments	5.6	5.4	6.9	8.4	9.3	7.1
Medical Equipment	6.9	7.0	6.2	6.2	6.6	6.6
Other Industrial	7.9	6.6	7.8	7.6	8.0	7.6
Consumer	6.0	5.8	7.7	8.0	8.8	7.3
Audio	9.2	10.3	11.6	12.0	11.4	10.9
Video	7.8	6.5	7.8	8.2	8.8	7.8
Personal Electronics	4.4	4.9	9.0	11.6	13.0	8.5
Appliances	3.9	3.5	5.5	4.4	5.9	4.6
Other Consumer	5.2	5.0	5.9	5.9	5.6	5.5
Military/Civil Aerospace	-0.9	1.5	2.1	2.4	2.4	1.5
Transportation	8.1	6.9	8.6	9.9	9.6	8.6
U.S.$ Appreciation versus Yen	-2.5	0	0	0	0	-0.5
U.S.$ Appreciation versus ECU	-3.0	0	0	0	0	-0.6

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 6
Regional Revenue from Production of Each Electronic Equipment Group, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Worldwide Total	560,300	592,967	594,265	632,565	689,668
Data Processing	175,685	184,139	181,439	192,684	214,463
Communications	87,922	94,550	101,662	114,287	127,356
Industrial	92,350	96,298	94,586	97,843	105,189
Consumer	120,422	133,190	132,142	141,081	154,677
Military/Civil Aerospace	62,764	62,245	59,830	59,276	57,729
Transportation	21,158	22,544	24,607	27,394	30,255
North American Total	187,909	187,889	186,492	195,149	208,500
Data Processing	66,664	65,314	61,037	60,617	64,098
Communications	27,471	29,126	33,035	38,615	44,037
Industrial	36,628	37,702	37,844	40,410	43,881
Consumer	17,005	16,616	17,804	19,582	21,279
Military/Civil Aerospace	36,603	35,577	32,861	31,284	29,668
Transportation	3,537	3,554	3,911	4,641	5,537
Japanese Total	160,930	177,790	167,297	174,131	189,799
Data Processing	45,901	50,464	49,083	50,766	56,503
Communications	21,298	22,857	22,375	25,216	28,390
Industrial	26,585	28,870	25,229	26,517	28,959
Consumer	56,038	63,960	58,420	58,248	62,112
Military/Civil Aerospace	1,601	1,590	1,675	1,865	1,992
Transportation	9,507	10,048	10,516	11,519	11,843
European Total	139,089	142,541	143,603	148,761	156,715
Data Processing	37,469	36,860	34,899	37,160	39,981
Communications	28,698	31,087	32,899	34,886	37,325
Industrial	26,078	26,196	27,491	26,295	27,217
Consumer	19,606	20,410	19,450	20,415	21,389
Military/Civil Aerospace	20,976	21,171	21,055	21,447	20,851
Transportation	6,262	6,818	7,809	8,558	9,953
Asia/Pacific-ROW Total	72,372	84,747	96,873	114,523	134,654
Data Processing	25,650	31,502	36,420	44,140	53,881
Communications	10,455	11,480	13,353	15,570	17,604
Industrial	3,059	3,530	4,022	4,621	5,132
Consumer	27,773	32,204	36,469	42,835	49,897
Military/Civil Aerospace	3,583	3,907	4,239	4,680	5,218
Transportation	1,852	2,124	2,371	2,676	2,922
Yen/U.S.$ Exchange Rate	144.00	136.00	126.45	111.20	101.81
ECU/U.S.$ Exchange Rate	0.788	0.811	0.770	0.858	0.844

Source: Dataquest (April 1995)

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Table 7
Regional Revenue from Production of Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Worldwide Total	734,265	777,018	829,250	892,901	967,058
Data Processing	230,160	241,836	256,463	277,593	303,587
Communications	138,663	150,522	162,152	174,464	187,651
Industrial	111,498	118,066	126,396	136,393	148,156
Consumer	164,032	173,560	186,965	201,995	219,725
Military/Civil Aerospace	57,193	58,045	59,274	60,677	62,145
Transportation	32,719	34,989	37,999	41,779	45,793
North American Total	220,425	229,933	240,437	252,320	265,836
Data Processing	67,605	69,036	70,684	73,212	76,584
Communications	48,224	52,265	55,817	59,677	63,206
Industrial	47,192	50,270	53,438	57,204	61,564
Consumer	22,560	23,072	24,239	24,889	26,138
Military/Civil Aerospace	28,698	28,932	29,466	30,018	30,585
Transportation	6,145	6,357	6,793	7,321	7,758
Japanese Total	191,594	193,696	200,922	209,910	222,000
Data Processing	55,113	54,359	54,535	55,107	56,787
Communications	30,148	31,699	33,605	35,449	37,768
Industrial	30,075	31,195	33,484	36,294	39,614
Consumer	62,124	62,007	64,220	67,020	70,711
Military/Civil Aerospace	2,012	1,990	1,965	1,941	1,918
Transportation	12,122	12,445	13,114	14,099	15,202
European Total	166,832	176,992	186,881	199,476	211,637
Data Processing	43,475	45,875	48,286	52,940	56,715
Communications	40,377	43,877	46,738	49,405	52,089
Industrial	28,525	30,196	32,202	34,539	37,359
Consumer	22,595	23,949	25,305	26,753	28,217
Military/Civil Aerospace	20,628	20,489	20,275	20,075	19,719
Transportation	11,231	12,606	14,075	15,763	17,538
Asia/Pacific-ROW Total	155,414	176,397	201,009	231,195	267,585
Data Processing	63,967	72,565	82,959	96,334	113,502
Communications	19,914	22,681	25,992	29,934	34,588
Industrial	5,706	6,404	7,273	8,355	9,619
Consumer	56,753	64,533	73,200	83,332	94,658
Military/Civil Aerospace	5,855	6,633	7,569	8,644	9,923
Transportation	3,220	3,581	4,018	4,596	5,295
Yen/U.S.$ Exchange Rate	99.25	99.25	99.25	99.25	99.25
ECU/U.S.$ Exchange Rate	0.819	0.819	0.819	0.819	0.819

Source: Dataquest (April 1995)

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Table 8
Regional Revenue Growth from Production of Each Electronic Equipment Group, 1990-1994 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Worldwide Total	8.0	5.8	0.2	6.4	9.0
Data Processing	9.7	4.8	-1.5	6.2	11.3
Communications	11.3	7.5	7.5	12.4	11.4
Industrial	10.2	4.3	-1.8	3.4	7.5
Consumer	5.6	10.6	-0.8	6.8	9.6
Military/Civil Aerospace	1.7	-0.8	-3.9	-0.9	-2.6
Transportation	6.2	6.6	9.2	11.3	10.4
North American Total	4.8	0	-0.7	4.6	6.8
Data Processing	5.8	-2.0	-6.5	-0.7	5.7
Communications	8.6	6.0	13.4	16.9	14.0
Industrial	4.8	2.9	0.4	6.8	8.6
Consumer	-1.0	-2.3	7.1	10.0	8.7
Military/Civil Aerospace	4.9	-2.8	-7.6	-4.8	-5.2
Transportation	-9.3	0.5	10.0	18.7	19.3
Japanese Total	4.8	10.5	-5.9	4.1	9.0
Data Processing	4.6	9.9	-2.7	3.4	11.3
Communications	7.8	7.3	-2.1	12.7	12.6
Industrial	6.5	8.6	-12.6	5.1	9.2
Consumer	3.9	14.1	-8.7	-0.3	6.6
Military/Civil Aerospace	-12.2	-0.7	5.3	11.4	6.8
Transportation	3.4	5.7	4.7	9.5	2.8
European Total	12.2	2.5	0.7	3.6	5.3
Data Processing	17.9	-1.6	-5.3	6.5	7.6
Communications	14.7	8.3	5.8	6.0	7.0
Industrial	22.8	0.5	4.9	-4.4	3.5
Consumer	3.4	4.1	-4.7	5.0	4.8
Military/Civil Aerospace	-3.6	0.9	-0.5	1.9	-2.8
Transportation	20.6	8.9	14.5	9.6	16.3
Asia/Pacific-ROW Total	16.9	17.1	14.3	18.2	17.6
Data Processing	19.4	22.8	15.6	21.2	22.1
Communications	16.9	9.8	16.3	16.6	13.1
Industrial	14.7	15.4	13.9	14.9	11.1
Consumer	16.2	16.0	13.2	17.5	16.5
Military/Civil Aerospace	9.2	9.0	8.5	10.4	11.5
Transportation	14.0	14.7	11.6	12.9	9.2
U.S.$ Appreciation versus Yen	4.3	-5.6	-7.0	-12.1	-8.4
U.S.$ Appreciation versus ECU	-13.2	2.9	-5.1	11.4	-1.6

Source: Dataquest (April 1995)

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Table 9
Regional Revenue Growth from Production of Each Electronic Equipment Group, 1995-1999 (Millions of U.S. Dollars)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Worldwide Total	6.5	5.8	6.7	7.7	8.3	7.0
Data Processing	7.3	5.1	6.0	8.2	9.4	7.2
Communications	8.9	8.6	7.7	7.6	7.6	8.1
Industrial	6.0	5.9	7.1	7.9	8.6	7.1
Consumer	6.0	5.8	7.7	8.0	8.8	7.3
Military/Civil Aerospace	-0.9	1.5	2.1	2.4	2.4	1.5
Transportation	8.1	6.9	8.6	9.9	9.6	8.6
North American Total	5.7	4.3	4.6	4.9	5.4	5.0
Data Processing	5.5	2.1	2.4	3.6	4.6	3.6
Communications	9.5	8.4	6.8	6.9	5.9	7.5
Industrial	7.5	6.5	6.3	7.0	7.6	7.0
Consumer	6.0	2.3	5.1	2.7	5.0	4.2
Military/Civil Aerospace	-3.3	0.8	1.8	1.9	1.9	0.6
Transportation	11.0	3.4	6.9	7.8	6.0	7.0
Japanese Total	0.9	1.1	3.7	4.5	5.8	3.2
Data Processing	-2.5	-1.4	0.3	1.0	3.0	0.1
Communications	6.2	5.1	6.0	5.5	6.5	5.9
Industrial	3.9	3.7	7.3	8.4	9.1	6.5
Consumer	0	-0.2	3.6	4.4	5.5	2.6
Military/Civil Aerospace	1.0	-1.1	-1.3	-1.2	-1.1	-0.7
Transportation	2.4	2.7	5.4	7.5	7.8	5.1
European Total	6.5	6.1	5.6	6.7	6.1	6.2
Data Processing	8.7	5.5	5.3	9.6	7.1	7.2
Communications	8.2	8.7	6.5	5.7	5.4	6.9
Industrial	4.8	5.9	6.6	7.3	8.2	6.5
Consumer	5.6	6.0	5.7	5.7	5.5	5.7
Military/Civil Aerospace	-1.1	-0.7	-1.0	-1.0	-1.8	-1.1
Transportation	12.8	12.2	11.7	12.0	11.3	12.0
Asia/Pacific-ROW Total	15.4	13.5	14.0	15.0	15.7	14.7
Data Processing	18.7	13.4	14.3	16.1	17.8	16.1
Communications	13.1	13.9	14.6	15.2	15.5	14.5
Industrial	11.2	12.2	13.6	14.9	15.1	13.4
Consumer	13.7	13.7	13.4	13.8	13.6	13.7
Military/Civil Aerospace	12.2	13.3	14.1	14.2	14.8	13.7
Transportation	10.2	11.2	12.2	14.4	15.2	12.6
U.S.$ Appreciation versus Yen	-2.5	0	0	0	0	-0.5
U.S.$ Appreciation versus ECU	-3.0	0	0	0	0	-0.6

Source: Dataquest (April 1995)

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Table 10
Revenue from North American Data Processing Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Total Electronic Equipment	187,909	187,889	186,492	195,149	208,500
Data Processing	66,664	65,314	61,037	60,617	64,098
Computer[1]	46,231	45,160	41,468	40,909	43,702
Supercomputer	1,476	1,542	1,441	1,542	1,683
Mainframe	13,326	11,327	9,344	7,925	7,371
Midrange	16,820	16,712	13,437	12,613	12,219
Workstation	5,589	5,936	5,912	6,801	7,173
Personal Computer	9,020	9,643	11,334	12,028	15,256
Data Storage Device	5,972	5,715	4,494	3,824	3,573
Rigid Disk Drive	5,027	4,619	3,392	2,845	2,402
14-Inch	1,093	681	279	0	0
8-10-Inch	2,373	2,938	2,481	1,737	994
5.25-Inch	551	301	175	98	67
3.5-Inch	1,010	699	458	971	1,278
2.5-Inch	0	0	0	36	56
1.8-Inch	0	0	0	3	6
Optical Disk Drive	33	38	40	34	43
Rewrite Optical Disk Drive	15	18	20	12	16
WORM Optical Disk Drive	17	19	19	12	8
CD-ROM	1	1	2	10	19
Tape Drive	911	1,058	1,062	945	1,128
Input/Output Device	8,371	8,562	8,924	8,885	9,307
Terminal	1,558	1,290	1,112	906	870
Graphics Terminal	113	138	228	297	369
X Terminal	87	130	226	296	368
Other Graphics Terminal	26	8	2	2	1
Alphanumeric Terminal	1,445	1,152	884	609	500
Printer	3,096	3,314	3,518	3,333	3,442
Serial Printer	670	690	735	834	830
Line Printer	912	1,004	1,042	593	549
Page Printer	1,514	1,620	1,741	1,906	2,063
Other Input/Output Device	3,717	3,958	4,294	4,645	4,995

(Continued)

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Table 10 (Continued)
Revenue from North American Data Processing Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Dedicated System	4,794	4,595	4,823	5,503	5,895
Copier and Duplicator	1,424	1,420	1,457	1,936	2,104
Personal Copier	79	87	98	170	241
Segments 1-3	863	803	815	894	891
Segments 4-6	482	530	544	871	971
Personal Organizer	0	0	0	0	0
Smart Card (IC Card)	0	0	0	0	10
Other Dedicated System	3,370	3,175	3,366	3,567	3,781
Other Data Processing	1,297	1,282	1,329	1,497	1,621
Sound/Audio Board	0	3	12	24	40
Digital Video Board	144	214	263	326	378
Accelerator Board	501	379	332	354	330
Embedded CPU Board	652	686	722	794	873

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 11
Revenue from North American Data Processing Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Total Electronic Equipment	220,425	229,933	240,437	252,320	265,836
Data Processing	67,605	69,036	70,684	73,212	76,584
Computer[1]	46,184	46,690	47,919	49,871	52,590
Supercomputer	1,821	1,947	2,061	2,267	2,849
Mainframe	6,662	5,886	5,989	5,965	5,813
Midrange	11,969	11,352	10,030	9,226	8,438
Workstation	7,710	8,207	8,735	9,161	9,614
Personal Computer	18,022	19,298	21,104	23,252	25,876
Data Storage Device	3,484	3,372	2,835	2,587	2,385
Rigid Disk Drive	2,065	1,757	1,274	1,222	1,180
14-Inch	0	0	0	0	0
8-10-Inch	568	46	0	0	0
5.25-Inch	58	47	8	0	0
3.5-Inch	1,380	1,594	1,207	1,169	1,125
2.5-Inch	46	36	17	8	2
1.8-Inch	13	34	42	45	52
Optical Disk Drive	55	66	75	86	100
Rewrite Optical Disk Drive	19	24	21	17	14
WORM Optical Disk Drive	8	8	8	8	7
CD-ROM	28	35	46	62	79
Tape Drive	1,364	1,548	1,486	1,279	1,105
Input/Output Device	9,806	10,302	10,672	11,029	11,406
Terminal	887	948	989	1,016	1,038
Graphics Terminal	471	603	707	783	851
X Terminal	470	602	706	782	851
Other Graphics Terminal	1	1	1	0	0
Alphanumeric Terminal	416	344	283	233	187
Printer	3,560	3,674	3,708	3,740	3,782
Serial Printer	825	827	844	859	874
Line Printer	507	483	455	433	420
Page Printer	2,228	2,364	2,409	2,448	2,488
Other Input/Output Device	5,359	5,681	5,975	6,273	6,587

(Continued)

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Table 11 (Continued)
Revenue from North American Data Processing Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Dedicated System	6,343	6,775	7,284	7,667	8,070
Copier and Duplicator	2,305	2,472	2,650	2,723	2,780
Personal Copier	294	363	430	445	456
Segments 1-3	902	876	861	826	779
Segments 4-6	1,109	1,233	1,359	1,452	1,545
Personal Organizer	0	0	0	0	0
Smart Card (IC Card)	30	55	130	170	230
Other Dedicated System	4,008	4,249	4,504	4,774	5,060
Other Data Processing	1,788	1,897	1,974	2,058	2,133
Sound/Audio Board	44	32	27	21	13
Digital Video Board	433	429	413	398	380
Accelerator Board	351	381	374	364	350
Embedded CPU Board	960	1,055	1,160	1,275	1,390

[1]Includes the value of central processing units (that is, boxes) only. Computer estimate does not include the value of the following systems: rigid disk drives, flexible disk drives, keyboards, and displays. Computer estimate does include the value of aftermarket sales of the following: graphics boards, motherboards, memory cards-SIMMs, storage host adapters, and serial and parallel I/O boards.

Source: Dataquest (April 1995)

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Table 12
Revenue Growth from North American Data Processing Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Total Electronic Equipment	4.8	0	-0.7	4.6	6.8
Data Processing	5.8	-2.0	-6.5	-0.7	5.7
Computer	6.0	-2.3	-8.2	-1.3	6.8
Supercomputer	8.5	4.5	-6.5	7.0	9.1
Mainframe	-3.6	-15.0	-17.5	-15.2	-7.0
Midrange	-5.5	-0.6	-19.6	-6.1	-3.1
Workstation	51.6	6.2	-0.4	15.0	5.5
Personal Computer	29.6	6.9	17.5	6.1	26.8
Data Storage Device	29.0	-4.3	-21.4	-14.9	-6.6
Rigid Disk Drive	27.4	-8.1	-26.6	-16.1	-15.6
14-Inch	-22.6	-37.7	-59.1	NM	NM
8-10-Inch	125.6	23.8	-15.6	-30.0	-42.8
5.25-Inch	-9.7	-45.5	-41.9	-44.0	-31.6
3.5-Inch	16.1	-30.8	-34.5	112.2	31.6
2.5-Inch	NM	NM	NM	NM	55.0
1.8-Inch	NM	NM	NM	NM	129.0
Optical Disk Drive	70.1	15.1	6.0	-16.2	26.6
Rewrite Optical Disk Drive	102.8	16.0	9.6	-39.5	30.3
WORM Optical Disk Drive	50.5	15.1	-2.6	-35.9	-31.0
CD-ROM	30.4	1.5	94.8	360.9	90.3
Tape Drive	37.0	16.1	0.4	-10.9	19.4
Input/Output Device	-1.3	2.3	4.2	-0.4	4.8
Terminal	-22.1	-17.2	-13.8	-18.5	-4.0
Graphics Terminal	8.7	22.1	65.2	30.5	24.2
X Terminal	278.3	49.4	73.8	30.9	24.5
Other Graphics Terminal	-67.9	-69.2	-75.0	-16.6	-28.1
Alphanumeric Terminal	-23.8	-20.3	-23.3	-31.1	-17.8
Printer	5.3	7.0	6.2	-5.2	3.3
Serial Printer	-11.4	3.0	6.5	13.5	-0.5
Line Printer	-7.8	10.1	3.8	-43.0	-7.5
Page Printer	26.6	7.0	7.5	9.5	8.2
Other Input/Output Device	5.0	6.5	8.5	8.2	7.5

(Continued)

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Table 12 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Dedicated System	-4.6	-4.2	5.0	14.1	7.1
Copier and Duplicator	-4.1	-0.3	2.6	32.9	8.7
Personal Copier	8.2	10.1	12.6	73.8	41.6
Segments 1-3	-4.4	-7.0	1.5	9.7	-0.3
Segments 4-6	-5.3	10.0	2.6	60.1	11.5
Personal Organizer	NM	NM	NM	NM	NM
Smart Card (IC Card)	NM	NM	NM	NM	NM
Other Dedicated System	-4.8	-5.8	6.0	6.0	6.0
Other Data Processing	3.3	-1.2	3.6	12.6	8.3
Sound/Audio Board	NM	NM	290.2	98.3	69.1
Digital Video Board	37.1	48.3	23.0	24.0	16.0
Accelerator Board	-4.6	-24.3	-12.5	6.4	-6.6
Embedded CPU Board	4.2	5.2	5.2	10.0	9.9

NM = Not meaningful
Source: Dataquest (April 1995)

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Table 13
Revenue Growth from North American Data Processing Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Electronic Equipment	5.7	4.3	4.6	4.9	5.4	5.0
Data Processing	5.5	2.1	2.4	3.6	4.6	3.6
Computer	5.7	1.1	2.6	4.1	5.5	3.8
Supercomputer	8.2	6.9	5.9	10.0	25.7	11.1
Mainframe	-9.6	-11.6	1.7	-0.4	-2.5	-4.6
Midrange	-2.0	-5.2	-11.6	-8.0	-8.5	-7.1
Workstation	7.5	6.4	6.4	4.9	4.9	6.0
Personal Computer	18.1	7.1	9.4	10.2	11.3	11.1
Data Storage Device	-2.5	-3.2	-15.9	-8.7	-7.8	-7.8
Rigid Disk Drive	-14.0	-14.9	-27.5	-4.1	-3.4	-13.3
14-Inch	NM	NM	NM	NM	NM	NM
8-10-Inch	-42.9	-91.8	NM	NM	NM	-100.0
5.25-Inch	-13.6	-18.3	-83.5	NM	NM	-100.0
3.5-Inch	8.0	15.5	-24.3	-3.1	-3.8	-2.5
2.5-Inch	-17.7	-22.5	-52.2	-56.4	-69.9	-47.5
1.8-Inch	117.8	172.9	22.4	7.2	16.6	55.5
Optical Disk Drive	28.2	20.9	13.1	14.3	16.6	18.5
Rewrite Optical Disk Drive	24.9	21.8	-11.3	-20.4	-14.5	-1.7
WORM Optical Disk Drive	-7.7	3.7	-1.6	-3.1	-2.8	-2.3
CD-ROM	46.1	24.9	32.9	32.8	27.4	32.6
Tape Drive	20.9	13.5	-4.0	-13.9	-13.6	-0.4
Input/Output Device	5.4	5.1	3.6	3.3	3.4	4.2
Terminal	2.0	6.8	4.4	2.7	2.1	3.6
Graphics Terminal	27.5	28.0	17.1	10.8	8.7	18.2
X Terminal	27.6	28.2	17.2	10.8	8.7	18.2
Other Graphics Terminal	-20.1	-24.6	-29.8	-21.0	-26.6	-24.5
Alphanumeric Terminal	-16.8	-17.3	-17.9	-17.6	-19.9	-17.9
Printer	3.4	3.2	0.9	0.9	1.1	1.9
Serial Printer	-0.6	0.2	2.1	1.8	1.8	1.0
Line Printer	-7.7	-4.7	-5.8	-4.7	-3.0	-5.2
Page Printer	8.0	6.1	1.9	1.6	1.6	3.8
Other Input/Output Device	7.3	6.0	5.2	5.0	5.0	5.7

(Continued)

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Table 13 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Dedicated System	7.6	6.8	7.5	5.3	5.3	6.5
Copier and Duplicator	9.6	7.2	7.2	2.7	2.1	5.7
Personal Copier	22.1	23.2	18.6	3.6	2.3	13.6
Segments 1-3	1.2	-2.9	-1.7	-4.0	-5.7	-2.7
Segments 4-6	14.2	11.2	10.2	6.8	6.4	9.7
Personal Organizer	NM	NM	NM	NM	NM	NM
Smart Card (IC Card)	200.0	83.3	136.4	30.8	35.3	87.2
Other Dedicated System	6.0	6.0	6.0	6.0	6.0	6.0
Other Data Processing	10.3	6.1	4.1	4.3	3.6	5.6
Sound/Audio Board	10.3	-27.4	-15.5	-22.2	-40.5	-20.7
Digital Video Board	14.8	-1.0	-3.7	-3.7	-4.5	0.1
Accelerator Board	6.3	8.6	-1.8	-2.6	-3.8	1.2
Embedded CPU Board	10.0	9.9	10.0	9.9	9.0	9.7

NM = Not meaningful
Source: Dataquest (April 1995)

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Table 14
Revenue from North American Communications Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Communication	27,471	29,126	33,035	38,615	44,037
Premise Telecom	10,009	10,811	12,222	13,901	15,301
Image and Text Communication	322	432	547	687	726
Facsimile (Card, See Modem)	207	228	230	235	235
Video Teleconferencing	115	204	317	452	491
Data Communications Equipment	4,377	5,125	6,492	7,663	8,536
Modem (Modem Card)	804	673	636	709	811
Statistical Multiplexer	163	146	144	150	140
T-1 Multiplexer	434	416	470	477	500
Front-End Processor	479	466	462	460	440
DSU/CSU	213	335	380	363	350
Protocol Converter	153	141	137	133	130
LAN Cards	1,140	1,173	1,274	1,541	1,614
LAN Hubs/Internetworking	685	1,455	2,647	3,465	4,131
Packet Data Switching	306	320	342	365	420
Premise Switching	3,066	2,866	2,759	2,906	2,947
PBX Telephone	2,060	1,896	1,779	1,912	1,941
Key Telephone	1,006	970	980	994	1,006
Call Processing	1,667	1,833	1,971	2,186	2,639
Voice Messaging	861	945	1,004	1,091	1,333
Interactive Voice Response	404	480	529	556	670
Automatic Call Distributor	402	408	438	539	636
Desktop Terminal	577	555	452	458	453
Telephone Sets/Answerers	387	385	367	393	408
Teleprinter	190	170	85	65	45
Public Telecom	5,064	5,559	6,251	7,446	8,176
Transmission	2,990	3,184	3,474	4,091	4,811
Central Office Switching	2,074	2,375	2,777	3,355	3,365
Mobile Communication	7,175	7,456	9,034	11,398	14,222
Mobile Radio	6,978	7,148	8,692	11,077	13,890
Cellular/PCS Terminal	2,828	3,017	3,731	4,839	6,785
Other Portable Radio	2,037	1,857	1,721	1,643	1,824
Mobile Radio Base Station	1,568	1,797	2,508	3,559	4,169
Pager (One- and Two-Way)	545	477	732	1,035	1,112
Radio Checkout	197	308	342	321	332

(Continued)

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Table 14 (Continued)
Revenue from North American Communications Equipment Production, 1990-1994
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994
Broadcast and Studio	1,838	1,690	1,756	1,917	2,133
Audio	367	389	408	430	460
Video	466	424	428	443	470
Transmitter, RF Power Amp	124	111	115	122	138
Studio Transmitter Link	25	25	26	30	30
Cable TV (Head End)	554	422	506	608	730
CCTV	165	182	185	194	205
Other (Including Studio, Theater)	137	137	87	90	100
Other Telecom	3,385	3,610	3,773	3,954	4,205
Intercomm., Elec. Amp.	346	301	315	340	360
Communication Equipment, nec*	3,039	3,309	3,458	3,614	3,845

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 15
Revenue from North American Communications Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Communication	48,224	52,265	55,817	59,677	63,206
Premise Telecom	16,960	18,353	19,686	20,980	22,530
Image and Text Communication	775	808	1,017	1,315	1,727
Facsimile (Card, See Modem)	232	230	228	226	224
Video Teleconferencing	543	578	789	1,089	1,503
Data Communications Equipment	9,621	10,324	10,812	11,003	11,205
Modem (Modem Card)	923	1,025	1,085	1,115	1,146
Statistical Multiplexer	133	120	113	107	101
T-1 Multiplexer	490	481	470	459	448
Front-End Processor	415	400	380	360	341
DSU/CSU	308	295	283	271	260
Protocol Converter	120	115	109	105	101
LAN Cards	1,646	1,661	1,691	1,702	1,713
LAN Hubs/Internetworking	5,126	5,732	6,143	6,303	6,467
Packet Data Switching	460	495	538	581	627
Premise Switching	3,010	3,086	3,174	3,284	3,399
PBX Telephone	1,998	2,066	2,141	2,243	2,350
Key Telephone	1,012	1,020	1,033	1,041	1,049
Call Processing	3,106	3,668	4,223	4,898	5,698
Voice Messaging	1,607	1,932	2,155	2,414	2,704
Interactive Voice Response	783	952	1,188	1,498	1,889
Automatic Call Distributor	716	784	880	986	1,105
Desktop Terminal	448	468	460	479	501
Telephone Sets/Answerers	423	453	452	474	498
Teleprinter	25	15	8	5	3
Public Telecom	8,640	9,346	10,535	11,403	12,381
Transmission	5,675	6,742	8,018	8,951	9,993
Central Office Switching	2,965	2,604	2,517	2,452	2,389
Mobile Communication	15,944	17,594	18,319	19,682	20,330
Mobile Radio	15,589	17,232	17,965	19,337	20,010
Cellular/PCS Terminal	7,480	8,192	8,141	9,061	9,115
Other Portable Radio	2,024	2,330	2,677	3,079	3,540
Mobile Radio Base Station	5,023	5,436	5,879	6,002	6,038
Pager (One- and Two-Way)	1,062	1,273	1,268	1,195	1,317
Radio Checkout	355	362	354	345	320

(Continued)

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Table 15 (Continued)
Revenue from North American Communications Equipment Production, 1995-1999
(Millions of U.S. Dollars)

	1995	1996	1997	1998	1999
Broadcast and Studio	2,282	2,444	2,603	2,741	2,887
Audio	474	496	518	541	565
Video	500	545	588	625	664
Transmitter, RF Power Amp	143	147	148	150	152
Studio Transmitter Link	31	32	32	33	34
Cable TV (Head End)	810	885	958	1,020	1,086
CCTV	215	226	239	246	253
Other (Including Studio, Theater)	109	113	120	126	132
Other Telecom	4,398	4,528	4,673	4,871	5,078
Intercomm., Elec. Amp.	360	362	364	368	372
Communication Equipment, nec*	4,038	4,166	4,309	4,503	4,706

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 16
Revenue Growth from North American Communications Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Communication	8.6	6.0	13.4	16.9	14.0
Premise Telecom	7.7	8.0	13.0	13.7	10.1
Image and Text Communication	25.8	34.2	26.6	25.6	5.7
Facsimile (Card, See Modem)	5.6	10.1	0.9	2.2	0
Video Teleconferencing	91.7	77.4	55.4	42.6	8.6
Data Communications Equipment	7.7	17.1	26.7	18.0	11.4
Modem (Modem Card)	-16.8	-16.3	-5.5	11.5	14.4
Statistical Multiplexer	-7.9	-10.4	-1.4	4.2	-6.7
T-1 Multiplexer	-2.7	-4.1	13.0	1.5	4.8
Front-End Processor	-0.6	-2.7	-0.9	-0.4	-4.3
DSU/CSU	52.1	57.3	13.4	-4.5	-3.6
Protocol Converter	-6.7	-7.8	-2.8	-2.9	-2.3
LAN Cards	14.2	2.9	8.6	20.9	4.7
LAN Hubs/Internetworking	71.3	112.4	81.9	30.9	19.2
Packet Data Switching	5.2	4.6	6.9	6.7	15.1
Premise Switching	-4.4	-6.5	-3.7	5.3	1.4
PBX Telephone	-5.4	-8.0	-6.2	7.5	1.5
Key Telephone	-2.1	-3.6	1.0	1.4	1.2
Call Processing	43.0	10.0	7.5	10.9	20.7
Voice Messaging	52.9	9.8	6.2	8.7	22.2
Interactive Voice Response	97.1	18.8	10.2	5.1	20.5
Automatic Call Distributor	1.0	1.5	7.4	23.1	18.0
Desktop Terminal	-3.8	-3.8	-18.5	1.4	-1.1
Telephone Sets/Answerers	-2.0	-0.5	-4.6	7.1	3.8
Teleprinter	-7.3	-10.5	-50.0	-23.5	-30.8
Public Telecom	7.0	9.8	12.4	19.1	9.8
Transmission	15.5	6.5	9.1	17.8	17.6
Central Office Switching	-3.2	14.5	16.9	20.8	0.3
Mobile Communication	24.7	3.9	21.2	26.2	24.8
Mobile Radio	25.9	2.4	21.6	27.4	25.4
Cellular/PCS Terminal	20.9	6.7	23.7	29.7	40.2
Other Portable Radio	38.5	-8.8	-7.3	-4.5	11.0
Mobile Radio Base Station	7.2	14.6	39.5	41.9	17.1
Pager (One- and Two-Way)	101.8	-12.4	53.4	41.4	7.4
Radio Checkout	-6.6	56.3	11.0	-6.1	3.4

(Continued)

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Table 16 (Continued)
Revenue Growth from North American Communications Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Broadcast and Studio	2.1	-8.1	3.9	9.2	11.2
Audio	-11.1	6.0	4.9	5.5	6.9
Video	-2.9	-9.0	1.0	3.5	6.0
Transmitter, RF Power Amp	18.1	-10.5	3.6	6.1	13.1
Studio Transmitter Link	19.0	0	4.0	15.4	0
Cable TV (Head End)	2.4	-23.8	20.0	20.0	20.1
CCTV	13.8	10.3	1.6	4.9	5.7
Other (Including Studio, Theater)	44.2	0	-36.5	3.4	11.1
Other Telecom	-8.8	6.6	4.5	4.8	6.4
Intercomm., Elec. Amp.	-6.0	-13.0	4.7	7.9	5.9
Communication Equipment, nec*	-9.1	8.9	4.5	4.5	6.4

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 17
Revenue Growth from North American Communications Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Communication	9.5	8.4	6.8	6.9	5.9	7.5
Premise Telecom	10.8	8.2	7.3	6.6	7.4	8.0
Image and Text Communication	6.7	4.3	25.9	29.3	31.3	18.9
Facsimile (Card, See Modem)	-1.3	-0.9	-0.9	-0.9	-0.9	-1.0
Video Teleconferencing	10.6	6.4	36.5	38.0	38.0	25.1
Data Communications Equipment	12.7	7.3	4.7	1.8	1.8	5.6
Modem (Modem Card)	13.8	11.1	5.9	2.8	2.8	7.2
Statistical Multiplexer	-5.0	-9.8	-5.8	-5.3	-5.3	-6.3
T-1 Multiplexer	-2.0	-1.8	-2.3	-2.3	-2.3	-2.2
Front-End Processor	-5.7	-3.6	-5.0	-5.3	-5.3	-5.0
DSU/CSU	-12.0	-4.2	-4.1	-4.2	-4.2	-5.8
Protocol Converter	-7.7	-4.2	-5.2	-3.7	-3.7	-4.9
LAN Cards	2.0	0.9	1.9	0.6	0.6	1.2
LAN Hubs/Internetworking	24.1	11.8	7.2	2.6	2.6	9.4
Packet Data Switching	9.5	7.6	8.7	8.0	8.0	8.4
Premise Switching	2.1	2.5	2.9	3.5	3.5	2.9
PBX Telephone	2.9	3.4	3.6	4.8	4.8	3.9
Key Telephone	0.6	0.8	1.3	0.8	0.8	0.8
Call Processing	17.7	18.1	15.1	16.0	16.3	16.6
Voice Messaging	20.6	20.2	11.5	12.0	12.0	15.2
Interactive Voice Response	16.9	21.6	24.8	26.1	26.1	23.0
Automatic Call Distributor	12.6	9.5	12.2	12.0	12.0	11.7
Desktop Terminal	-1.1	4.3	-1.7	4.3	4.6	2.0
Telephone Sets/Answerers	3.7	6.9	-0.2	5.0	5.0	4.1
Teleprinter	-44.4	-40.0	-46.7	-37.5	-37.5	-41.3
Public Telecom	5.7	8.2	12.7	8.2	8.6	8.7
Transmission	18.0	18.8	18.9	11.6	11.6	15.7
Central Office Switching	-11.9	-12.2	-3.3	-2.6	-2.6	-6.6
Mobile Communication	12.1	10.4	4.1	7.4	3.3	7.4
Mobile Radio	12.2	10.5	4.3	7.6	3.5	7.6
Cellular/PCS Terminal	10.2	9.5	-0.6	11.3	0.6	6.1
Other Portable Radio	11.0	15.1	14.9	15.0	15.0	14.2
Mobile Radio Base Station	20.5	8.2	8.1	2.1	0.6	7.7
Pager (One- and Two-Way)	-4.5	19.9	-0.4	-5.7	10.2	3.4
Radio Checkout	6.9	2.0	-2.2	-2.5	-7.2	-0.7

(Continued)

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Table 17 (Continued)
Revenue Growth from North American Communications Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Broadcast and Studio	7.0	7.1	6.5	5.3	5.3	6.2
Audio	3.0	4.6	4.4	4.4	4.4	4.2
Video	6.4	9.0	7.9	6.3	6.3	7.2
Transmitter, RF Power Amp	3.6	2.8	0.7	1.4	1.4	2.0
Studio Transmitter Link	3.3	3.2	0	3.1	3.1	2.6
Cable TV (Head End)	11.0	9.3	8.2	6.5	6.5	8.3
CCTV	4.9	5.1	5.8	2.9	2.9	4.3
Other (Including Studio, Theater)	9.0	3.7	6.2	5.0	5.0	5.8
Other Telecom	4.6	3.0	3.2	4.2	4.2	3.8
Intercomm., Elec. Amp.	0	0.6	0.6	1.1	1.1	0.7
Communication Equipment, nec*	5.0	3.2	3.4	4.5	4.5	4.1

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 18
Revenue from North American Industrial Equipment Production, 1990-1994
(Millions of Dollars)

	1990	1991	1992	1993	1994
Industrial	36,628	37,702	37,844	40,410	43,881
Security/Energy Management	3,311	3,472	3,424	3,445	3,562
Alarm System	1,027	1,145	1,186	1,193	1,233
Intrusion Detection	607	665	677	669	680
Fire Detection	420	480	509	524	554
Energy Management	2,284	2,327	2,239	2,252	2,329
Manufacturing System	14,598	14,446	14,743	15,987	17,773
Semiconductor Production	1,595	1,519	1,584	2,171	3,105
Controls	5,836	5,672	5,693	6,035	6,469
Process Controls	2,404	2,401	2,414	2,575	2,778
Control and Processing Displays	4,488	4,560	4,736	4,872	5,062
Robots	275	294	315	334	359
Test and Measuring Equipment	7,426	8,052	7,855	8,472	9,175
ATE-Semiconductor Equipment	824	854	874	1,144	1,398
Other Test and Measurement	6,035	6,628	6,399	6,725	7,140
Nuclear Electronics	567	571	582	604	637
Medical Equipment	5,444	6,499	6,628	7,040	7,565
Diagnostic	1,842	1,901	1,912	2,034	2,193
Therapeutic	1,190	1,742	1,732	1,835	1,968
Patient Monitoring	797	921	996	1,061	1,154
Surgical Support	378	570	532	566	610
Irradiation Equipment	1,237	1,365	1,456	1,543	1,640
Other Industrial System	5,849	5,233	5,195	5,466	5,806

Source: Dataquest (April 1995)

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Table 19
Revenue from North American Industrial Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Industrial	47,192	50,270	53,438	57,204	61,564
Security/Energy Management	3,637	3,851	4,047	4,241	4,442
Alarm System	1,259	1,334	1,402	1,469	1,538
Intrusion Detection	681	708	730	750	770
Fire Detection	578	625	671	718	768
Energy Management	2,377	2,518	2,646	2,773	2,904
Manufacturing System	19,241	20,312	21,518	23,273	25,504
Semiconductor Production	3,530	3,542	3,752	4,505	5,676
Controls	7,003	7,550	8,071	8,599	9,159
Process Controls	3,030	3,289	3,540	3,796	4,069
Control and Processing Displays	5,288	5,511	5,704	5,893	6,087
Robots	389	420	450	480	512
Test and Measuring Equipment	9,891	10,554	11,256	11,989	12,768
ATE-Semiconductor Equipment	1,559	1,676	1,849	2,025	2,214
Other Test and Measurement	7,648	8,150	8,634	9,145	9,686
Nuclear Electronics	683	729	773	819	868
Medical Equipment	8,199	8,932	9,634	10,341	11,094
Diagnostic	2,394	2,619	2,844	3,081	3,336
Therapeutic	2,124	2,312	2,483	2,644	2,812
Patient Monitoring	1,261	1,380	1,500	1,627	1,765
Surgical Support	666	729	791	857	928
Irradiation Equipment	1,755	1,893	2,016	2,131	2,252
Other Industrial System	6,225	6,620	6,983	7,360	7,757

Source: Dataquest (April 1995)

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Table 20
Revenue Growth from North American Industrial Equipment Production, 1990-1994
(Percentage Change)

	1990	1991	1992	1993	1994
Industrial	4.8	2.9	0.4	6.8	8.6
Security/Energy Management	-0.9	4.9	-1.4	0.6	3.4
Alarm System	-9.3	11.5	3.6	0.6	3.4
Intrusion Detection	-10.8	9.6	1.8	-1.2	1.6
Fire Detection	-7.0	14.2	6.0	2.9	5.8
Energy Management	3.4	1.9	-3.8	0.6	3.4
Manufacturing System	4.9	-1.0	2.1	8.4	11.2
Semiconductor Production	-4.2	-4.8	4.3	37.1	43.0
Controls	7.2	-2.8	0.4	6.0	7.2
Process Controls	8.0	-0.1	0.6	6.7	7.9
Control and Processing Displays	3.8	1.6	3.9	2.9	3.9
Robots	7.4	7.1	7.0	6.2	7.4
Test and Measuring Equipment	13.2	8.4	-2.5	7.9	8.3
ATE-Semiconductor Equipment	44.5	3.7	2.3	30.8	22.2
Other Test and Measurement	12.1	9.8	-3.5	5.1	6.2
Nuclear Electronics	-6.5	0.7	1.9	3.8	5.5
Medical Equipment	7.6	19.4	2.0	6.2	7.4
Diagnostic	5.4	3.2	0.6	6.4	7.8
Therapeutic	17.2	46.4	-0.6	5.9	7.2
Patient Monitoring	3.0	15.5	8.2	6.6	8.7
Surgical Support	-3.7	50.9	-6.7	6.4	7.8
Irradiation Equipment	9.3	10.3	6.6	6.0	6.3
Other Industrial System	-3.9	-10.5	-0.7	5.2	6.2

Source: Dataquest (April 1995)

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Table 21
Revenue Growth from North American Industrial Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Industrial	7.5	6.5	6.3	7.0	7.6	7.0
Security/Energy Management	2.1	5.9	5.1	4.8	4.7	4.5
Alarm System	2.1	5.9	5.1	4.8	4.7	4.5
Intrusion Detection	0.2	3.9	3.1	2.7	2.6	2.5
Fire Detection	4.4	8.2	7.4	7.0	6.9	6.8
Energy Management	2.1	5.9	5.1	4.8	4.7	4.5
Manufacturing System	8.3	5.6	5.9	8.2	9.6	7.5
Semiconductor Production	13.7	0.3	5.9	20.1	26.0	12.8
Controls	8.3	7.8	6.9	6.5	6.5	7.2
Process Controls	9.1	8.6	7.6	7.2	7.2	7.9
Control and Processing Displays	4.5	4.2	3.5	3.3	3.3	3.8
Robots	8.4	8.0	7.1	6.7	6.7	7.4
Test and Measuring Equipment	7.8	6.7	6.7	6.5	6.5	6.8
ATE-Semiconductor Equipment	11.5	7.5	10.4	9.5	9.3	9.6
Other Test and Measurement	7.1	6.6	5.9	5.9	5.9	6.3
Nuclear Electronics	7.4	6.7	6.0	6.0	6.0	6.4
Medical Equipment	8.4	8.9	7.9	7.3	7.3	8.0
Diagnostic	9.2	9.4	8.6	8.3	8.3	8.8
Therapeutic	7.9	8.9	7.4	6.5	6.4	7.4
Patient Monitoring	9.3	9.4	8.7	8.5	8.5	8.9
Surgical Support	9.2	9.4	8.6	8.3	8.3	8.8
Irradiation Equipment	7.0	7.8	6.5	5.7	5.6	6.5
Other Industrial System	7.2	6.3	5.5	5.4	5.4	6.0

Source: Dataquest (April 1995)

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Table 22
Revenue from North American Consumer Equipment Production, 1990-1994
(Millions of Dollars)

	1990	1991	1992	1993	1994
Consumer	17,005	16,616	17,804	19,582	21,279
Audio	753	671	641	668	703
Compact Disc Player	15	20	26	32	39
Radio	273	203	157	163	170
Stereo Component	207	204	212	216	228
Musical Instrument	240	230	232	242	250
Tape Recorder	18	14	14	16	16
Video	3,376	3,382	3,999	4,191	4,508
VCR, VTR	265	266	271	276	297
Videodisk Player	1	1	0	0	0
Color Televisions	3,110	3,115	3,142	3,268	3,457
Cable/Satellite Set-Top Decoder	0	0	586	647	753
Personal Electronics	451	438	445	458	477
Games (Systems and Cartridges)	261	259	263	272	283
Camera	25	24	24	24	25
Watches	100	100	103	105	109
Clocks	65	55	56	57	59
Appliances	11,358	11,033	11,539	13,014	14,243
Air Conditioner	1,935	1,683	1,759	1,930	2,348
Microwave Oven	531	478	500	547	597
Washer and Dryer	3,032	2,973	3,109	3,349	3,550
Refrigerator	3,923	3,962	4,144	4,977	5,344
Dishwasher	981	971	1,016	1,112	1,224
Range and Oven	956	966	1,010	1,099	1,181
Other Consumer	1,067	1,092	1,180	1,251	1,348
Automatic garage door opener	257	267	318	352	411
Other Consumer Equipment, nec*	810	825	862	899	936

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 23
Revenue from North American Consumer Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Consumer	22,560	23,072	24,239	24,889	26,138
Audio	744	792	842	894	950
Compact Disc Player	48	59	73	90	111
Radio	179	189	199	208	218
Stereo Component	239	253	266	279	293
Musical Instrument	261	273	285	297	308
Tape Recorder	17	18	19	20	20
Video	5,018	5,382	5,761	6,071	6,388
VCR, VTR	319	343	366	391	417
Videodisk Player	0	0	0	0	0
Color Televisions	3,666	3,870	4,069	4,259	4,449
Cable/Satellite Set-Top Decoder	1,033	1,169	1,326	1,421	1,522
Personal Electronics	501	528	555	580	605
Games (Systems and Cartridges)	298	314	330	345	361
Camera	27	28	29	30	31
Watches	114	120	126	132	137
Clocks	62	66	69	73	76
Appliances	14,887	14,885	15,523	15,717	16,499
Air Conditioner	2,420	2,354	2,466	2,484	2,602
Microwave Oven	633	667	696	713	739
Washer and Dryer	3,733	3,725	3,898	3,919	4,096
Refrigerator	5,574	5,521	5,727	5,844	6,153
Dishwasher	1,290	1,334	1,398	1,398	1,489
Range and Oven	1,238	1,284	1,338	1,359	1,419
Other Consumer	1,410	1,485	1,558	1,627	1,697
Automatic garage door opener	435	463	491	519	547
Other Consumer Equipment, nec*	975	1,022	1,067	1,109	1,150

*nec = not elsewhere classified
Source: Dataquest (April 1995)

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Table 24
Revenue Growth from North American Consumer Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Consumer	-1.0	-2.3	7.1	10.0	8.7
Audio	-0.6	-10.9	-4.5	4.2	5.3
Compact Disc Player	87.5	33.3	28.7	22.5	22.6
Radio	-5.0	-25.6	-22.7	3.9	4.3
Stereo Component	-0.5	-1.4	3.8	1.9	5.7
Musical Instrument	2.1	-4.2	0.7	4.3	3.5
Tape Recorder	-5.3	-22.2	3.0	9.3	3.7
Video	-0.9	0.2	18.2	4.8	7.6
VCR, VTR	8.2	0.4	1.8	2.1	7.5
Videodisk Player	0	0	NM	NM	NM
Color Televisions	-1.6	0.2	0.9	4.0	5.8
Cable/Satellite Set-Top Decoder	NM	NM	NM	10.3	16.5
Personal Electronics	-12.2	-2.9	1.6	2.9	4.2
Games (Systems and Cartridges)	-22.2	-0.7	1.3	3.6	4.2
Camera	0	-4.0	0.1	1.1	4.7
Watches	0	0	3.0	2.0	4.0
Clocks	22.6	-15.4	1.1	2.0	4.4
Appliances	-0.6	-2.9	4.6	12.8	9.4
Air Conditioner	4.8	-13.0	4.5	9.7	21.6
Microwave Oven	-14.2	-10.0	4.7	9.3	9.2
Washer and Dryer	1.7	-1.9	4.6	7.7	6.0
Refrigerator	-2.5	1.0	4.6	20.1	7.4
Dishwasher	0.2	-1.0	4.6	9.4	10.1
Range and Oven	-2.6	1.0	4.5	8.8	7.5
Other Consumer	0.2	2.3	8.1	6.0	7.7
Automatic garage door opener	2.0	3.7	19.2	10.6	16.9
Other Consumer Equipment, nec*	-0.4	1.9	4.5	4.3	4.1

NM = Not meaningful

*nec = not elsewhere classified

Source: Dataquest (April 1995)

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Table 25
Revenue Growth from North American Consumer Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Consumer	6.0	2.3	5.1	2.7	5.0	4.2
Audio	5.8	6.5	6.3	6.2	6.2	6.2
Compact Disc Player	23.5	24.2	23.8	23.3	23.1	23.6
Radio	5.1	5.6	5.2	4.8	4.5	5.0
Stereo Component	4.9	5.6	5.2	5.0	4.9	5.1
Musical Instrument	4.3	4.8	4.4	3.9	3.7	4.2
Tape Recorder	5.3	5.0	4.6	4.2	3.9	4.6
Video	11.3	7.2	7.1	5.4	5.2	7.2
VCR, VTR	7.4	7.3	6.9	6.7	6.6	7.0
Videodisk Player	NM	NM	NM	NM	NM	NM
Color Televisions	6.0	5.6	5.1	4.7	4.5	5.2
Cable/Satellite Set-Top Decoder	37.1	13.2	13.4	7.1	7.1	15.1
Personal Electronics	5.0	5.4	5.0	4.6	4.3	4.9
Games (Systems and Cartridges)	5.1	5.5	5.1	4.6	4.4	4.9
Camera	4.6	4.4	4.0	3.8	3.6	4.1
Watches	4.8	5.3	4.9	4.4	4.2	4.7
Clocks	5.2	5.7	5.3	4.8	4.6	5.1
Appliances	4.5	0	4.3	1.2	5.0	3.0
Air Conditioner	3.1	-2.7	4.8	0.7	4.7	2.1
Microwave Oven	5.9	5.4	4.3	2.5	3.7	4.4
Washer and Dryer	5.2	-0.2	4.6	0.5	4.5	2.9
Refrigerator	4.3	-1.0	3.7	2.0	5.3	2.9
Dishwasher	5.4	3.4	4.8	0	6.6	4.0
Range and Oven	4.8	3.7	4.2	1.5	4.4	3.7
Other Consumer	4.6	5.3	4.9	4.5	4.2	4.7
Automatic garage door opener	5.6	6.5	6.1	5.6	5.4	5.8
Other Consumer Equipment, nec*	4.1	4.8	4.4	3.9	3.7	4.2

NM = Not meaningful

*nec = not elsewhere classified

Source: Dataquest (April 1995)

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Table 26
Revenue from North American Military/Civil Aerospace Equipment Production, 1990-1994 (Millions of Dollars)

	1990	1991	1992	1993	1994
Military/Civil Aerospace	36,603	35,577	32,861	31,284	29,668
Radar/Sonar/Reconnaissance	15,032	15,049	13,845	13,291	12,627
Missile/Space	5,903	5,700	5,472	5,362	5,041
Navigation	5,669	5,448	5,012	4,761	4,618
Electronic Warfare	4,533	4,137	3,723	3,537	3,342
Aircraft Flight Systems	4,183	3,814	3,451	3,015	2,749
Command, Control	1,284	1,430	1,358	1,318	1,291

Source: Dataquest (April 1995)

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Table 27
Revenue from North American Military/Civil Aerospace Equipment Production, 1995-1999 (Millions of Dollars)

	1995	1996	1997	1998	1999
Military/Civil Aerospace	28,698	28,932	29,466	30,018	30,585
Radar/Sonar/Reconnaissance	12,122	12,303	12,611	12,926	13,249
Missile/Space	4,940	4,964	4,989	5,014	5,039
Navigation	4,572	4,618	4,687	4,758	4,829
Electronic Warfare	3,175	3,112	3,158	3,206	3,254
Aircraft Flight Systems	2,611	2,637	2,690	2,744	2,799
Command, Control	1,278	1,298	1,330	1,370	1,415

Source: Dataquest (April 1995)

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Table 28
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Military/Civil Aerospace	4.9	-2.8	-7.6	-4.8	-5.2
Radar/Sonar/Reconnaissance	3.8	0.1	-8.0	-4.0	-5.0
Missile/Space	7.4	-3.4	-4.0	-2.0	-6.0
Navigation	24.2	-3.9	-8.0	-5.0	-3.0
Electronic Warfare	-10.0	-8.8	-10.0	-5.0	-5.5
Aircraft Flight Systems	3.5	-8.8	-9.5	-12.6	-8.8
Command, Control	1.1	11.4	-5.0	-3.0	-2.0

Source: Dataquest (April 1995)

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Table 29
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Military/Civil Aerospace	-3.3	0.8	1.8	1.9	1.9	0.6
Radar/Sonar/Reconnaissance	-4.0	1.5	2.5	2.5	2.5	1.0
Missile/Space	-2.0	0.5	0.5	0.5	0.5	0
Navigation	-1.0	1.0	1.5	1.5	1.5	0.9
Electronic Warfare	-5.0	-2.0	1.5	1.5	1.5	-0.5
Aircraft Flight Systems	-5.0	1.0	2.0	2.0	2.0	0.4
Command, Control	-1.0	1.5	2.5	3.0	3.3	1.8

Source: Dataquest (April 1995)

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Table 30
Revenue from North American Transportation Equipment Production, 1990-1994
(Millions of Dollars)

	1990	1991	1992	1993	1994
Transportation	3,537	3,554	3,911	4,641	5,537
Entertainment	457	407	422	478	526
Vehicle/Body Control	329	303	337	378	433
Driver Information	649	649	681	771	881
Powertrain	1,646	1,590	1,722	1,964	2,259
Safety and Convenience	455	606	749	1,050	1,438

Source: Dataquest (April 1995)

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Table 31
Revenue from North American Transportation Equipment Production, 1995-1999
(Millions of Dollars)

	1995	1996	1997	1998	1999
Transportation	6,145	6,357	6,793	7,321	7,758
Entertainment	562	553	562	586	612
Vehicle/Body Control	462	470	493	527	571
Driver Information	952	972	1,030	1,129	1,226
Powertrain	2,447	2,479	2,589	2,733	2,865
Safety and Convenience	1,722	1,883	2,119	2,346	2,484

Source: Dataquest (April 1995)

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Table 32
Revenue Growth from North American Transportation Equipment Production, 1990-1994 (Percentage Change)

	1990	1991	1992	1993	1994
Transportation	-9.3	0.5	10.0	18.7	19.3
Entertainment	-6.8	-11.0	3.8	13.3	10.0
Vehicle/Body Control	-8.5	-8.1	11.4	12.2	14.6
Driver Information	-8.6	0	5.0	13.2	14.3
Powertrain	-14.0	-3.4	8.3	14.1	15.0
Safety and Convenience	6.8	33.3	23.6	40.2	37.0

Source: Dataquest (April 1995)

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Table 33
Revenue Growth from North American Transportation Equipment Production, 1995-1999 (Percentage Change)

	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Transportation	11.0	3.4	6.9	7.8	6.0	7.0
Entertainment	6.8	-1.6	1.6	4.3	4.4	3.1
Vehicle/Body Control	6.7	1.7	4.9	6.9	8.3	5.7
Driver Information	8.1	2.1	6.0	9.6	8.6	6.8
Powertrain	8.3	1.3	4.4	5.6	4.8	4.9
Safety and Convenience	19.7	9.3	12.5	10.7	5.9	11.6

Source: Dataquest (April 1995)

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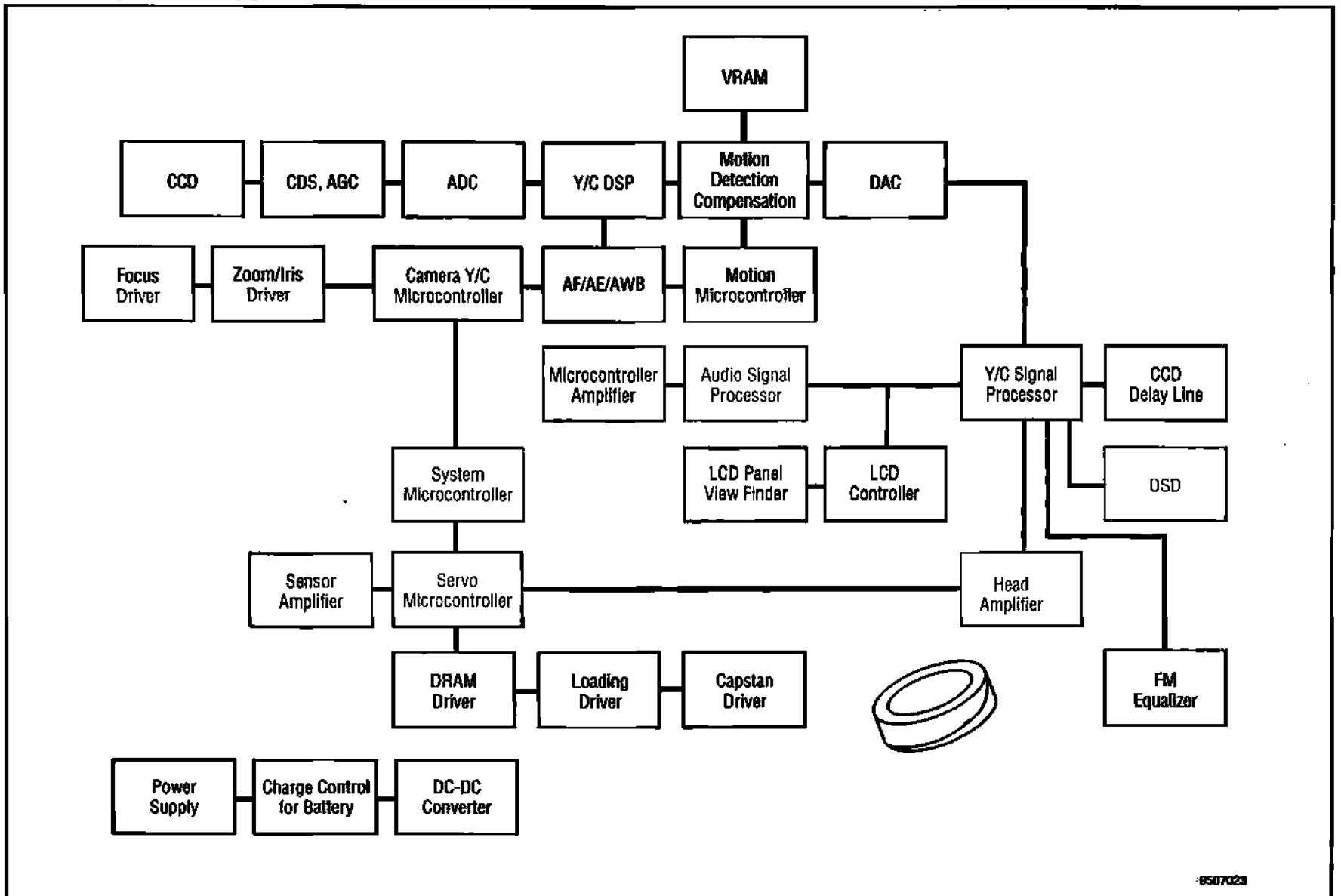
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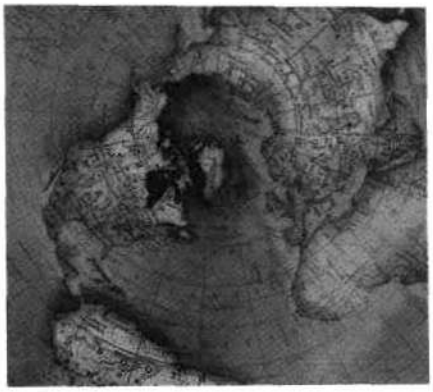
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Figure 4-13
Block Diagram of a Typical Camcorder



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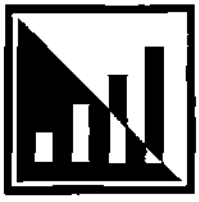
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Communications Application Markets—Telephones and Mobile Communication



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Chapter 1
Introduction and Methodology

This document is the fifth in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, wireline communications, wireless communications and fixed terminals, consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The brand share information presented in this book comes from The Scout Report® of The Polk Company. The Scout Report® has been designed to accurately measure the retail purchase activity of U.S. households. Based on a widely accepted survey methodology, the sample is drawn quarterly from a nationally representative group of 50,000 respondents, and response rates average 70 percent. Brand shares reported in The Scout Report® are point estimates of the actual brand shares and have a small margin of error. Brand shares are based on a representation of retail sales to end-use consumers in the United States and may not correspond directly to other commonly reported measures of product movement such as production or wholesale shipments.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending, assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analyst: Dale Ford

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Chapter 2
Terminal Devices and Mobile Applications

Overview

Telephone handsets have traditionally been classified in the communications application sector, but all the three telephone types, corded, cordless and cellular, are rapidly becoming consumer-oriented products. The consumer market has given new life to pager sales as they have even reached "fashion accessory" status. World demand for telephones and pagers continues to rise, driven by the following:

- Demand for more than one telephone per household
- The rapid introduction of telephone capacity in the developing regions of the world, especially Asia and Central and Eastern Europe
- The growing demand for mobile communications for both data and voice

Despite the demand for standard corded telephones for both residential and business users, there is a groundswell of demand for wireless telephony products, either cordless or cellular. The global direction is to embrace the benefits of wireless connectivity. The demand is in all four major regions of the world, Asia/Pacific, Japan, Europe, and North America.

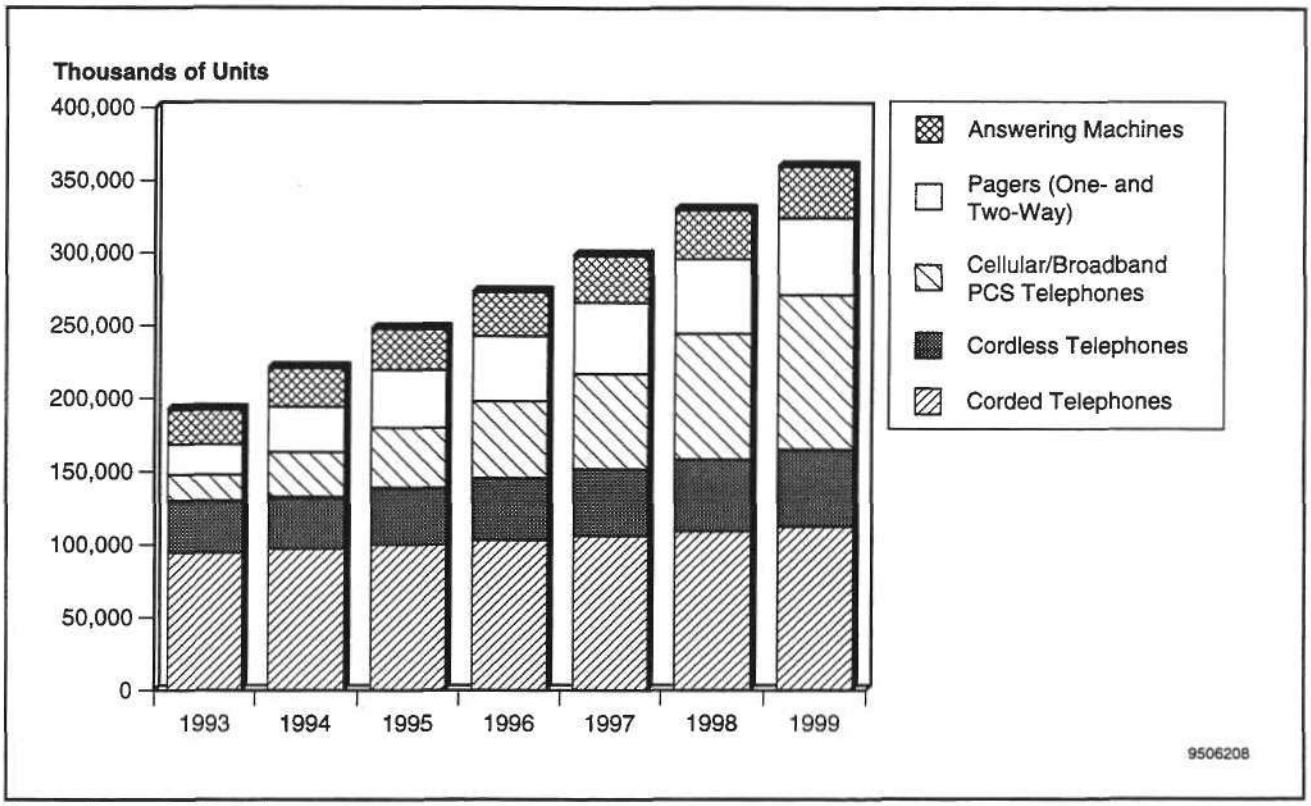
The future of wireless communications is already taking its next logical step, with the concept of a personal communications network (PCN in Europe) and personal communications service (PCS in the United States). The idea is that the same telephone can be used in the home, at work, and out in public places. This is one step away from the ultimate concept of a person with a single telephone number (so calls are placed to a person not a place) and one single telephone that can be used anywhere in the world.

Worldwide production of telephone handsets, pagers, and answering machines is forecast to grow at 10.3 percent compound annual growth rate (CAGR) for the next five years, led by cellular/PCS telephone and pager production expanding at 28.2 percent and 11.3 percent CAGR, respectively. Table 2-1 and Figure 2-1 show the worldwide production forecast summary for telephone handsets, pagers, and answering machines.

Overall, as a producer of telephone handsets and other communications terminals, North America produces less than half of what the region consumes. Although sales are dominated by brand names such as AT&T, General Electric, Motorola, and the regional Bell operating companies (RBOCs), production and design of commodity corded and cordless products are predominantly contracted to Pacific Rim suppliers or offshore captive operations. However, for the fast-growing cellular and emerging PCS areas, a majority of market needs is expected to continue to be designed and built locally. This trend can be attributed to time-to-market needs, diminishing labor content in the final product, and the desire to mitigate trade friction by the large Japanese OEMs. Table 2-2 and Figure 2-2 show the forecast for North American production of communications terminals. Table 2-3 lists companies with telephone handset manufacturing facilities in North America.

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Figure 2-1
Worldwide Terminal Device Production



Source: Dataquest (November 1995)

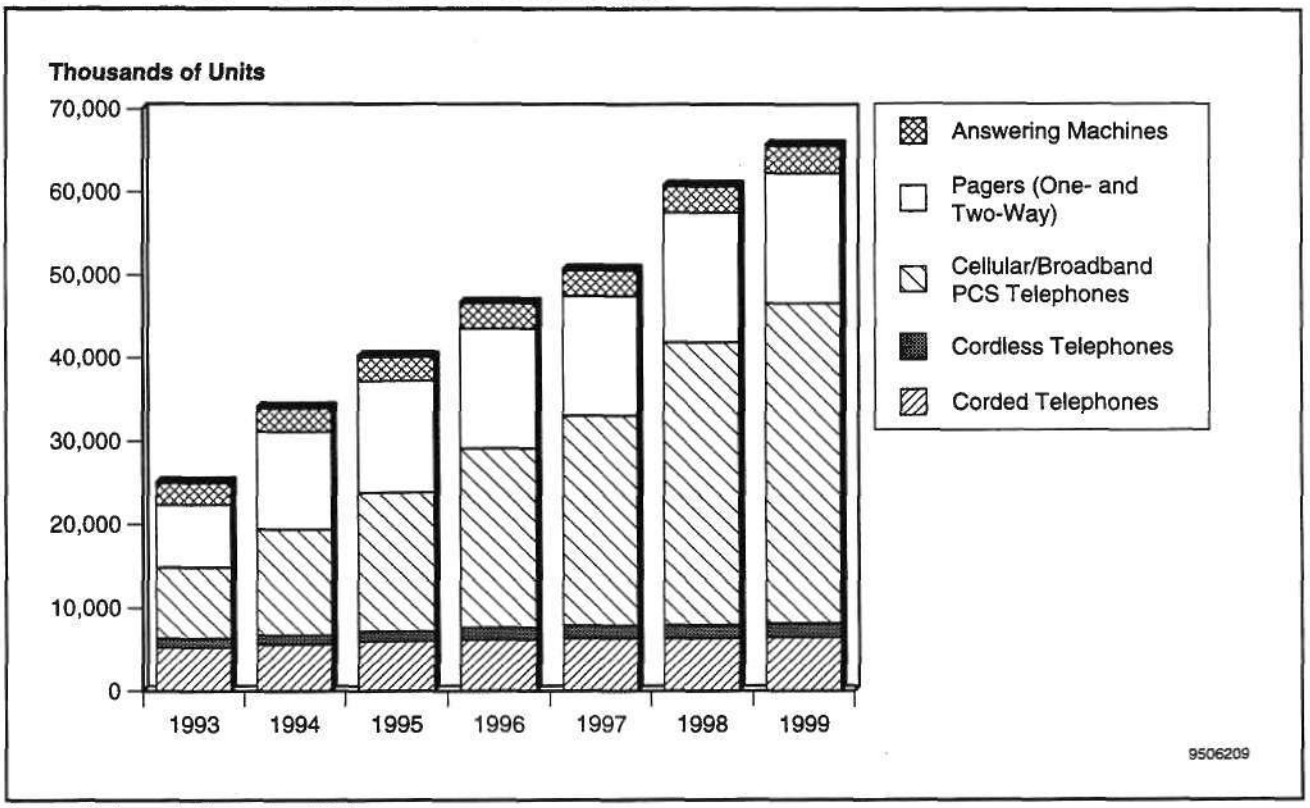
Table 2-1
Worldwide Terminal Device Productions (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Corded Telephones	94,762	97,257	100,174	103,180	106,275	109,463	112,747	3.0
Cordless Telephones	35,405	35,685	39,134	42,668	45,764	49,173	52,744	8.1
Cellular/Broadband PCS Telephones	17,848	30,534	40,779	52,382	64,818	85,900	105,939	28.2
Pagers (One- and Two-Way)	20,672	30,919	39,336	44,564	48,989	51,287	52,768	11.3
Answering Machines	23,470	26,273	28,194	30,099	31,901	33,655	35,431	6.2
Total	192,156	220,668	247,618	272,893	297,748	329,479	359,629	10.3

Source: Dataquest (November 1995)

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Figure 2-2
North American Terminal Device Production



Source: Dataquest (November 1995)

Table 2-2
North American Terminal Device Production (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Corded Telephones	5,264	5,584	5,980	6,180	6,297	6,333	6,460	3.0
Cordless Telephones	1,080	1,134	1,215	1,516	1,596	1,652	1,735	8.9
Cellular/Broadband PCS Telephones	8,515	12,697	16,636	21,433	25,180	33,906	38,402	24.8
Pagers (One- and Two-Way)	7,517	11,723	13,405	14,415	14,418	15,657	15,712	6.0
Answering Machines	2,608	2,803	2,887	3,078	3,099	3,145	3,302	3.3
Total	24,984	33,940	40,123	46,621	50,589	60,693	65,610	14.1

Source: Dataquest (November 1995)

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Table 2-3
Companies Manufacturing Telephones in North America

Company	Location	Corded	Cordless	TAM*	Cellular
Alpine	Greenwood, Indiana				3
AT&T	Guadalajara, Mexico			✓	
	Little Rock, Arkansas				✓
Ericsson–GE	Lynchburg, Virginia				✓
Fujitsu	Richardson, Texas				✓
Hughes Network Systems	San Diego, California				✓
JRC International	Alberta, Canada				✓
Mitel	Ontario, Canada	✓			
Mitsubishi	Atlanta, Georgia				✓
Motorola	Schaumburg, Illinois		✓		
	Libertyville, Illinois				✓
	Grayslake, Illinois				✓
NEC	Irving, Texas				✓
	Hillsborough, Oregon				✓
Nokia	Fort Worth, Texas				✓
	(Second site planned)				✓
Northern Telecom	Canada	✓			
	Mexico		✓		
Intek/Acquired from NovAtel	Lethbridge, Alberta, Canada				✓
Oki	Suwanee, Georgia				✓
Panasonic	Peachtree City, Georgia				✓
Qualcomm	San Diego, California				✓
Siemens/ROLM	Austin, Texas	✓			
Sony Wireless Telecomm	San Diego, California				✓
Tandy	Texas	✓	✓	✓	✓
Uniden	Fort Worth, Texas				✓

*TAM = Telephone answering machine
Source: Dataquest (November 1995)

The worldwide semiconductor market for telephones, pagers, and answering machines will grow at an amazing 29.5 percent CAGR from 1993 to 1998, led by cellular/PCS handsets and the rapidly expanding wireless market. Table 2-4 and Figure 2-3 show a summary of this forecast. Table 2-5 and Figure 2-4 show the North American semiconductor market forecast for communications terminals.

North America remains an active region both as a market and as a producer of telephone handsets, pagers, and answering machines. Cordless or wireless telephone terminals and pagers, in particular, are finding tremendous acceptance in the home market.

The penetration of U.S. households by the various types of communications terminal equipment is shown in Table 2-6. As implied in the list, there remains substantial room for further penetration by cordless and cellular telephones. Digital versions of these are expected to rapidly replace their analog predecessors as well. The other looming opportunity

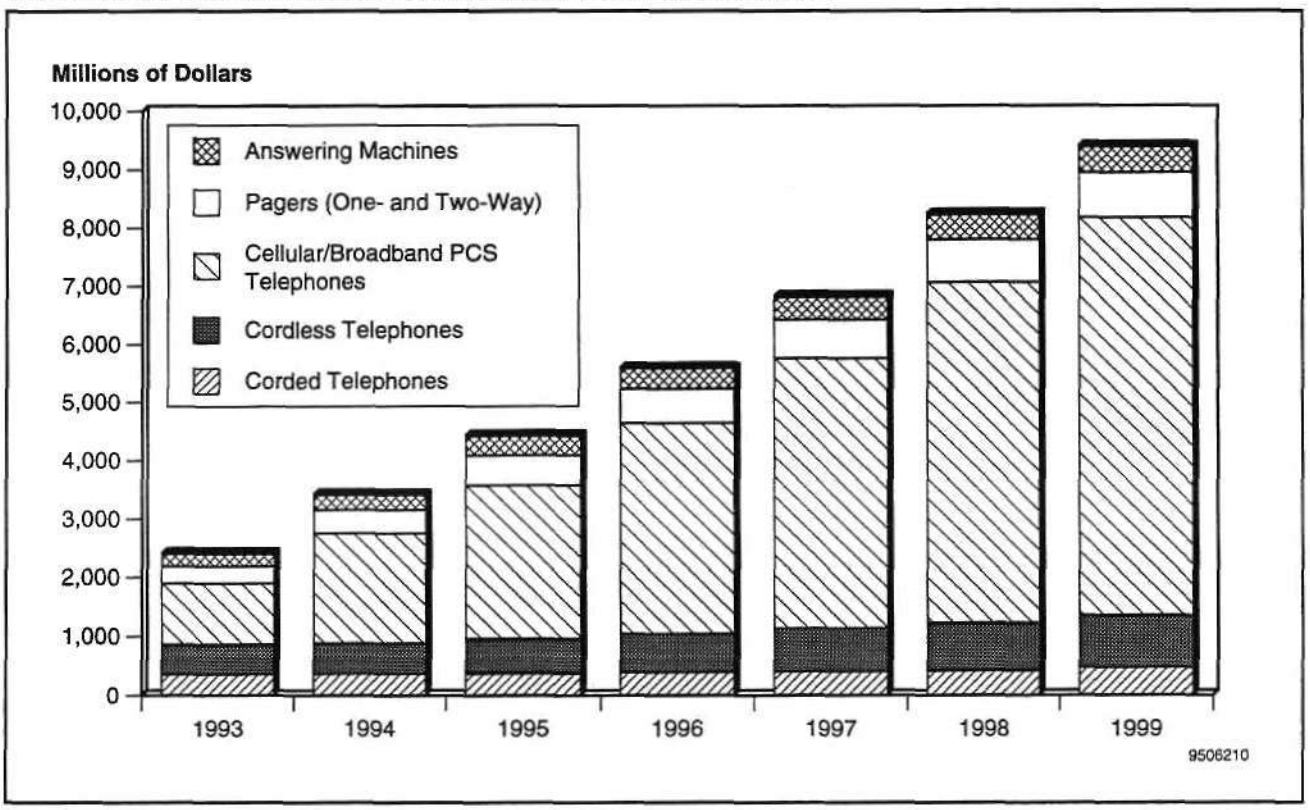
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Table 2-4
Worldwide Semiconductor Market for Terminal Devices (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Corded Telephones	365	374	378	393	405	415	471	4.7
Cordless Telephones	498	508	581	649	725	807	873	11.4
Cellular/Broadband PCS Telephones	1,038	1,874	2,619	3,591	4,620	5,838	6,827	29.5
Pagers (One- and Two-Way)	285	404	515	593	665	738	774	13.9
Answering Machines	213	252	324	358	393	427	442	11.9
Total	2,398	3,412	4,418	5,584	6,807	8,226	9,387	22.4

Source: Dataquest (November 1995)

Figure 2-3
Worldwide Semiconductor Market for Terminal Devices



Source: Dataquest (November 1995)

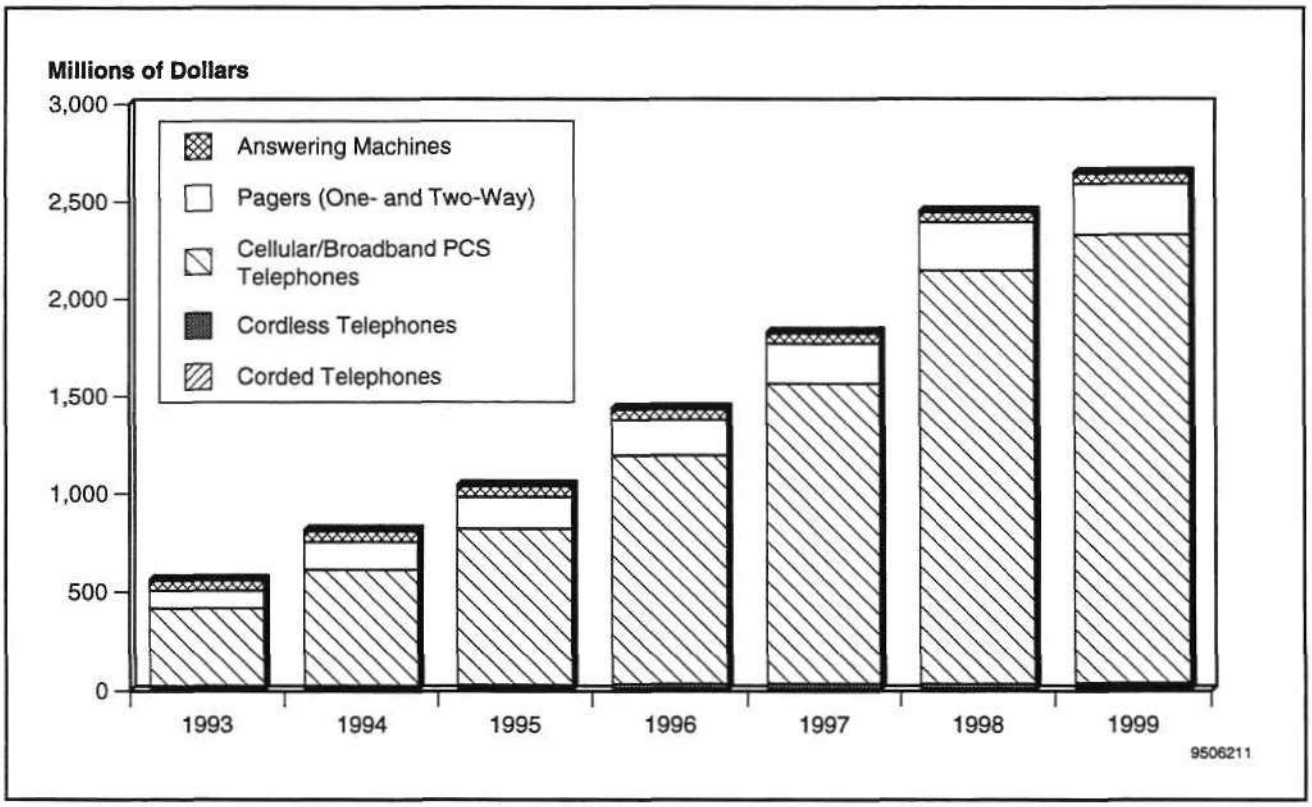
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Table 2-5
North American Semiconductor Market for Terminal Devices (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Corded Telephones	13	14	15	16	16	16	19	6.6
Cordless Telephones	14	15	17	21	22	21	23	8.9
Cellular/Broadband PCS Telephones	393	587	793	1,159	1,528	2,108	2,289	31.3
Pagers (One- and Two-Way)	90	141	161	182	204	250	261	13.2
Answering Machines	50	55	54	55	52	50	50	-2.2
Total	560	812	1,041	1,433	1,823	2,446	2,642	26.6

Source: Dataquest (November 1995)

Figure 2-4
North American Semiconductor Market for Terminal Devices



Source: Dataquest (November 1995)

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Table 2-6
U.S. Household Penetration of Communications Devices, January 1995 (Percent)

Category	Percentage
All Telephones	96
Telephone Answering Devices	54
Cordless Telephones	52
Cellular Telephones	20
Pagers	12
Caller ID Units	6

Source: EIA/CEG

in the United States is PCS handsets now that the Federal Communications Commission (FCC) has completed the initial rounds to auction off the required spectrum. Figure 2-5 shows a time line of the rollout of PCS services in the United States. Canada is also moving ahead with PCS trials and plans to award licenses soon. The fast-growing economy of Mexico, along with its newly privatized phone system, is creating many fertile opportunities. New PCS services targeted at two-way pagers will add significantly to the growth of this market, beginning in 1997. Caller ID boxes have penetrated the U.S. market. With new FCC regulations that will expand caller ID services into California, growth in this market is expected to remain strong.

The North American market shipments and revenue for all types of communications terminals are shown in Table 2-7. The largest category by far remains corded telephones. However, cellular/PCS shipments will rival corded phone shipments toward the end of the decade. Cordless telephones are penetrating the market rapidly as they become the replacement phone of choice. Answering machines continue their home penetration as sociological fears have been replaced by the messaging needs of two-income homes. Cellular phones continue to penetrate the so-called business consumer market, but recent surveys suggest that nonbusiness use is becoming even more important. Pager sales are increasingly driven by the consumer market. Figure 2-6 illustrates the cost/benefit relationship between various devices.

The strong growth of wireless communications markets will drive a robust wireless infrastructure equipment market. Table 2-8 presents a preliminary forecast for worldwide wireless infrastructure production.

Definitions

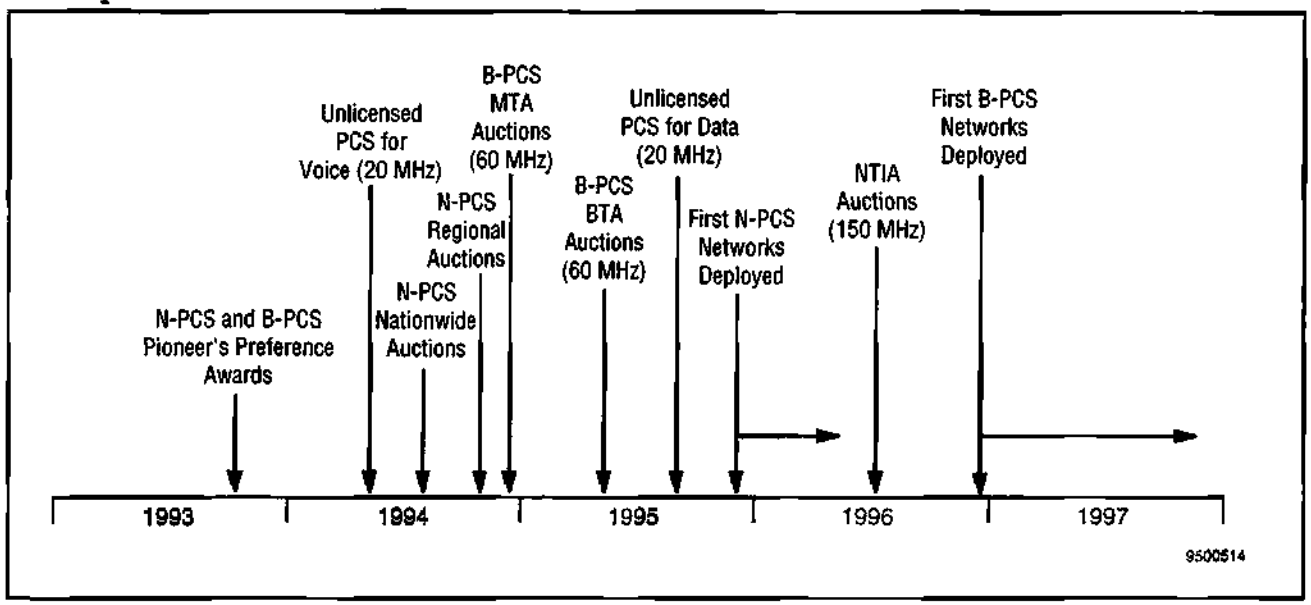
Corded

Standard: This includes all one- and two-piece telephones that connect via a cord directly to the public switched telephone network (PSTN) or a PBX. These telephones have a limited range of additional capabilities; as a maximum it would include a "last-number redial" facility and a limited number of telephone number memories (maximum 10 memories).

Feature: This definition typically includes those telephones that include, as a minimum, a liquid crystal display (LCD), last-number redial, and 10 or more telephone number memories. This type would usually also include on-hook dialing or a speakerphone capability.

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Figure 2-5
PCS Spectrum Time Line



Source: Dataquest (November 1995)

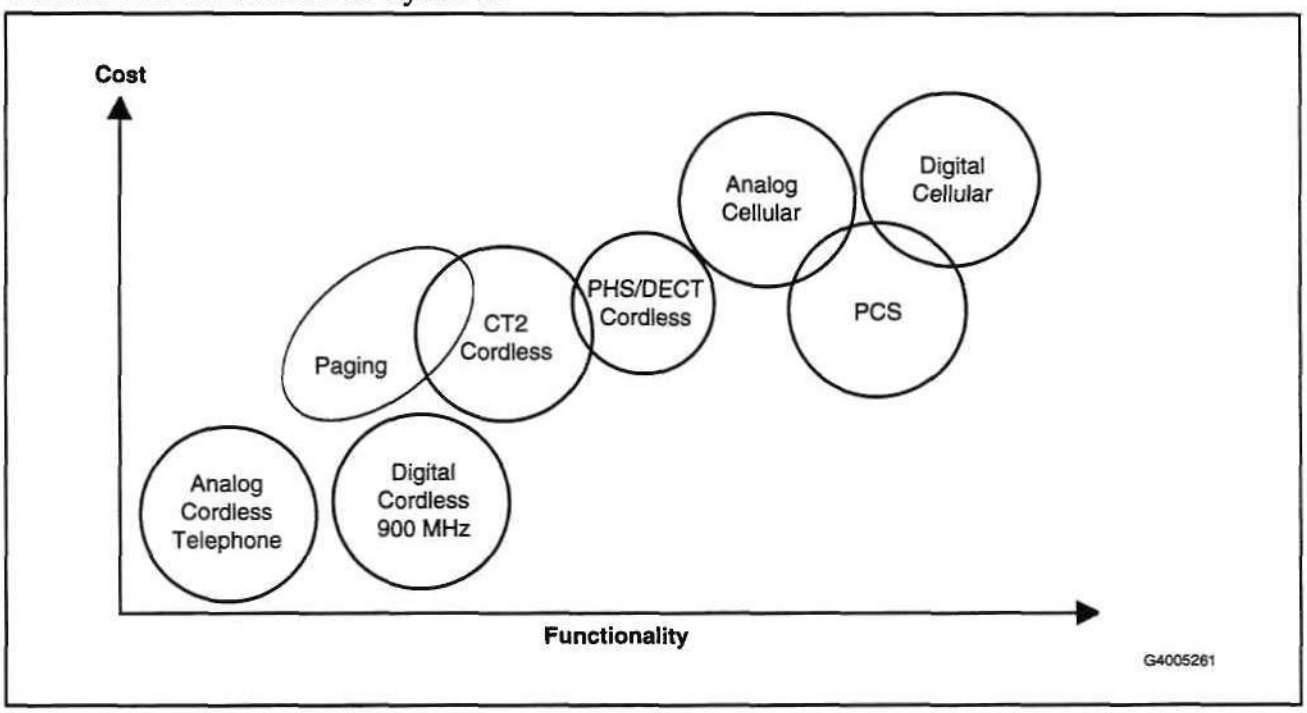
Table 2-7
North American Communications Terminal Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Shipments (K)								
Corded Telephones	42,019	39,954	39,339	39,059	38,831	38,874	38,963	-1.5
Cordless Telephones	17,801	19,030	20,625	21,533	22,609	23,740	24,927	5.9
Cellular/Broadband PCS Telephones	9,001	13,478	17,186	21,367	24,285	32,031	36,223	21.9
Pagers (One- and Two-Way)	7,069	11,548	13,291	14,430	14,277	15,687	15,393	5.9
Answering Machines	17,930	19,360	18,590	19,140	19,523	19,913	20,312	1.0
Total (K)	93,820	103,370	109,031	115,529	119,525	130,244	135,816	5.6
Revenue ($M)								
Corded Telephones	1,279	1,268	1,237	1,214	1,206	1,207	1,207	-1.1
Cordless Telephones	1,282	1,294	1,279	1,184	1,130	1,092	1,047	-3.2
Cellular/Broadband PCS Telephones	4,084	5,703	6,178	6,997	7,144	8,476	8,983	9.5
Pagers (One- and Two-Way)	557	866	988	1,072	1,228	1,589	1,576	12.7
Answering Machines	1,091	1,085	977	951	920	898	897	-3.7
Total	8,292	10,216	10,658	11,418	11,628	13,262	13,710	6.1

Source: Dataquest (November 1995)

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Figure 2-6
Mobile Communications Systems



Source: Dataquest (November 1995)

Table 2-8
Worldwide Wireless Infrastructure Equipment Production Forecast* (Preliminary)
(Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Revenue	9,680	10,907	12,991	15,534	18,011	20,817	23,124	16.2
Semiconductor Market	484	563	692	854	1,019	1,214	1,387	19.8

*Includes base station and microcell equipment for PCS, cellular, paging, and other wireless radio communications.
Note: These numbers are preliminary estimates. More detailed information will be available from Dataquest's Personal Communications North America program in early 1996.
Source: Dataquest (November 1995)

Cordless

This definition includes all telephones with a handset that has no wired connection to the PSTN or PBX. The base station usually includes the line interface to the PSTN or PBX. This category includes both analog and digital cordless telephones. It also includes digital cordless telephones for telepoint-type systems. The major differentiator for cordless telephones from cellular telephones is the lack of capability to roam from one base station to another or the ability to roam only at pedestrian speeds.

Cellular/Broadband PCS

This definition includes all handsets (hand-portable, transportable, and mobile) that have a radio link to a cellular or microcellular base station. The cellular system maintains a control link with each handset whether

stationary or moving at speed, and controls an automatic seamless handover from one cell base station to the next adjacent cell as the handset user moves.

Pagers

This definition includes all tone-only, tone-and-voice, digital (numeric), and alphanumeric paging devices. It also incudes paging devices developed for use in narrow-band PCS service. These pagers have limited two-way messaging capability and can also serve as "mobile answering machines."

Answering Machines

Integrated Telephone Answering Machine (TAM): This equipment category includes devices that can play an outgoing message and record an incoming message, and, most important, also include a telephone. The answering function may be solid-state or tape-based.

Standalone Answering Machine (AM): This equipment category includes devices that can play an outgoing message and record an incoming message. The answering function may be solid-state or tape-based. This product is a standalone device that does not include a telephone handset. Normally it would be used in conjunction with an existing telephone.

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Chapter 3
Corded Telephones

Market and Production Trends

Until recently, the implementation of voice telephony had been entrenched in the standard corded telephone, which had functionally changed very little in the last 50 years. Business users were the drivers to take the corded telephone to the next level of functionality. They drove the demand for feature telephones, with capabilities to recall stored numbers, provide hands-free dialing, and enable speakerphone conversations. The cost of such telephones dropped substantially with the development of low-cost 8- and 4-bit microcontrollers.

The demand for corded telephones remains high; however, the growth rate for standard corded telephones is falling in all world regions except Asia. The demand is now from both business and residential users for more feature-rich telephones, which are exhibiting positive growth rates. Tables 3-1 through 3-3 and Figures 3-1 and 3-2 present the worldwide corded telephone production forecast and the North American corded telephone production and market forecast.

Table 3-1
Worldwide Corded Telephone Handset Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	94,762	97,257	100,174	103,180	106,275	109,463	112,747	3.0
Standard	72,733	71,877	72,878	73,786	74,668	75,301	75,918	1.1
Feature/Multiline	22,029	25,380	27,297	29,393	31,607	34,163	36,829	7.7
Factory ASP ($)	30	29	29	28	27	27	27	-1.7
Factory Revenue ($M)	2,807	2,815	2,878	2,912	2,917	2,967	2,989	1.2
Semiconductor Content ($)	4	4	4	4	4	4	4	1.7
Semiconductor Market ($M)	365	374	378	393	405	415	471	4.7

Source: Dataquest (November 1995)

Table 3-2
North American Corded Telephone Handset Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	5,264	5,584	5,980	6,180	6,297	6,333	6,460	3.0
Factory ASP ($)	35	33	31	29	28	27	26	-4.7
Factory Revenue ($M)	184	184	185	179	176	171	168	-1.8
Semiconductor Content ($)	3	3	3	3	3	3	3	3.5
Semiconductor Market ($M)	13	14	15	16	16	16	19	6.6

Source: Dataquest (November 1995)

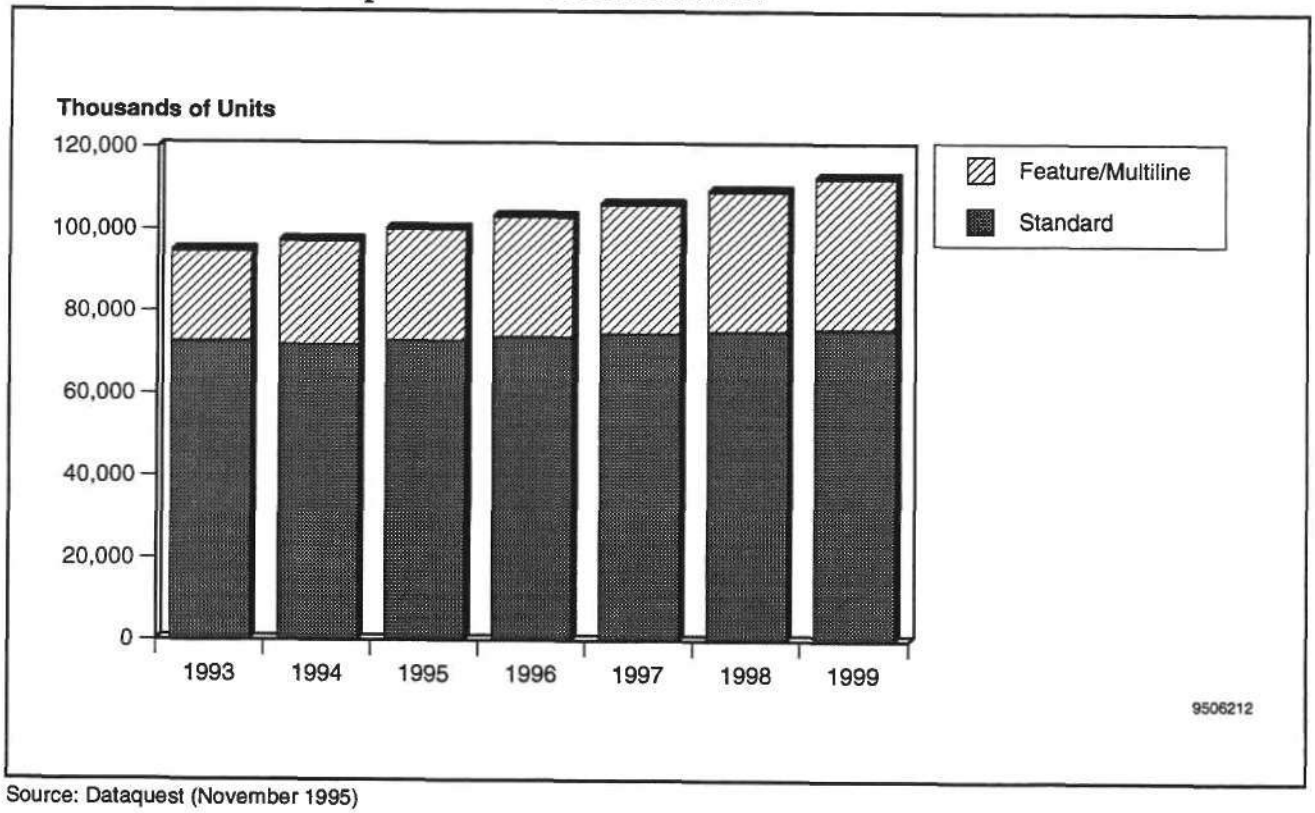
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Table 3-3
North American Corded Telephone Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Market Revenue ($M)	1,279	1,268	1,237	1,214	1,206	1,207	1,207	-1.1
Factory ASP Overall ($)	30	32	31	31	31	31	31	0.4
Factory ASP Standard ($)	14	14	14	14	14	14	14	0.0
Factory ASP Feature/ Multiline ($)	67	65	62	59	57	55	53	-3.9
Units (K)	42,019	39,954	39,339	39,059	38,831	38,874	38,963	-1.5
Standard	28,995	26,052	25,046	24,223	23,433	22,697	21,993	-4.8
Feature/Multiline	13,024	13,901	14,293	14,836	15,398	16,176	16,970	4.4

Source: Dataquest (November 1995)

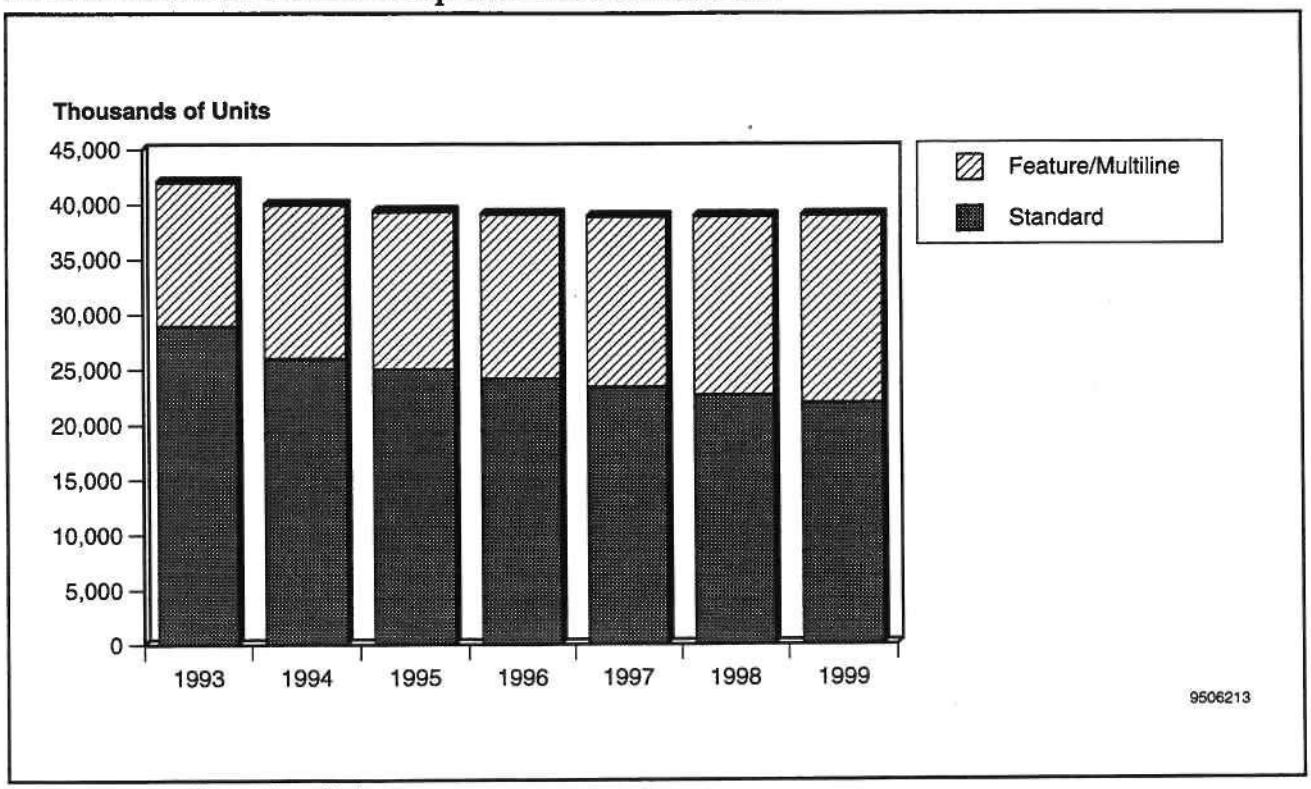
Figure 3-1
Worldwide Corded Telephone Handset Production



Source: Dataquest (November 1995)

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Figure 3-2
North American Corded Telephone Handset Market



Source: Dataquest (November 1995)

Brand Share Leaders

Tables 3-4 and 3-5 list the unit and revenue brand share leaders in corded telephones in the U.S. market for 1994 and for the third quarter of 1994 through the second quarter of 1995, respectively.

Table 3-4
U.S. Corded Telephone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	31.4	37.9
General Electric	15.4	15.8
Conair	11.8	6.7
BellSouth	7.3	6.0
Sony	5.1	6.8
Radio Shack	4.6	5.9
Unisonic	4.0	1.8
Lenoxx	3.5	1.7
Southwestern Bell	2.1	2.0
Panasonic	1.5	2.5
Others	13.3	12.9
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

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Table 3-5
U.S. Corded Telephone Brand Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	30.9	38.5
General Electric	14.7	14.7
Conair	11.6	6.7
BellSouth	5.7	4.8
Radio Shack	5.4	6.3
Lenoxx	4.9	2.5
Sony	4.4	5.7
Unisonic	3.6	1.8
Southwestern Bell	3.3	3.6
Panasonic	1.6	3.0
Others	13.9	12.4
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Feature and Technology Trends

In recent years, with the advent of the featurephone, the market mix of corded telephones began to change dramatically as phones with speakerphones, LCDs or touch screens, and caller ID energized product lines. Brief descriptions of some of these functions are as follows:

- Caller ID: The incorporation of the caller ID function in phones is probably the fastest-growing advanced feature. Caller ID entails the display of the telephone number of an inbound phone call. The benefit the marketers are promoting is the reduction of unwanted solicitation or harassment calls. It has become quite controversial in some states as privacy advocates have effectively blocked its incorporation in California, Texas, and Pennsylvania. Approximately 45 states have adopted caller ID capability. Telephones and special adjunct units are shipping in most states. New FCC regulations will open up the remaining states, including California, in the second half of 1995. Dataquest places the caller ID-featured phone and adjunct market at 3.3 million units in 1994, growing to 8 million in 1995. This includes caller ID features in both corded and cordless handsets.
- LCDs and touch screens: In general, LCDs are showing up on an ever-increasing number of phones. Used mostly for displaying the dialed number, they will eventually evolve into a caller ID role as well.
- ISDN: Even though Bellcore (the common research group of the RBOCs) claims that as many as half the access lines are ISDN ready, very few ISDN-capable telephones have shipped to the U.S. market. However, in the meantime, the SS7 signaling protocol (to create what is known as ISDN-1) has evolved to allow disparate ISDN systems to communicate with each other. This, along with a new tariff structure and new services, is making it feasible for ISDN to roll out in the United States, and shipments are beginning to accelerate. The promise of ISDN is that it

brings the advantages of being digital (transmission quality, compressibility). It also enables the PTO to grow services by offering integrated data and videophone services to a single terminal.

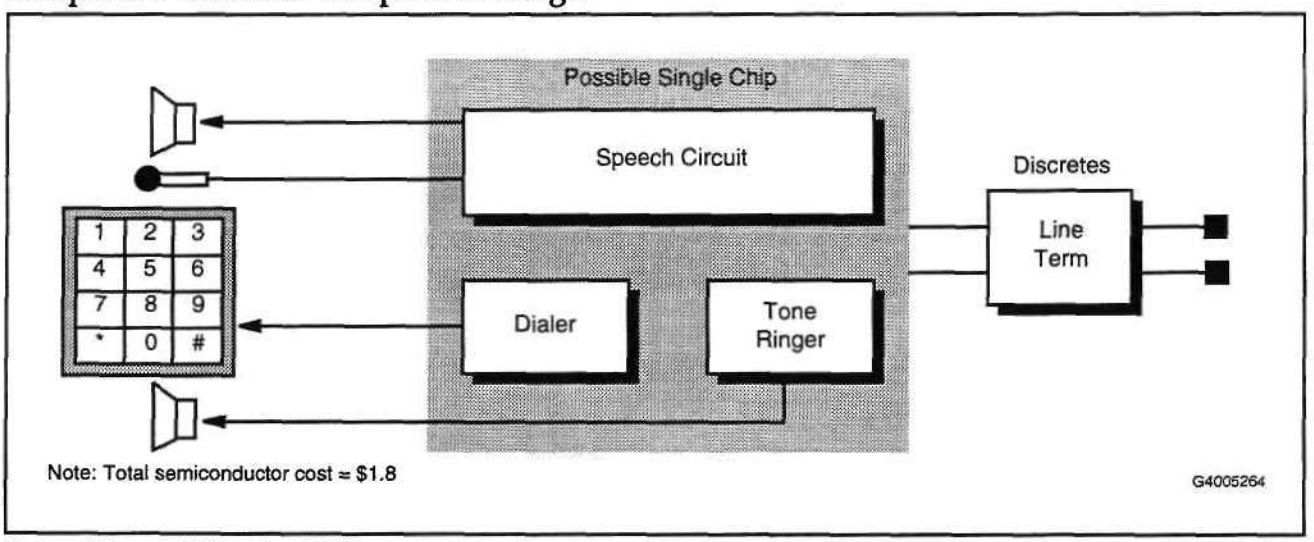
- Videophones: Videophone technology is beginning to emerge as a real opportunity as standards firm and costs come down. The decreasing of costs is due to several chip vendors hard at work on chipsets for CODECs, compression, protocols, and so on.

Standard Telephones

The standard telephone has evolved over the years from electromechanical equipment to the present full electronic design. Figure 3-3 shows a configuration for a standard telephone. Each of the three key devices currently in a telephone can be traced to individual key improvements in telephone handset design. The three key devices are as follows:

- Dual-tone multifrequency (DTMF) dialer: The DTMF dialer/keypad interface function was developed when DTMF dialing began to replace pulse dialing as digital exchange switching was introduced in the 1970s and 1980s. Also at this time the rotary dialer was replaced with a numeric keypad.
- Tone ringer: The tone ringer was developed as a replacement for the telephone electromechanical bell call ringer. This device detects the ring voltage on the telephone line and generates from an internal source a tone that will drive a loudspeaker or piezoelectric buzzer.
- Speech circuit: The speech circuit has traditionally been implemented in bipolar technology, and the dialer and tone ringer in CMOS. These technology splits have complicated the development of cost-effective, true single-chip telephones.

Figure 3-3
Simplified Standard Telephone Design



Source: Dataquest (November 1995)

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Another complication for telephone handset manufacturers, especially those building for export markets, is the different country variations of line characteristics. To address this challenge Philips Components has taken integration one step further with the recent development of the programmable single-chip telephone. This allows handset manufacturers to program (using on-chip, one-time-programmable memory) after assembly of the telephone "line and load" characteristics to suit individual country markets.

Feature Telephones

The original feature telephones were developed to support PBX/key telephone systems (KTS). These features originally included memory facilities and displays. A feature telephone today may have the following additional capabilities besides the standard telephone features:

- Multinumber store (usually more than 10)
- Alphanumeric display
- Hands-free dialing
- Speakerphone facility
- Mute (secrecy) capability
- Timer/clock function
- Caller identification

Figure 3-4 shows a configuration of a feature telephone, showing the following key devices:

- Speech circuit
- Microcontroller/DTMF dialer
- Tone ringer
- Speakerphone IC
- LCD

The major difference between a feature telephone and a standard telephone is the addition of a microcontroller/DTMF dialer and a speakerphone IC. The 4- or 8-bit microcontroller usually includes a DTMF dialer and provides all the memory storage capability, timer/clock functions, and interface/drive for the LCD. The speakerphone IC allows the user to have a conversation while the handset is still on the hook.

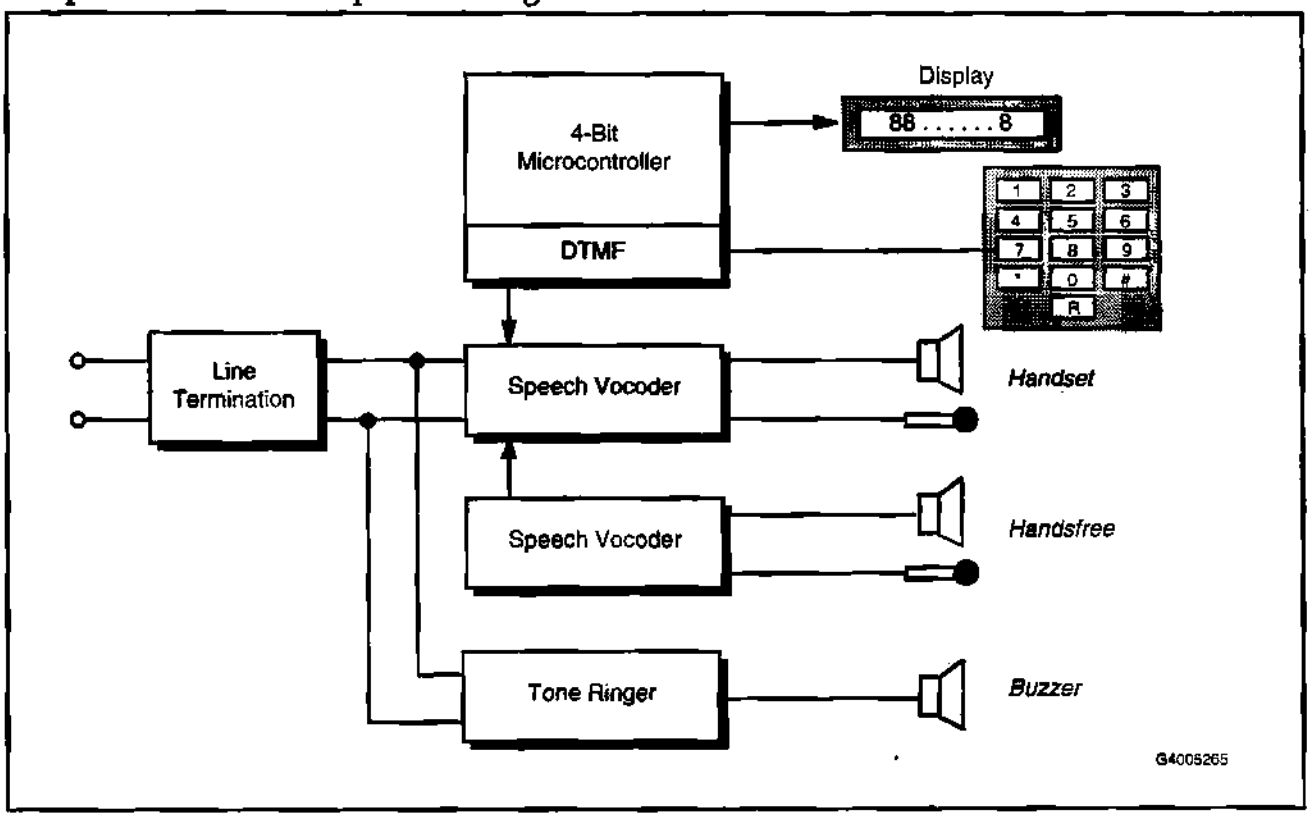
Semiconductor Opportunities

IC opportunities within advanced corded feature telephones include the following:

- Integrated speech, dialer, and speakerphone functions
- Caller ID (decode and LCD driver)
- Touch-screen interface
- Integrated versions of these with a 4- or 8-bit MCU
- ISDN (CODECs, S/T/U interface, and LAP-D controller)

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Figure 3-4
Simplified Feature Telephone Design



Source: Dataquest (November 1995)

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Chapter 4
Cordless Telephones

Market and Production Trends

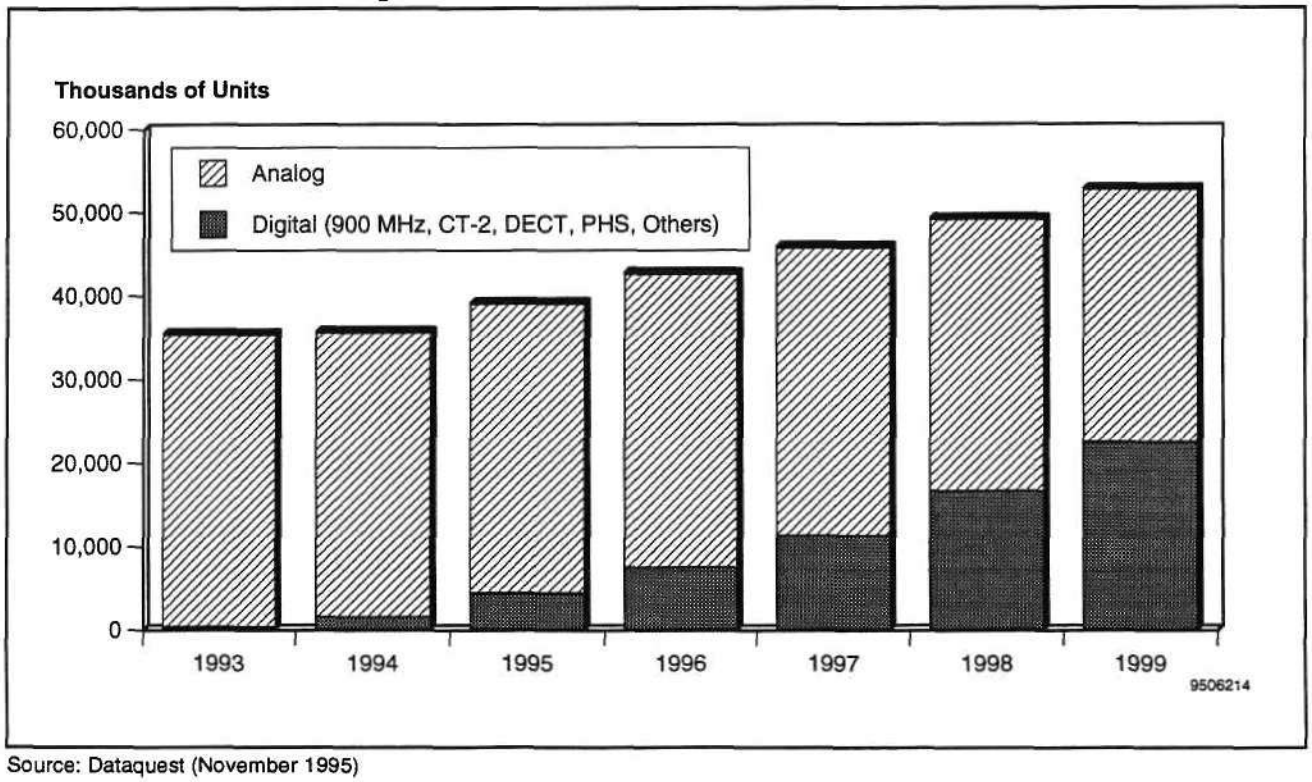
Worldwide production of cordless telephone handsets is forecast to grow at a strong 8.1 percent CAGR during the next five years, as shown in Figure 4-1 and Table 4-1. Digital handset production will grow at 69.5 percent CAGR during this time frame and account for more than 40 percent of all shipments by 1999. Table 4-2 shows that, although North American production will grow at a faster pace than the worldwide rate, it represents less than 4 percent of worldwide production.

The primary market driver of cordless telephones in North America has been the residential market. The residential cordless phone market continues to advance as the convenience and continuing price/performance improvements of cordless telephones keep attracting new users. With a 52 percent household penetration rate in the United States, there is nothing to prevent cordless phones from being in every home. Figure 4-2 and Table 4-3 present a market forecast for all of North America. Substantial growth opportunities exist in penetration of Mexican homes.

Brand Share Leaders

Tables 4-4 and 4-5 list the unit and revenue brand share leaders in cordless telephones in the U.S. market for 1994 and for the third quarter of 1994 through the second quarter of 1995, respectively.

Figure 4-1
Worldwide Cordless Telephone Handset Production



Source: Dataquest (November 1995)

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Table 4-1
Worldwide Cordless Telephone Handset Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	35,405	35,685	39,134	42,668	45,764	49,173	52,744	8.1
Digital (900 MHz, CT-2, DECT, PHS, Others)	414	1,614	4,532	7,638	11,360	16,718	22,599	69.5
Analog	34,991	34,071	34,602	35,030	34,403	32,456	30,146	-2.4
Factory ASP ($)	82	77	74	73	72	72	71	-1.6
Factory Revenue ($M)	2,907	2,747	2,914	3,120	3,297	3,523	3,741	6.4
Semiconductor Content ($)	14	14	15	15	16	16	17	3.1
Semiconductor Market ($M)	498	508	581	649	725	807	873	11.4

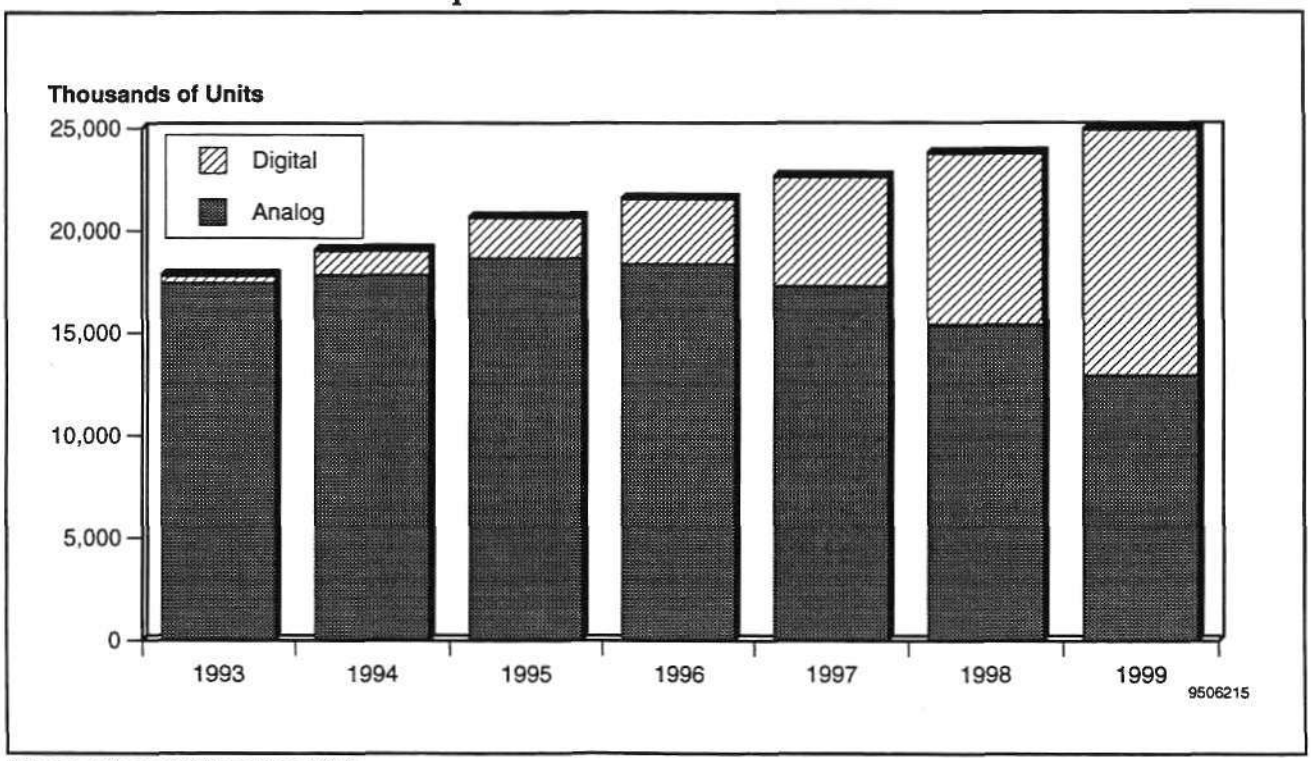
Source: Dataquest (November 1995)

Table 4-2
North American Cordless Telephone Handset Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	1,080	1,134	1,215	1,516	1,596	1,652	1,735	8.9
Factory ASP ($)	74	72	68	64	60	56	52	-6.4
Factory Revenue ($M)	80	82	83	97	96	93	90	1.9
Semiconductor Content ($)	13	13	14	14	14	13	13	0.0
Semiconductor Market ($M)	14	15	17	21	22	21	23	8.9

Source: Dataquest (November 1995)

Figure 4-2
North American Cordless Telephone Handset Production



Source: Dataquest (November 1995)

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Table 4-3
North American Cordless Telephone Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Market Revenue ($M)	1,282	1,294	1,279	1,184	1,130	1,092	1,047	-3.2
Factory ASP Overall ($)	74	73	68	61	58	55	51	-5.8
Factory ASP Analog ($)	72	68	62	55	50	46	42	-8.6
Factory ASP Digital ($)	183	155	124	99	84	72	61	-17.0
Units (K)	17,801	19,030	20,625	21,533	22,609	23,740	24,927	5.9
Analog	17,463	17,850	18,666	18,389	17,296	15,431	12,962	-2.4
Digital	338	1,180	1,959	3,144	5,313	8,309	11,965	89.7

Source: Dataquest (November 1995)

Table 4-4
U.S. Cordless Telephone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	27.3	31.1
General Electric	13.1	10.4
Sony	12.3	13.7
Panasonic	10.2	11.8
BellSouth	9.7	7.9
Uniden	8.8	6.8
Southwestern Bell	4.0	3.3
Cobra	3.3	3.5
Radio Shack	3.2	3.3
Toshiba	2.0	2.1
Others	6.1	6.1
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 4-5
U.S. Cordless Telephone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	27.2	31.3
General Electric	14.0	11.2
Sony	12.0	12.5
Uniden	9.8	7.6
Panasonic	9.8	12.1
BellSouth	9.1	7.3
Southwestern Bell	4.4	3.7
Radio Shack	3.2	3.5
Cobra	3.0	3.4
Toshiba	1.9	1.9
Others	5.6	5.5
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

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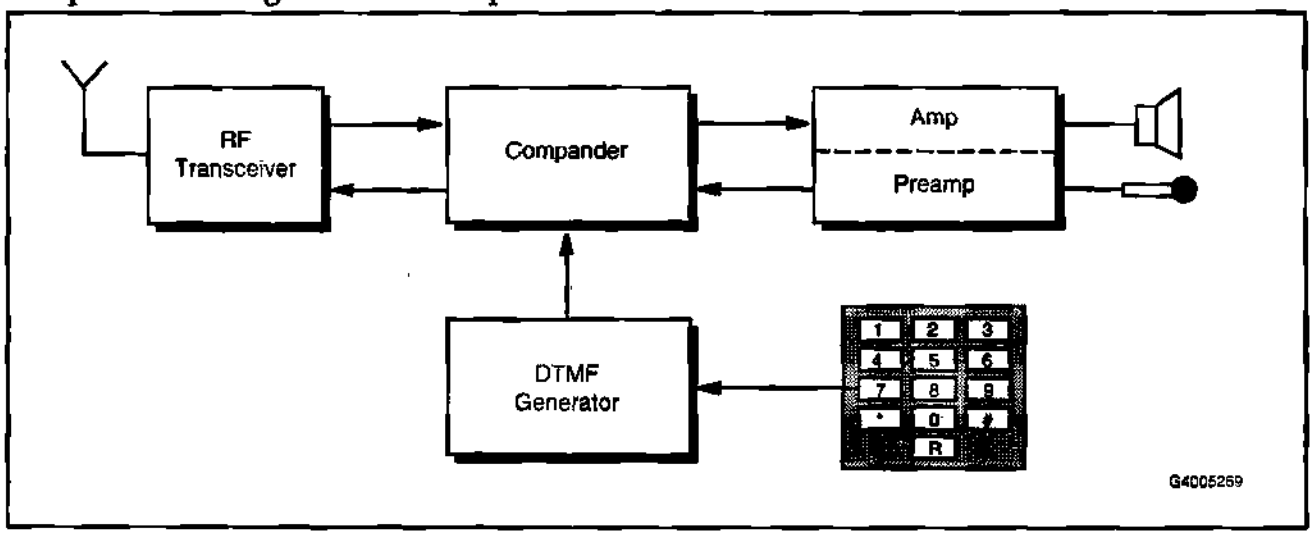
Feature and Technology Trends

There is a great deal of overlap in technologies and markets among cellular, cordless, and personal communications services. The 900-MHz digital cordless technology (DCT) is meant to be used within 100m of a base station. The personal handyphone system (PHS), CT2, CT2+, and DECT handsets can be used as basic cordless phones in the home/office or as a low-mobility PCS system outside the home. The PHS and DECT technologies have a chance of being employed as PCS or PCN communicators in the United States.

Despite the problems of analog cordless telephones such as poor speech quality, channel interference, and lack of privacy, there are some new technical and device performance improvements that will prolong the analog cordless life cycle. New 25-channel cordless phones have found strong market acceptance in the United States and could push out growth of digital handsets.

Figure 4-3 is a simplified diagram of a typical analog cordless telephone; a significant portion of the semiconductor cost is in the radio section. Opportunities still exist for greater levels of integration and improved performance and noise reduction. One advantage that digital cordless telephones will have over analog cordless telephones is that they will be smaller in size. To help sustain the market for analog cordless, many OEMs are demanding that semiconductor vendors supply 3V operation devices. This reduces battery requirements, which are the most significant contributors to weight and volume of bulky analog cordless telephones.

Figure 4-3
Simplified Analog Cordless Telephone



Source: Dataquest (November 1995)

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Digital Cordless

DCT will eventually supersede analog cordless. (Digital cordless has a number of regional and proprietary supporting standards.) The essential objectives in the development of digital telephones is to improve the following areas of performance over analog cordless:

- Superior speech quality
- Better range and propagation capabilities
- Secure speech/secure base station access
- Much greater user densities

To achieve these objectives, digital standards employ some of the following techniques:

- Speech compression—all current DCT use 32-Kbps, adaptive differential pulse-code modulation (ADPCM)
- Access methods such as time-division multiple access (TDMA) and time-division duplex (TDD)
- Higher frequencies (some at 1.8 to 1.9 GHz) for better propagation
- New frequency allocation, with more bandwidth

These capabilities have opened up additional opportunities for cordless from the present domination by residential users to business users (wireless PBX/key systems) and telepoint.

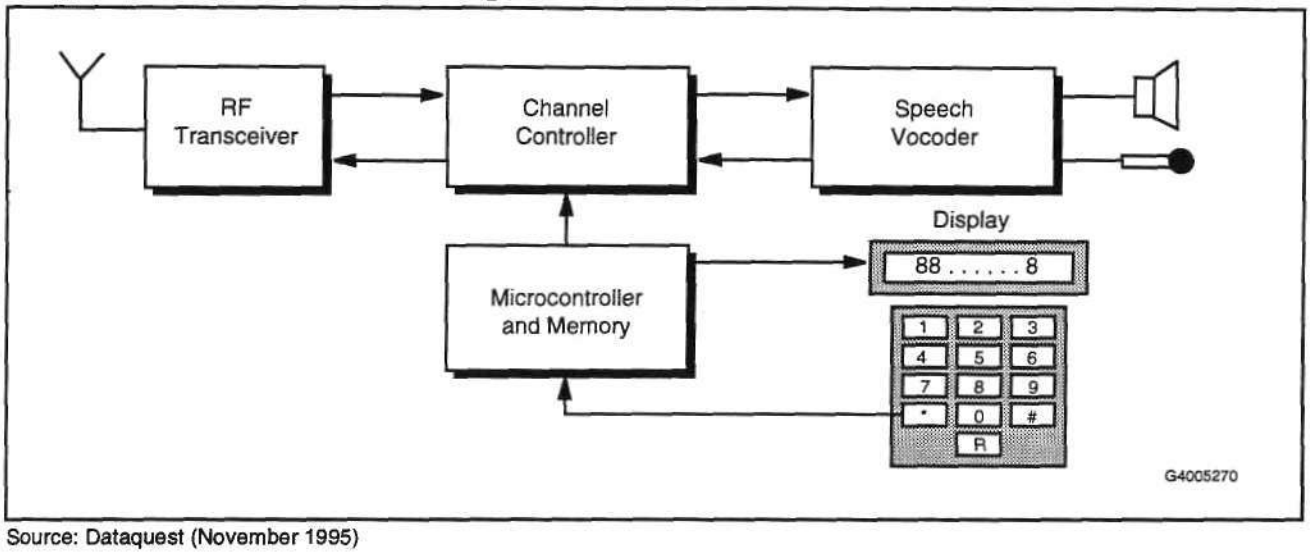
The current lineup of digital cordless systems/standards includes 900-MHz DCT (AT&T for the U.S. residential market), CT2 (and variants), DECT, and PHS for Japan. The last two have been designed from scratch to support very high user densities. The standards have also addressed the additional opportunities of public access (telepoint) and business users where this will be a major advantage. These standards also support roaming (at pedestrian speeds), which of course is mandatory in an office environment, as users move throughout a building from one base station area to another. This roaming capability has driven a strong market for PHS as a low-mobility system in Japan. The PHS system provides the foundation for the low-mobility PACS standard in the United States. DECT technology drives the proposed wireless communications premise equipment (WCPE) standard.

Figure 4-4 is a simplified diagram of a digital cordless telephone, showing the key elements:

- Speech vocoder
- Channel controller
- Microcontroller/memory
- RF transceiver

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Figure 4-4
Simplified Digital Cordless Telephone



Source: Dataquest (November 1995)

State-of-the-art semiconductor solutions have now integrated all baseband (non-RF) functions into a single chip with the exception of memory. These single-chip DCT devices include the following:

- Voice PCM CODEC/compression, decompression
- Channel processor—TDMA controller and signaling protocol processor
- 8-bit microcontroller with keyboard, display interface, and DTMF dialer

Some of these highly integrated devices are already available with 3V operation, with volume prices in the range of $10 to $15.

The RF section represents the most significant opportunity for integration and cost reduction. A single radio subsystem interface (RSSI) specification has been agreed upon that will define the interface between the RF section and the baseband section. This will do the following:

- Enable different chipset vendors to provide functional compatibility with others
- Give OEMs more choice and involve less design effort for integration of RF and baseband sections
- Present an opportunity for semiconductor vendors to work toward complementary or second-source chipsets

Digital cordless and digital cellular exhibit certain similarities. Table 4-6 shows that there are some key differences that will always keep a significant price differential between the opposing types of telephone.

The European digital cordless market has two competing solutions: CT-2 and DECT standards. Table 4-7 outlines the comparisons between these two systems. The potentially lower-cost RF solutions and the high level of support from semiconductor vendors will make DECT the ultimate winner in the DCT battle. The overall component costs (this includes all semiconductors and other components such as filters) for DECT were lower than CT-2 in 1995. Figure 4-5 shows a second-generation DECT product

Table 4-6
Differences between Digital Cordless and Digital Cellular Telephones

Feature	Cordless	Cellular
Speech Compression	ADPCM 32 Kbps G.722 CODEC	VSELP/RPE-LTP 7.25/13 Kbps DSP
Equalizer	No	Yes
Encryption	Not usual	Usual
Power Output	Usually fixed <250mW	Usually variable >250mW
Cell/Base Station Handover	Not usual (where possible under handset control)	Mandatory (under base station control)

ADPCM = Adaptive differential pulse-code modulation
VSELP = Vector sum excited linear predictive coding
RPE-LTP = Regular pulse excitation, long-term prediction
Source: Dataquest (November 1995)

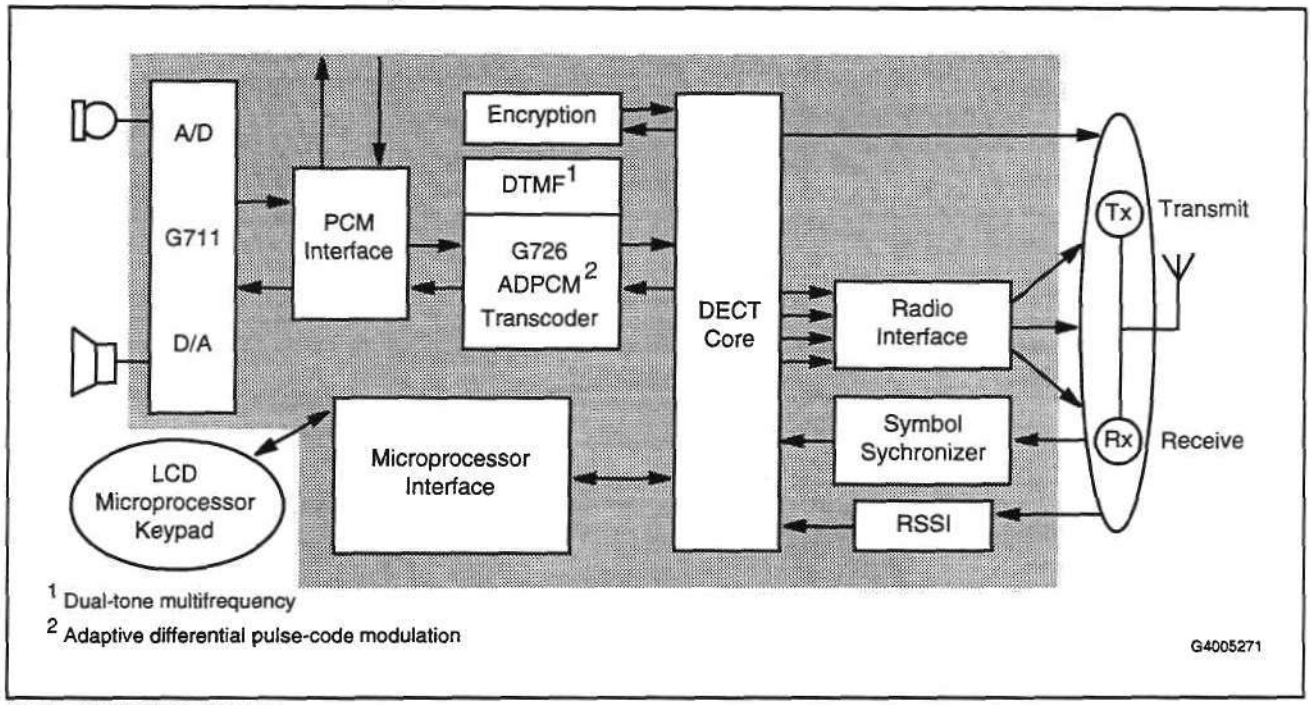
Table 4-7
DECT and CT2 Specification Comparison

	CT2	DECT
Radio Frequency Band (MHz)	864-868	1880-1900
Bandwidth (MHz)	4	20
Channelization	FDMA	TDMA/FDMA
Channel Spacing	100 KHz	1.728 MHz
Number of Frequency Channels	40	10
Voice Channels per Frequency Channel	1	12
Duplex Method	TDD	TDD
Total Duplex Channels	10	120
Speech Coder	ADPCM	ADPCM
Bit Rate (Kbps)	32	32
Channel Bit Rate (Kbps)	72	1,152
Modulation Technique	GFSK	GMSK
Voice and Data	No	Yes
Frame Time (ms)	2	10
Peak Transmit Power (mW)	10	250
Average Transmit Power (mW)	5	10

Source: Dataquest (November 1995)

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Figure 4-5
DECT Handset Block Diagram



Source: VLSI Technology Inc.

that will incorporate highly integrated solutions for both the RF and voice/channel CODEC/controller. The latest semiconductor solutions suggest that these second-generation telephones will have about seven devices for a complete solution, as shown in Table 4-8.

Semiconductor Opportunities

The worldwide semiconductor market for cordless telephones was $508 million in 1994. The majority of this market was for analog handsets. With the overlap between cellular and cordless telephone technologies, many of the semiconductor market opportunities are the same for both products. Chapter 5 provides a detailed listing of these opportunities.

Table 4-8
DECT Semiconductor Solution—Second-Generation

Function	No. of Devices	Semiconductor
Integrated Power Amplifier	1	GaAs linear*
RF Front End	4	RF linear
Voice CODEC/Channel Controller	1	MOS logic (ASIC)
Microcontroller (ROM/RAM/EEPROM)	1	MOS micro

*GaAs = Gallium arsenide
Source: Dataquest (November 1995)

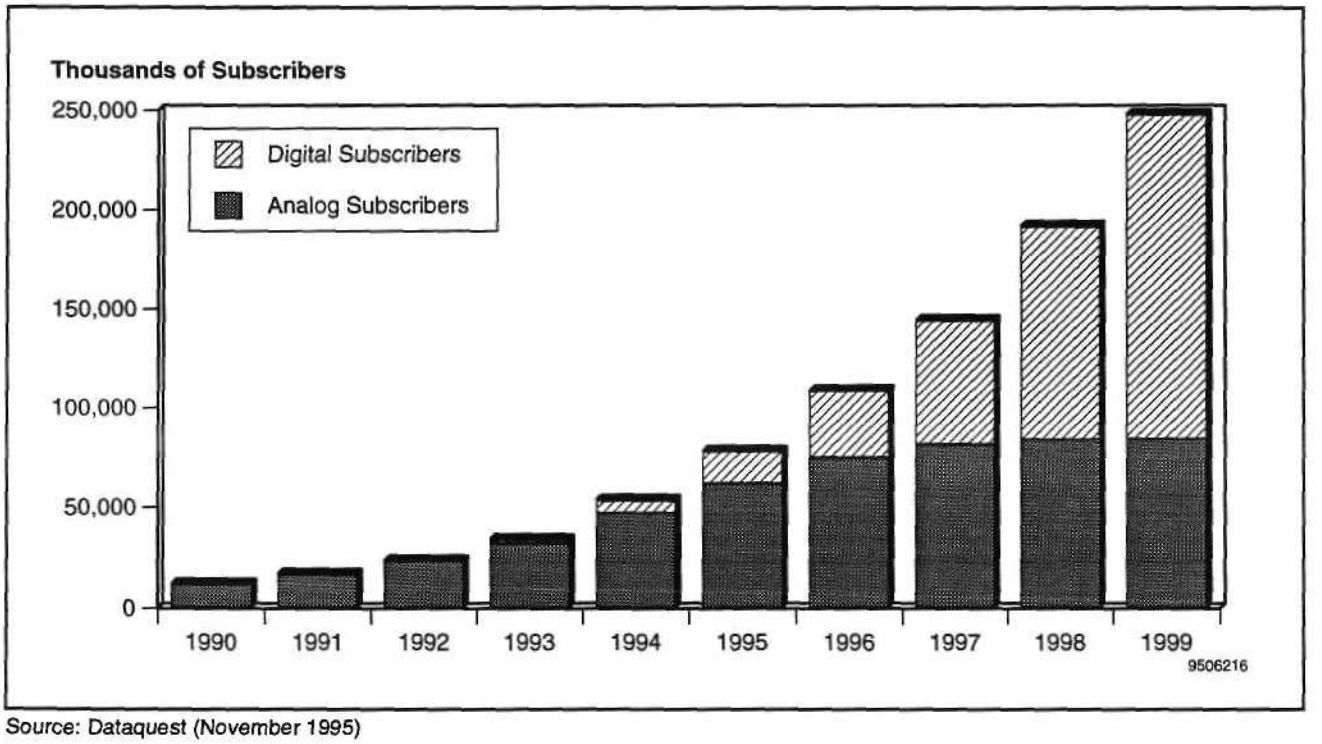
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Chapter 5
Cellular and Broadband PCS Telephones

Market and Production Trends

More than 53 million people were subscribing to cellular services worldwide by the end of 1994, with 49 percent in North America, 26 percent in Western Europe, and 20 percent in the Asia/Pacific and Japan region. North America's share of subscribers will decrease to 34 percent by 1999, while the Asia/Pacific and Japan subscribers will grow to 33 percent of the worldwide cellular population (see Figure 5-1). Table 5-1 provides a brief description of the cellular services in countries with the largest cellular subscriber populations. The highest levels of cellular telephone population penetration are found in the Scandinavian countries. The penetration of cellular telephones in the United States reached 9.1 percent of the population by the end of 1994. This translates into about a 20 percent U.S. household penetration.

Figure 5-1
Worldwide Cellular and Broadband PCS Subscribers



Source: Dataquest (November 1995)

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Table 5-1
Major International Cellular/PCS Markets

Country	Number of Subscribers* (Thousands)	Type of System	Cellular Carriers
United States	23,630	AMPS—CDMA/TDMA/ PCS (Multiple)	Two operators per market in 306 metropolitan statistical areas and 428 rural service areas
Japan	3,800	NTT/J—TACS/PDC	Nippon Telegraph & Telephone
			Nippon Idou Tsushin
			Daini Denden
United Kingdom	3,402	TACS/GSM/DCS-1800	Cellnet
			Vodafone Group
Germany	2,456	GSM/C-Netz/DCS-1800	Deutsche Bundespost Telekom
			Mannesmann Mobilfunk
			E-Plus Mobilfunk
Italy	2,148	ETACS/GSM	SIP
Canada	1,768	AMPS/DAMPS	A national Block A carrier (Rogers Cantel) and 10 Block B provincial carriers
China	1,570	AMPS/GSM/TACS/ ETDMA	MPT and various regional operators (PTAs)
Australia	1,444	AMPS	Telecom Australia
			Optus Communications
South Korea	960	AMPS/CDMA	Korea Telecommunications Authority
Sweden	843	NMT/GSM	Comvik AB
			Swedish Nordic Tel
			Telia Mobitel
Thailand	810	AMPS/NMT/GSM/ DCS-1800	Telephone Organization of Thailand
			Communications Authority of Thailand
			Advanced Information Services
			Total Access Communications
Finland	645	NMT/GSM	Oy Radiolinja
			Telecom Finland
			Alands Mobiltelefon
Taiwan	630	AMPS/GSM	Directorate General of Telecommunications
Malaysia	568	NMT/TACS/AMPS/ DAMPS/GSM/DCS-1800	Telekom Malaysia

(Continued)

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Table 5-1 (Continued)
Major International Cellular/PCS Markets

Country	Number of Subscribers* (Thousands)	Type of System	Cellular Carriers
Norway	554	NMT/GSM	Norwegian Telecom Mobile
			Celcom
Denmark	549	NMT/GSM	Telecom Denmark
France	536	NMT/GSM/DCS-1800	France Telecom
			Ligne SFR
Mexico	500	AMPS	Nine nonwireline companies and one wireline company
Hong Kong	439	GSM/AMPS/DAMPS	Pacific Link Communications
		TACS/ETACS	Hutchison Telecom
			Hong Kong Telecom CSL
Brazil	461	AMPS	Telebrasilia, Teleri, Regional

*Number of subscribers as of end of 1994.
Source: Dataquest (November 1995)

As worldwide cellular/PCS subscribers increase from 53.5 million in 1994 to 248 million in 1999, this will drive the handset market from 27.8 million units to 97 million in the same period (see Table 5-2). Worldwide production of cellular telephone handsets is forecast to grow at a strong 28.2 percent CAGR during the next five years. Figure 5-2 and Tables 5-3 and 5-4 show the worldwide forecast for cellular telephone handset production. Although analog handsets represented over 90 percent of the market in 1993, digital handset production will grow to surpass analog handset production by 1997.

Cellular telephones based on GSM technology represent the large majority of digital cellular phones with the adoption of a common standard in Europe. Multiple digital standards are competing for market acceptance in the United States. Digital telephones are expected to experience rapid growth, with dual-mode analog/digital cellular/PCS telephones representing the majority of the North American cellular/PCS handset market by 1998. Table 5-5 and Figure 5-3 show the forecast for the North American cellular/PCS telephone market. Figure 5-4 shows the growing number of U.S. cellular/PCS telephone subscribers, expected to exceed 76 million people by 1999, that are driving the handset market forecast. An increasing number of these subscribers are using their cellular/PCS telephones for personal calls and safety. Surveys have found that almost 60 percent of all cellular use in the United States is for personal calls.

The digital GSM handset market exploded in Europe during the 1990s as the European countries agreed on the unified GSM standard. This market had experienced very low cellular penetration rates before then. With the introduction of the GSM standard, which allowed easier roaming between countries, the market took off and quickly grew to become the largest digital cellular market in the world. Many countries in other regions have also adopted the GSM standard. However, the U.S. market has been much slower than expected in accepting the digital technology. Dataquest predicts that digital (dual-mode) handset shipments will account for a

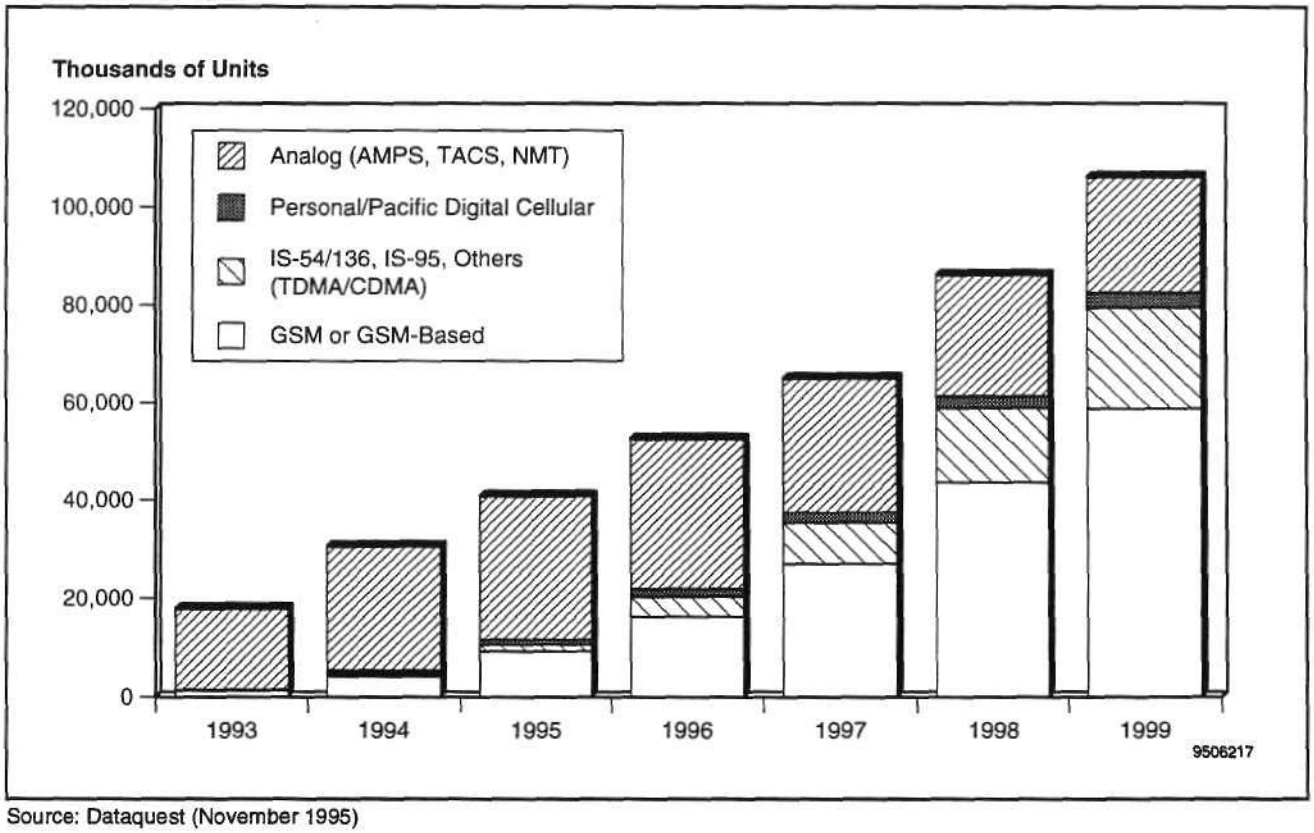
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Table 5-2
Worldwide Cellular and Broadband PCS Telephone Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Subscribers (K)	34,096	53,548	78,113	108,540	144,025	191,564	248,006	35.9
Units (K)	16,225	27,758	37,315	48,133	59,624	78,936	97,116	28.5
Analog Units (K)	14,796	22,779	26,748	28,188	25,622	23,241	22,225	-0.5
Digital Units (K)	1,429	4,979	10,567	19,945	34,002	55,696	74,891	72.0
Factory ASP ($)	472	426	375	340	306	269	249	-10.2
Factory Revenue ($M)	7,663	11,830	13,992	16,366	18,243	21,200	24,172	15.4

Source: Dataquest (November 1995)

Figure 5-2
Worldwide Cellular and Broadband PCS Telephone Handset Production Estimate by Type



Source: Dataquest (November 1995)

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Table 5-3
Worldwide Cellular and Broadband PCS Telephone Handset Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Analog Production								
Units (K)	16,275	25,057	29,155	30,443	27,416	24,635	23,559	-1.2
Factory ASP ($)	458	414	357	322	280	265	280	-7.5
Factory Revenue ($M)	7,454	10,374	10,408	9,803	7,676	6,528	6,596	-8.7
Semiconductor Content ($)	43	42	42	43	43	43	45	1.4
Semiconductor Market ($M)	700	1,052	1,225	1,309	1,179	1,059	1,060	0.1
Digital Production								
Units (K)	1,572	5,477	11,624	21,939	37,403	61,265	82,380	72.0
Factory ASP ($)	620	482	420	365	325	270	240	-13.0
Factory Revenue ($M)	975	2,640	4,882	8,008	12,156	16,542	19,771	49.6
Semiconductor Content ($)	215	150	120	104	92	78	70	-14.1
Semiconductor Market ($M)	338	822	1,395	2,282	3,441	4,779	5,767	47.7
Total Production								
Units (K)	17,848	30,534	40,779	52,382	64,818	85,900	105,939	28.2
Factory ASP ($)	472	426	375	340	306	269	249	-10.2
Factory Revenue ($M)	8,429	13,014	15,291	17,810	19,832	23,070	26,368	15.2
Semiconductor Content ($)	58	61	64	69	71	68	64	1.0
Semiconductor Market ($M)	1,038	1,874	2,619	3,591	4,620	5,838	6,827	29.5

Source: Dataquest (November 1995)

Table 5-4
Worldwide Cellular and Broadband PCS Telephone Handset Production Estimate by Type (Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Digital/Dual-Mode (All Types)								
GSM or GSM-Based	1,416	4,271	9,331	16,228	27,008	43,560	58,671	68.9
IS-54/136, IS-95, Others (TDMA/CDMA)	156	579	1,350	4,063	8,320	15,200	20,600	104.3
Personal/Pacific Digital Cellular	0	627	943	1,648	2,075	2,505	3,109	37.7
Analog (AMPS, TACS, NMT)	16,275	25,057	29,155	30,443	27,416	24,635	23,559	-1.2
Total	17,848	30,534	40,779	52,382	64,818	85,900	105,939	28.2

Source: Dataquest (November 1995)

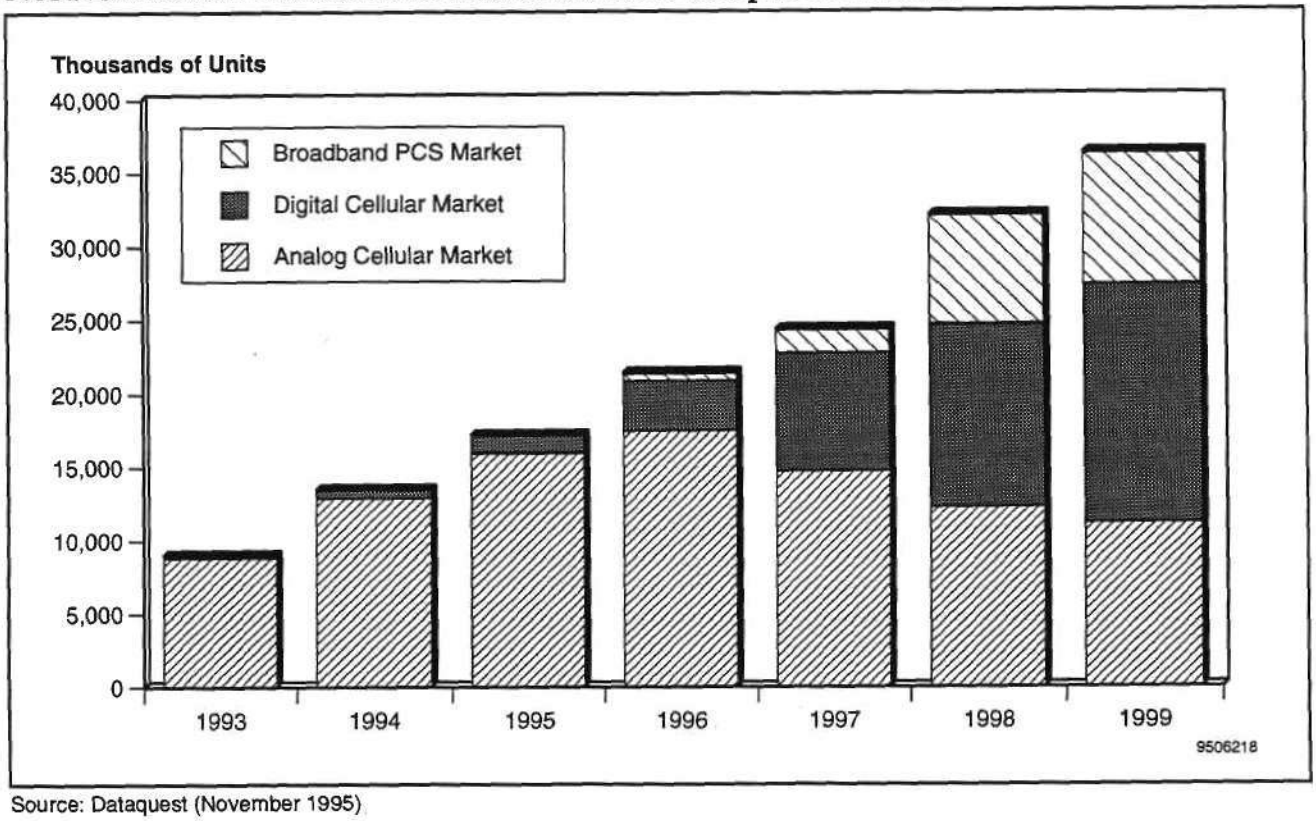
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Table 5-5
North American Cellular and Broadband PCS Telephone Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Cellular Market								
Units (K)	9,001	13,478	17,186	20,867	22,715	24,651	27,313	15.2
Analog Units (K)	8,859	12,951	16,007	17,509	14,758	12,287	11,189	-2.9
Digital Units (K)	142	527	1,179	3,358	7,957	12,364	16,124	98.2
Factory ASP ($)	454	423	359	326	294	267	255	-9.6
Factory Revenue ($M)	4,084	5,703	6,178	6,812	6,673	6,594	6,978	4.1
Broadband PCS Market								
Units (K)	-	-	-	500	1,570	7,380	8,910	NM
Factory ASP ($)	-	-	-	370	300	255	225	NM
Factory Revenue ($M)	-	-	-	185	471	1,882	2,005	NM
Total Market								
Units (K)	9,001	13,478	17,186	21,367	24,285	32,031	36,223	21.9
Factory ASP ($)	454	423	359	327	294	265	248	-10.1
Factory Revenue ($M)	4,084	5,703	6,178	6,997	7,144	8,476	8,983	9.5

Source: Dataquest (November 1995)

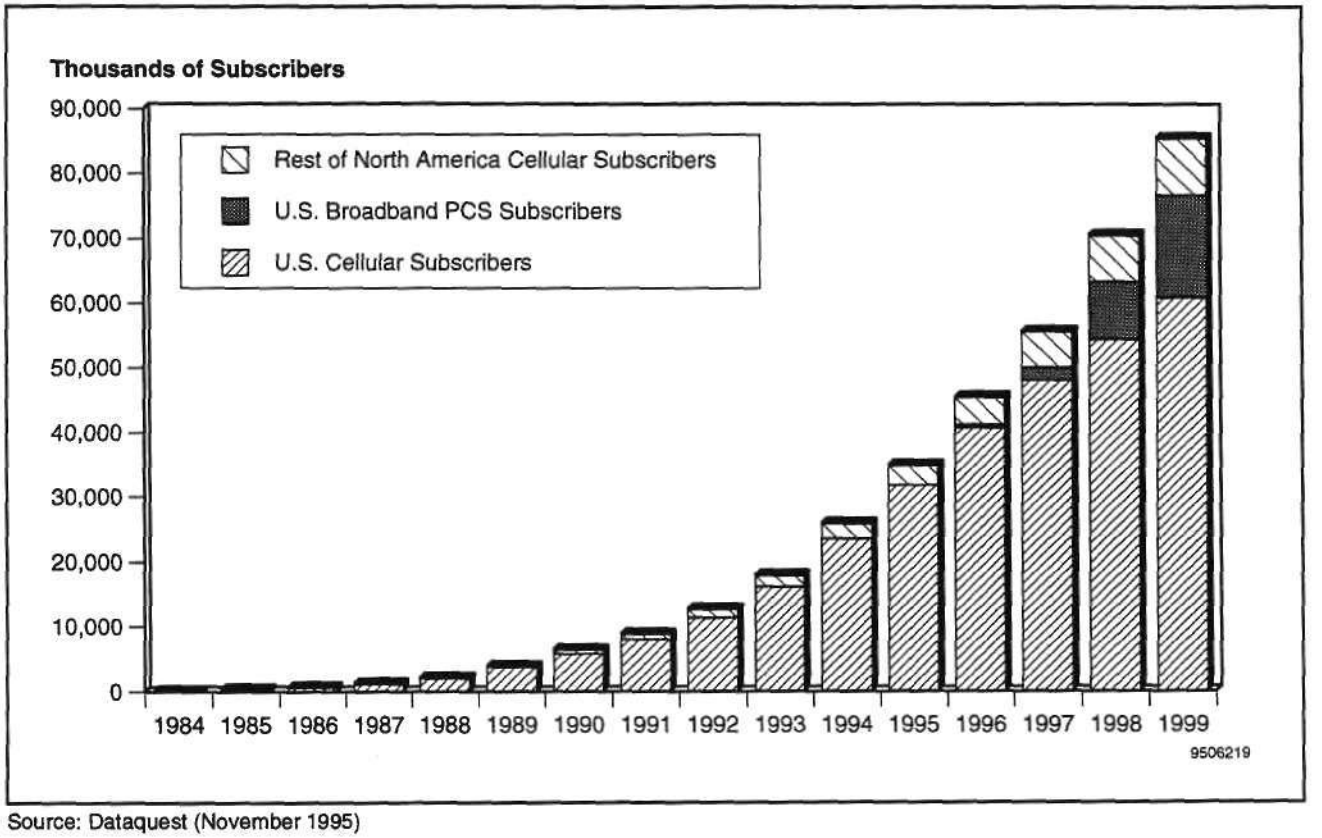
Figure 5-3
North American Cellular and Broadband PCS Telephone Market



Source: Dataquest (November 1995)

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Figure 5-4
North American and U.S. Cellular and Broadband PCS Subscribers



Source: Dataquest (November 1995)

little less than 7 percent of total North American handset shipments in 1995. This slower acceptance of digital handsets in the U.S. market in particular is because of a number of factors:

- The higher price of digital phones, compared with analog. Low-priced analog handsets have been very popular items as many consumers seek an economical entry into the market. Cellular providers have been pushing handset manufacturers for increased shipments of analog AMPS handsets as they seek to expand the consumer market. Also, the promotion of digital services and handsets by the service providers has not been as aggressive.
- The voice quality of early digital handsets, widely criticized by experienced cellular subscribers, who find it inferior to the voice quality offered by analog handsets. It is expected that newer speech technologies will improve the voice quality in the digital handsets.
- Limited consumer awareness of meaningful digital benefits. These include increased talk time and privacy enabled by encryption.
- The availability of digital service in relatively few markets.

The North American production of cellular/PCS handsets shown in Table 5-6 reflects this lower penetration of digital handsets into the market.

The rollout of digital cellular and PCS services will require additional investment in infrastructure equipment. An estimate of the worldwide cellular infrastructure market for the GSM standard and the semiconductor

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Table 5-6
North American Cellular and Broadband PCS Telephone Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Analog Production								
Total Shipments (k)	8,359	12,117	15,339	17,194	14,734	12,431	11,256	-1.5
Factory ASP ($)	448	420	355	320	285	270	285	-7.5
Handset Factory Revenue ($M)	3,745	5,089	5,445	5,502	4,199	3,356	3,208	-8.8
Semiconductor Content ($)	43	42	42	43	43	43	45	1.4
Semiconductor Market ($M)	359	509	644	739	634	535	507	-0.1
Digital Production								
Total Digital Shipments (K)	156	579	1,297	4,239	10,445	21,474	27,146	115.9
Digital Factory ASP ($)	810	500	420	361	308	261	232	-14.3
Handset Factory Revenue ($M)	126	290	545	1,531	3,221	5,612	6,285	85.0
Total Semiconductor Content ($)	215	135	115	99	86	73	66	-13.4
Baseband Content ($)	110	66	55	50	43	37	33	-12.8
RF/IF Content ($)	74	49	42	34	30	26	23	-14.0
Other Content ($)	32	21	18	15	13	11	10	-14.0
Semiconductor Market ($M)	33	78	149	420	895	1,573	1,782	86.9
Baseband Market ($M)	17	38	72	214	451	786	896	88.2
RF/IF Market ($M)	11	28	54	144	311	551	620	85.6
Other Markets ($M)	5	12	23	62	133	236	266	85.6
Total Production								
Shipments (K)	8,515	12,697	16,636	21,433	25,180	33,906	38,402	24.8
Factory ASP ($)	455	424	360	328	295	265	247	-10.2
Handset Factory Revenue ($M)	3,871	5,379	5,990	7,033	7,420	8,968	9,493	12.0
Semiconductor Content ($)	46	46	48	54	61	62	60	5.2
Semiconductor Market ($M)	393	587	793	1,159	1,528	2,108	2,289	31.3

Source: Dataquest (November 1995)

opportunity it drives is shown in Table 5-7. Table 5-8 provides an estimate of the market revenue generated by investments in the U.S. cellular infrastructure. This table does not include additional investment that will be made for the new PCS infrastructure.

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Table 5-7
Worldwide GSM Infrastructure Equipment Market Forecast (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Revenue	1,742	3,100	5,253	7,068	9,567	12,718	12,360	31.9
Semiconductor Market	87	160	280	389	541	742	741	35.9

Source: Dataquest (November 1995)

Table 5-8
U.S. Cellular Infrastructure Equipment Market Forecast*

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Base Stations								
Shipments (K)	3,884	6,623	7,661	9,148	11,404	13,215	15,581	18.7
Factory ASP ($K)	350	350	343	336	321	315	308	-2.5
Factory Revenue ($M)	1,359	2,318	2,628	3,075	3,661	4,157	4,803	15.7
Semiconductor Content ($K)	17.5	18.1	18.3	18.5	18.2	18.4	18.5	0.5
Semiconductor Market ($M)	68	120	140	169	207	243	288	19.2
Microcells								
Shipments (K)	254	277	2,910	2,591	3,877	5,368	4,240	72.6
Factory ASP ($K)	100	100	130	150	150	150	150	8.4
Factory Revenue ($M)	25	28	378	389	582	805	636	87.2
Semiconductor Content ($K)	6	6.2	8.2	9.8	10	10.2	10.5	11.3
Semiconductor Market ($M)	2	2	24	25	39	55	45	92.0

*Does not include equipment for PCS (2 GHz) base stations
Source: Dataquest (November 1995)

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Market and Brand Share Leaders

Table 5-9 presents the worldwide market share for cellular/PCS handsets. Table 5-10 lists the unit and revenue brand share leaders for cellular telephones in the U.S. market for the period of the third quarter of 1994 through the second quarter of 1995.

Table 5-9
Worldwide Cellular Telephone Market Share, 1994

Manufacturer	Shipments (K)	Unit Market Share (%)
Motorola	8,906.1	32.5
Nokia	5,740.8	21.0
Ericsson	2,980.8	10.9
NEC	2,433.9	8.9
Panasonic	1,476.0	5.4
Mitsubishi	1,201.2	4.4
Oki	889.5	3.2
Others	3,768.4	13.8
Total	27,396.6	100.0

Source: Dataquest (November 1995)

Table 5-10
U.S. Cellular Telephone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)

Brand	Unit Market Share	Revenue Market Share
Motorola	53.4	57.0
AT&T	7.4	7.3
Nokia-Mobira	5.6	4.5
Cellular One	4.4	4.3
NEC	3.8	3.5
Radio Shack	3.3	3.0
Audiovox	2.6	2.7
Uniden	1.8	1.4
GE/Ericsson	1.7	1.9
Panasonic	1.6	1.4
Others*	14.4	13.0
Total	100.0	100.0

*Others include Blaupunkt, Hughes, JVC, Mitsubishi, Muratec, Novatel, Omni, Pioneer, Qualcomm, Technophone, and Toshiba
Source: The Scout Report®/The Polk Company

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Feature and Technology Trends

Since the commercial launch of cellular systems in the early 1980s there have been a number of different regional analog cellular systems, and these are reviewed in Table 5-11. Some of the technical differences between the digital cellular and cordless standards are highlighted in Table 5-12.

Table 5-11
Analog Cellular Network Standards

	AMPS	TACS	NMT-450	NMT-900
Frequency Band (MHz)				
Tx	824-849	871-904	453-456	890-915
Rx	869-894	916-949	463-468	935-960
Carrier Spacing (kHz)	30	25	25	12.5
Access Method	FDMA	FDMA	FDMA	FDMA
Modulation Scheme	PSK	PSK	FFSK	FFSK
Implementation	Australia Canada Hong Kong Japan United States	Greece Italy Spain United Kingdom	Austria Belgium Scandinavia	Netherlands Scandinavia Switzerland

AMPS = Advanced mobile phone system
FDMA = Frequency-division multiple access
FFSK = Fast frequency shift keying
PSK = Phase shift keying
TACS = Total access communications system
Source: Dataquest (November 1995)

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Table 5-12
Digital Cellular and Digital Cordless Standards, Technical Differences

	GSM[1]	DCS-1800[2] / PCS-1900	IS-54/IS-136	PDC[3]	IS-95	CT2[4]	DECT[5]	PHS[6]
Region	Europe Other regions	Europe United States	United States	Japan	United States Asia	United Kingdom (Telepoint) Canada France (Telepoint) Hong Kong Singapore	Europe	Japan Hong Kong
Frequency	935-960 MHz 890-915 MHz	1.7-1.9 GHz 1.8-2.0 GHz	824-849 MHz 869-894 MHz 1.8-2.0 GHz	810-826 MHz 940-956 MHz 1429-1441 MHz 1447-1489 MHz 1501-1513 MHz	824-849 MHz 869-894 MHz 1.8-2.0 GHz	864-868 MHz	1.88-1.9 GHz	1.9 GHz
Access Method	TDMA[7]	TDMA	TDMA	TDMA	CDMA	TDMA	TDD/TDMA	TDD/TDMA
Modulation	GMSK[8]	GMSK	π/4 DQPSK[9]	π/4 DQPSK	QPSK[10] DQPSK	Two-level GFSK	GMSK	π/4 DQPSK
Speech CODEC	RPE-LTP[11] 8/13 Kbps	RPE-LTP 8/13 Kbps	VSELP[12] 7.25/13 Kbps	VSELP/PSI-CELP 11.2/5.6 Kbps	ADPCM[13] 8.55/13 Kbps	ADPCM 32 Kbps	ADPCM 32 Kbps	ADPCM 32 Kbps
Output Power	20mW to 20W	2.5mW to 1W	2.2mW to 6W	Up to 2W	0.2W to 6.3W	1mW to 10mW	250mW	10mW (Indoor) 500mW (Outdoor)
Channel Spacing	200 kHz	200 kHz	30 kHz	25 kHz	1.23 MHz	100 kHz	1.728 MHz	300 kHz
Number of Frequencies	124	374	832	1,600	10	40	10	40
Time Slots	8	8	3	3	NA	2 (TDMA) 40 (FDMA)[14]	24 (2 x12)	8 (2 x4)

NA = Not applicable
[1]Global system mobile
[2](PCN) digital cellular
[3]Personal/Pacific digital cellular
[4]Digital cordless telephone
[5]Digital European cordless
[6]Japanese digital cordless Personal Handyphone System
[7]Time-division multiple access
[8]Gaussian mean shift keying
[9]Differential quadrature phase shift keying
[10]Quadrature phase shift keying
[11]Regular pulse excitation, long-term prediction
[12]Vector sum excited linear predictive coding
[13]Adaptive differential pulse-code modulation
[14]Frequency-division multiple access
Source: Dataquest (November 1995)

SAMM-WW-MT-9505

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November 27, 1995

Countries that use AMPS cellular systems, according to *Cellular Business*, are as follows:

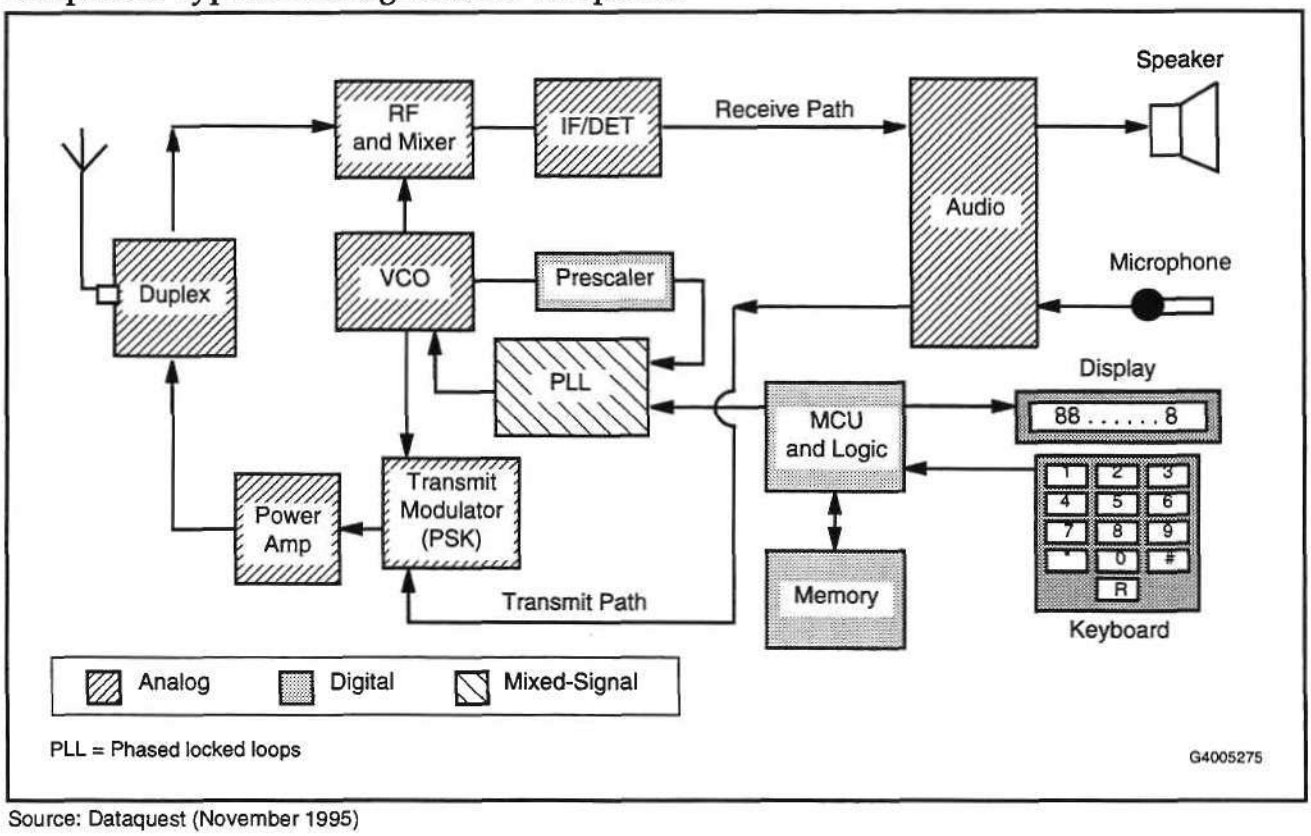
- Anguilla
- Antigua
- Argentina
- Aruba
- Australia
- Bahamas
- Bangladesh
- Barbados
- Barbuda
- Belize
- Bermuda
- Bolivia
- Brazil
- Brunei
- Cambodia
- Canada
- Cayman Islands
- Chile
- China
- Colombia
- Costa Rica
- Cote d'Ivoire
- Cuba
- Curacao
- Dominican Republic
- Ecuador
- El Salvador
- Fiji
- Gabon
- Ghana
- Grenada
- Guadeloupe
- Guam
- Guatemala
- Guyana
- Hong Kong
- Indonesia
- Israel
- Jamaica
- Kazakhstan
- Korea
- Laos
- Lebanon
- Malaysia
- Mexico
- Montserrat
- Myanmar
- Netherlands Antilles
- New Zealand
- Nicaragua
- Pakistan
- Paraguay
- Peru
- Philippines
- Russia
- Samoa (American)
- Singapore
- St. Kitts/Nevis
- St. Lucia/St. Vincent/Grenadines
- St. Martin/Bartholemy
- Suriname
- Taiwan
- Thailand
- Trinidad & Tobago
- Turks/Caicos
- United States
- Uruguay
- Venezuela
- Vietnam
- Virgin Islands
- Zaire

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Figures 5-5 and 5-6 show an AMPS (analog) cellular and a dual-mode (digital) phone (based on TDMA or CDMA access). A digital or dual-mode phone can be separated into two major sections, the baseband and the RF or access arrangement. New designs of these phones will reduce the chip count to 4 or 5 chips, from earlier designs that use 8 to 12 ICs and dozens of discrete components and passive filters. In digital cellular and PCS, the baseband and transmission/reception section of the phone deal primarily with digitized bit streams. There are six major functions in the baseband section and each one could be an individual DSP-based IC, as follows:

- Audio interface/CODEC—manages amplification, signal conditioning, A/D, and D/A to the handset speaker and microphone. This functionality can also include the full duplex speakerphone circuit and voice recognition circuits.
- Vocoder—encodes and compresses the digitized voice according to specification, such as vector sum excited linear predictive coding (VSELP) for the IS-54.
- Baseband CODEC—takes the compressed voice bit stream (or data stream) and prepares it for the transmission by putting it into the right time slot for TDMA or several channels according to CDMA. Dual-mode and AMPS phones also use FDMA channelization.
- Modem—optional for accepting computer bit streams and converts them for transmission over voice channel. It can include "packetizing" for the new data standards like cellular digital packet data (CDPD at 108 bytes per packet) or Mobitex.

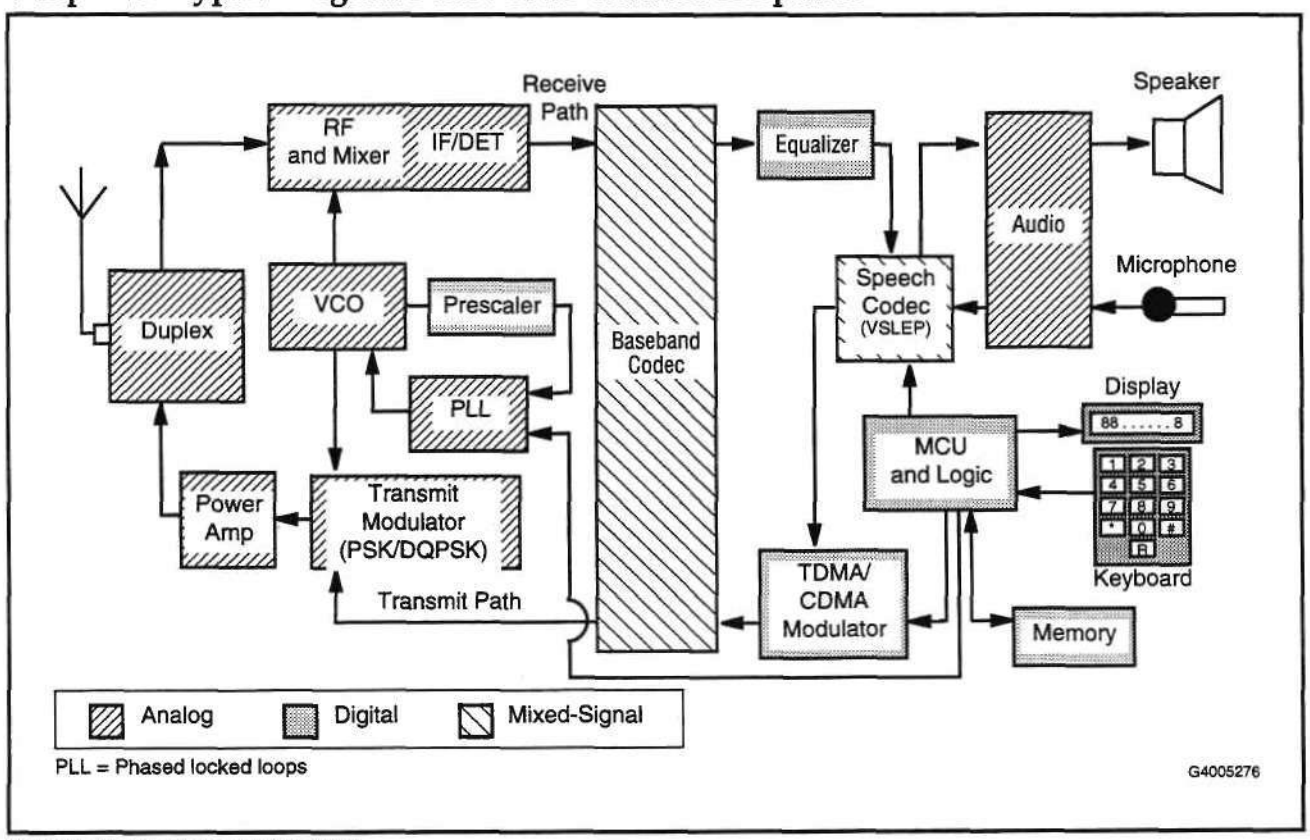
Figure 5-5
Simplified Typical Analog Cellular Telephone



Source: Dataquest (November 1995)

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Figure 5-6
Simplified Typical Digital/Dual-Mode Cellular Telephone



Source: Dataquest (November 1995)

- Microcontroller—8-bit or 16-bit for handling dialer, ringer, and LCD control and interface.
- Memory—either a 64K EEPROM/flash for user presets; SRAM (32K×8) for the same purpose or for a scratch pad.

The RF or access arrangement section has two major functions, transmission and reception, and involves at least six ICs and numerous discrete transistors and diodes (including gallium arsenide [GaAs] versions), passive filters, and oscillators. There are three major functions in the RF section:

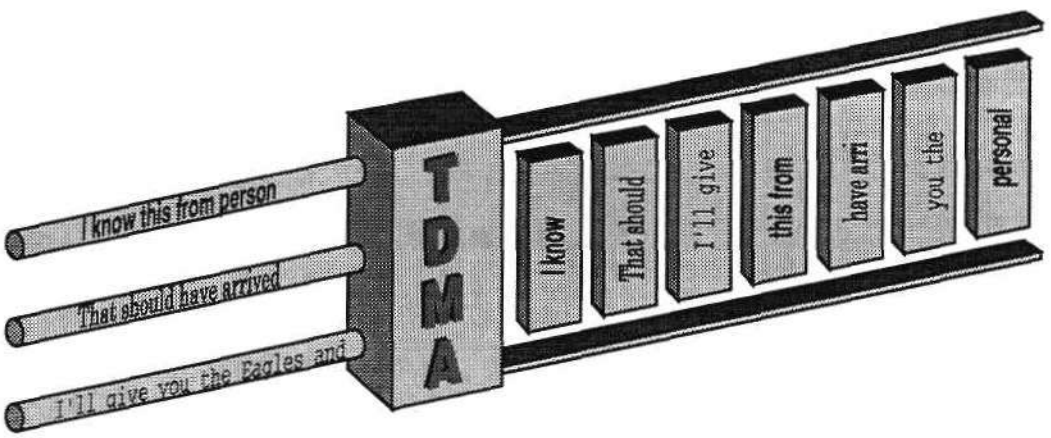
- Differential quadrature phase shift keying (DQPSK) transmitter and receiver, which handle many of the transceiver modulation functions. Dual-mode and AMPS phones use phase shift keying for modulation as well.
- Phase locked loops (at least two), prescalers, and a voltage-controlled oscillator (VCO) for generating necessary frequency signals.
- Power amplifier for transmission and a low-noise amplifier for reception.

The principal contenders for digital encoding are TDMA, extended-TDMA (E-TDMA), and CDMA. Figure 5-7 provides an illustration of how these technologies work. In converting to digital encoding it is necessary that both the base station equipment at the service provider and the subscriber handsets have the same standard. It has been decided that a new

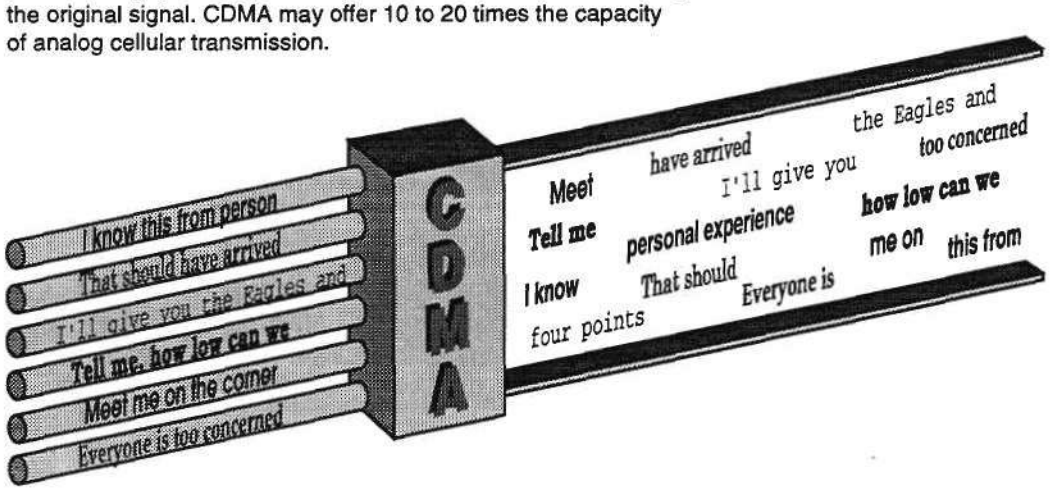
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Figure 5-7
TDMA and CDMA Digital Transmission Technologies

Two emerging forms of digital transmission can save spectrum space in both cellular phones and the PCS of the future. Time division multiple access (TDMA) chops calls into pieces of data that are identified on the receiving end by the time slots to which they are assigned. TDMA enables one wireless channel to handle several calls.



The second technology, code division multiple access (CDMA), spreads its pieces of calls across a wide swath of communications frequencies. The fragments carry a code identifying their phone of origin, and the receiving station uses the code to identify and reconstitute the original signal. CDMA may offer 10 to 20 times the capacity of analog cellular transmission.



Source: Eric Zimits, Volpe, Welty & Co. 9500515

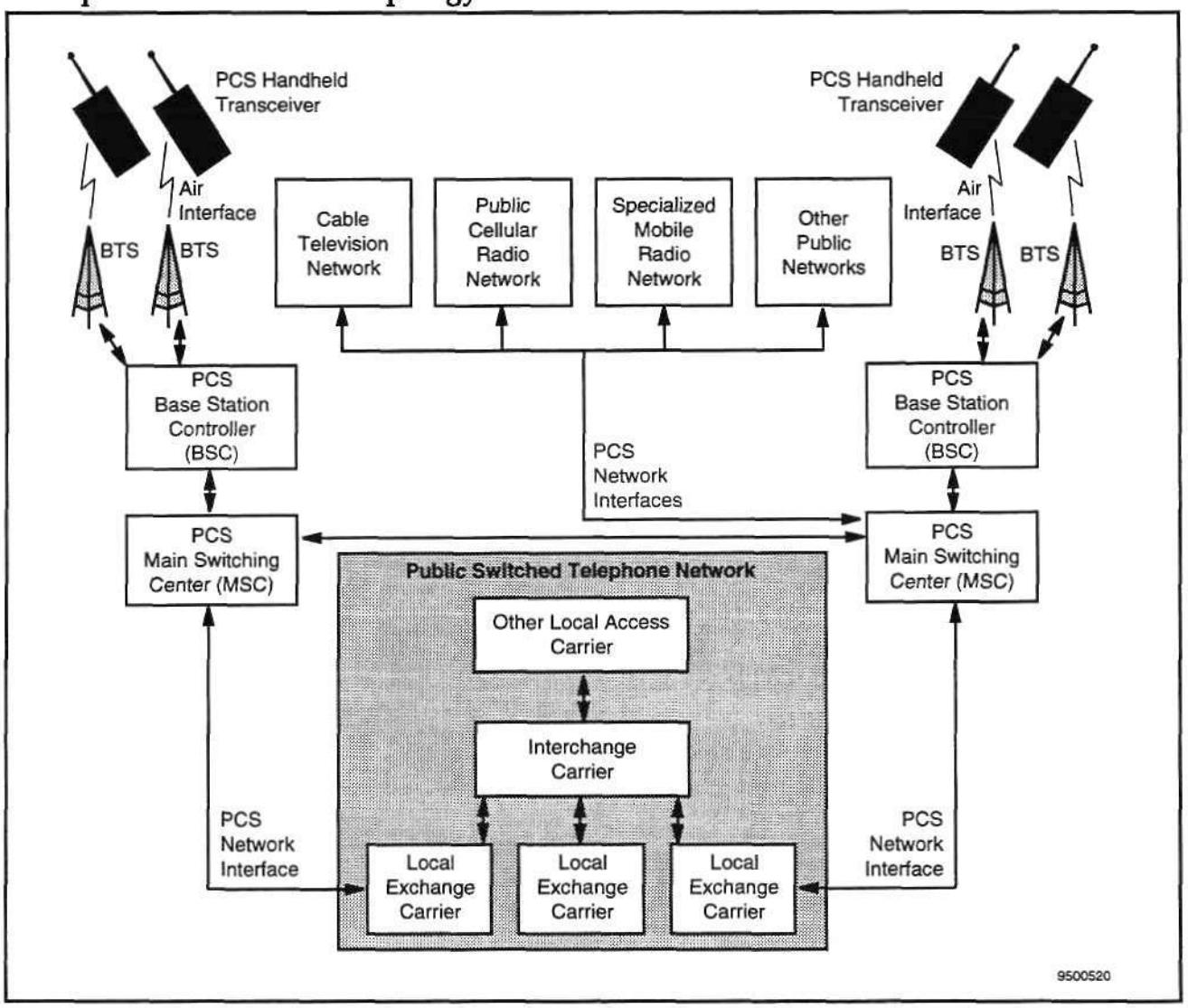
Source: Eric Zimits, Volpe, Welty & Co.

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digital system will be backwardly compatible with AMPS. This is forcing the carriers to use dual-mode technology capable of AMPS and either TDMA or CDMA, the leading digital contenders. Figure 5-8 shows an example of a PCS network topology.

The CTIA has endorsed the use of dual-mode technology based on TDMA. This combination is also known as standard IS-54. A new enhanced standard based on IS-54 was introduced this year. This standard, called IS-136, provides improved voice quality and power savings. TDMA, as the name implies, provides time slots for various users and can achieve a threefold improvement in time capacity over AMPS. The major equipment backers of TDMA include AT&T, Ericsson-GE (joint venture), and Motorola-Nortel (joint venture for base stations). Some of the basic patents for TDMA are controlled by InterDigital Communications (King of Prussia, Pennsylvania).

Figure 5-8
Example of PCS Network Topology



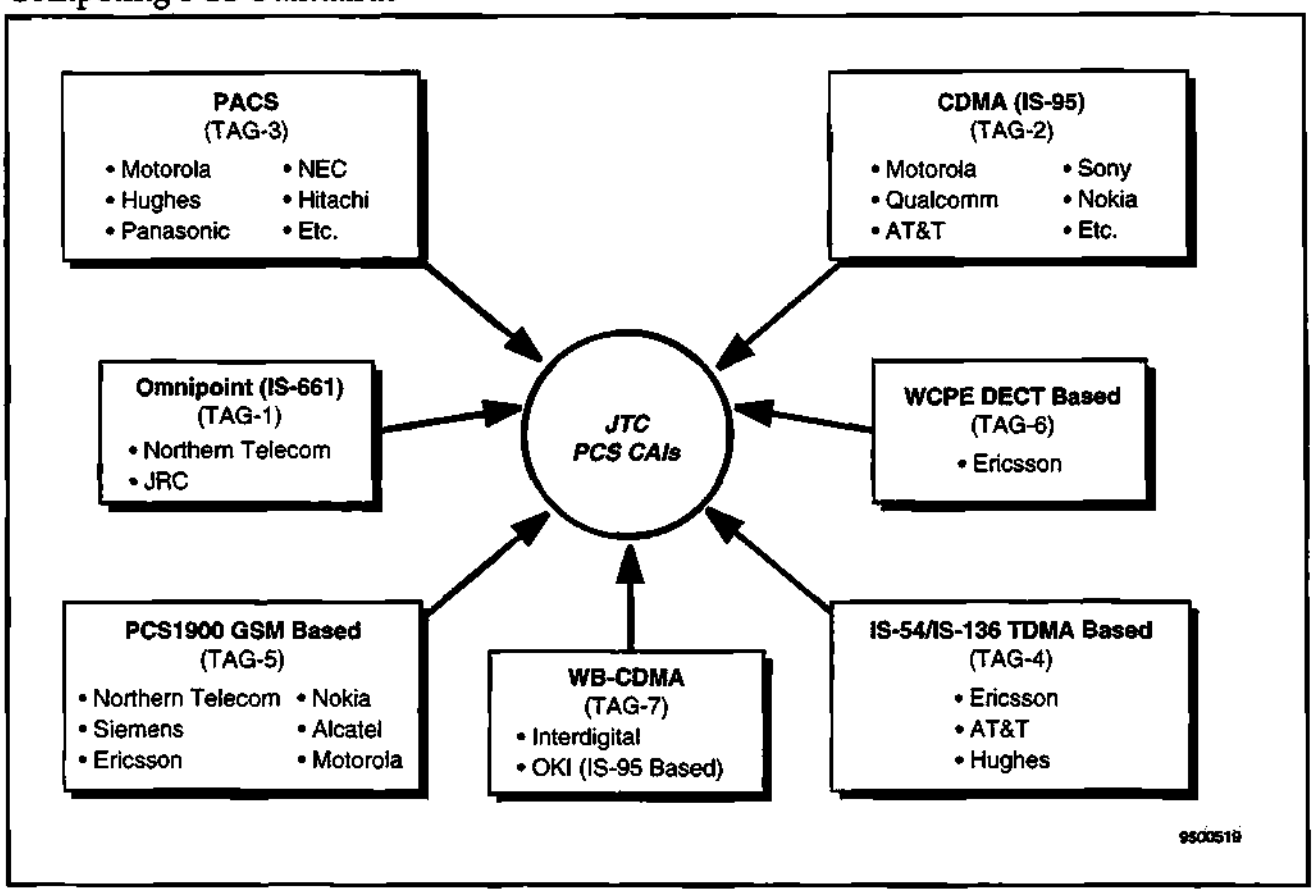
Source: Federal Communications Commission

CDMA technology has also been endorsed as a standard and has been labeled IS-95. CDMA employs spread-spectrum techniques. According to a key patent holder and licenser, Qualcomm of San Diego, California, CDMA has the capability of improving channel capacity 10 or 20 times over AMPS. CDMA backers include AT&T, Ericsson-GE, Motorola, and Qualcomm.

In addition to the IS-54/IS-136 and IS-95 standards, there are a number of other standards competing for the PCS market in the United States. The most recent standard to receive interim status approval is the Omnipoint standard, which employs a combination of TDMA, CDMA, and frequency division (FDMA) technologies. This standard has been labeled IS-661. The PCS-1900 technology is based on the GSM standard and uses TDMA technology. The PACS and WCPE standards are also gaining some momentum for use in low-mobility applications. Figure 5-9 illustrates the competing U.S. standards and some of their principal supporters. Table 5-13 lists the digital technology endorsements by major U.S. mobile carriers and winners of the first broadband PCS auction.

Dataquest believes that both TDMA and CDMA dual-mode cellular telephone systems will coexist. CDMA apparently has superior capacity and power performance, and recent test results indicate that TDMA is subject to warbling or distortion. Many of the service providers admit that CDMA is superior but that time-to-market pressures have forced them to adopt TDMA.

Figure 5-9
Competing PCS Standards



Source: Dataquest (November 1995)

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Table 5-13
Major Cellular/PCS Players and Their Technology Selections

Service Provider	North American TDMA	CDMA	PCS-1900 (GSM)
Cellular			
AirTouch Cellular		X	
Ameritech Cellular		X	
Bell Atlantic Mobile		X	
BellSouth Cellular	X		
GTE Mobilnet		X	
McCaw Cellular	X		
NYNEX Mobile		X	
Southwestern Bell Mobile	X		
Sprint Cellular		X*	
PCS			
APC			X
AT&T Wireless	X		
BellSouth			X
GTE Macro		X	
PCS PrimeCo		X	
Pacific Telesis			X
Sprint Telecom Venture (WirelessCo)		X*	
Western Wireless			X

*Negotiating with CDMA vendors
Source: Dataquest (November 1995)

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As stated previously, digital cellular handsets based on GSM technology represent the large majority of digital cellular telephones. The unified European standard has enabled strong growth in this market. Some of the countries that operate or plan to operate GSM systems are as follows:

- Australia
- Austria
- Bahrain
- Belgium
- Cameroon
- China
- Cyprus
- Denmark
- Egypt
- Finland
- France
- Germany
- Greece
- Hong Kong
- Hungary
- India
- Indonesia
- Iran
- Ireland
- Italy
- Kuwait
- Laos
- Lebanon
- Luxembourg
- Malaysia
- Morocco
- Netherlands
- New Zealand
- Norway
- Oman
- Pakistan
- Philippines
- Portugal
- Qatar
- Russia
- Saudi Arabia
- Singapore
- South Africa
- Spain
- Sweden
- Switzerland
- Syria
- Taiwan
- Thailand
- Turkey
- United Arab Emirates
- United Kingdom
- Vietnam

There is much activity to reduce component count in these systems. Table 5-14 shows the semiconductor technology solutions for second-generation handsets. Figure 5-10 is a block diagram of a second-generation GSM telephone that supports voice and data services. Figure 5-11 shows a block diagram for a CDMA handset.

Figures 5-12 and 5-13 present the radio frequency allocation for the new broadband PCS services and the overall wireless spectrum allocation for various wireless applications in the United States.

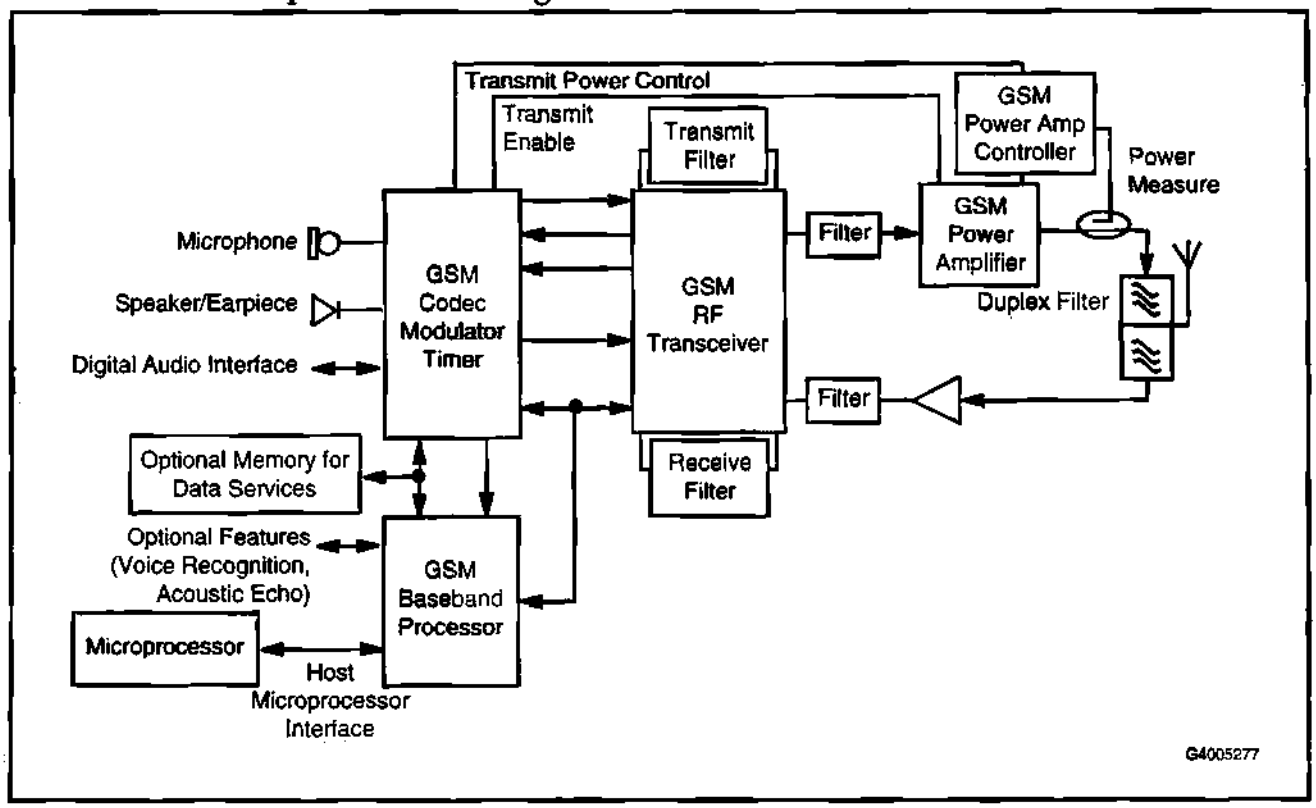
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Table 5-14
GSM Telephone Handset Semiconductor Devices

Function	No. of Devices	Semiconductor
Integrated Power Amplifier	1	Analog (GaAs)
RF Front End	1	RF linear
Baseband Processor	1	Mixed-signal (ASIC)
Channel Controller	1	MOS logic (ASIC)
Voice Processor	1	DSP
Audio I/O	2	Linear
Microcontroller/Microprocessor	1	MOS microcomponent
Flash EPROM (4Mb)	2	MOS memory

Source: Dataquest (November 1995)

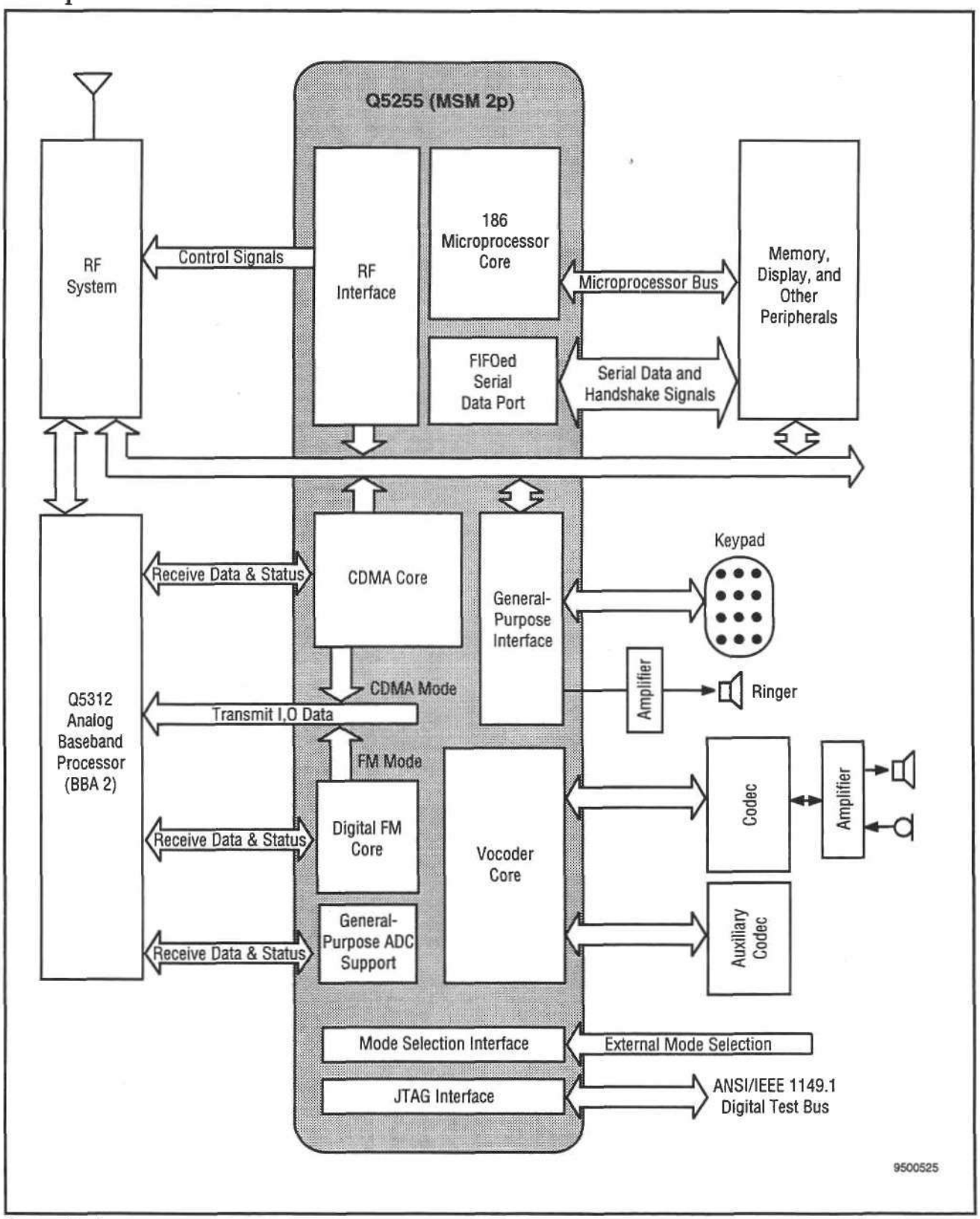
Figure 5-10
GSM Cellular Telephone Block Diagram



Source: AT&T Microelectronics

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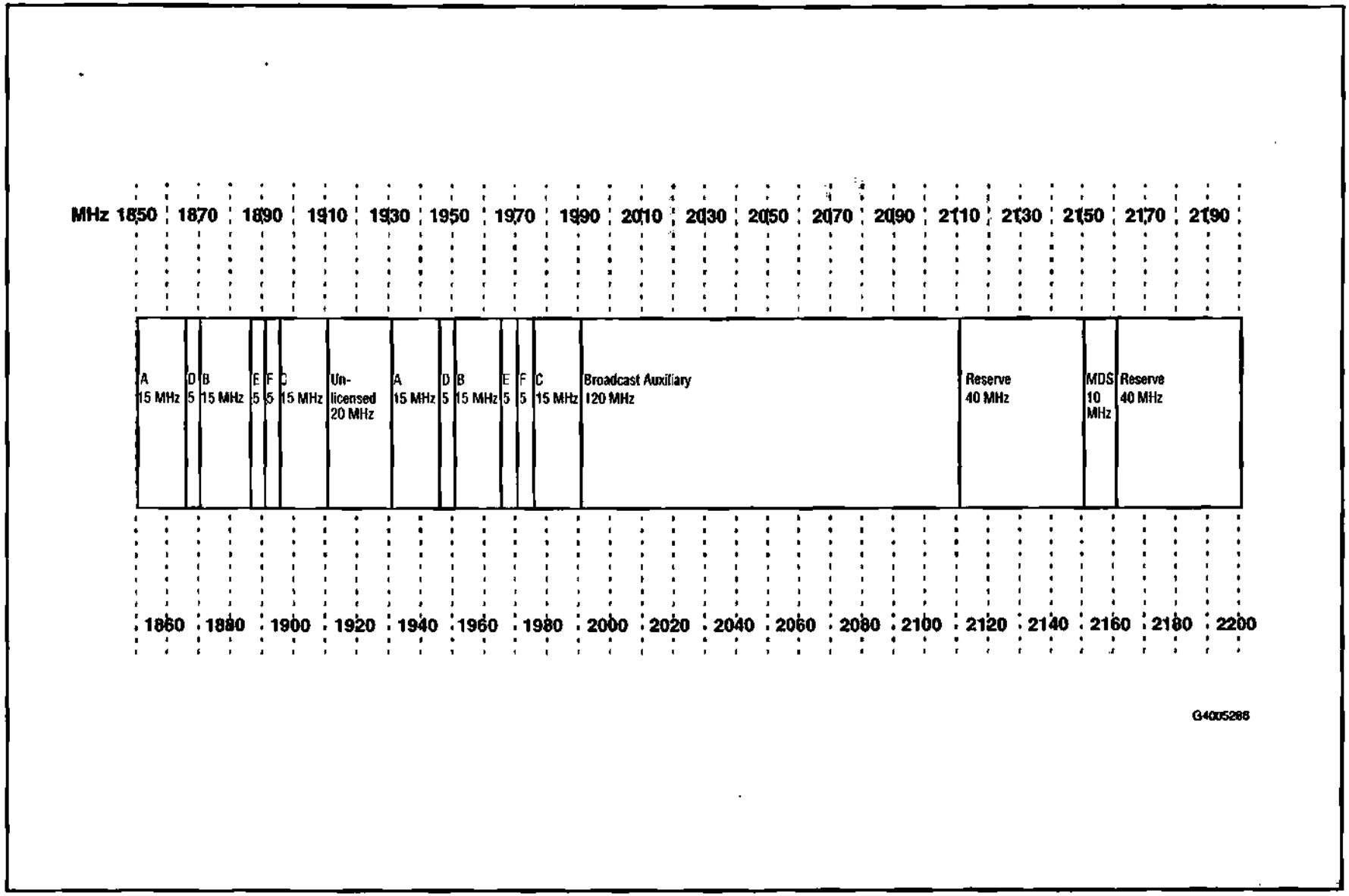
Figure 5-11
Example of a CDMA Handset



Source: Qualcomm

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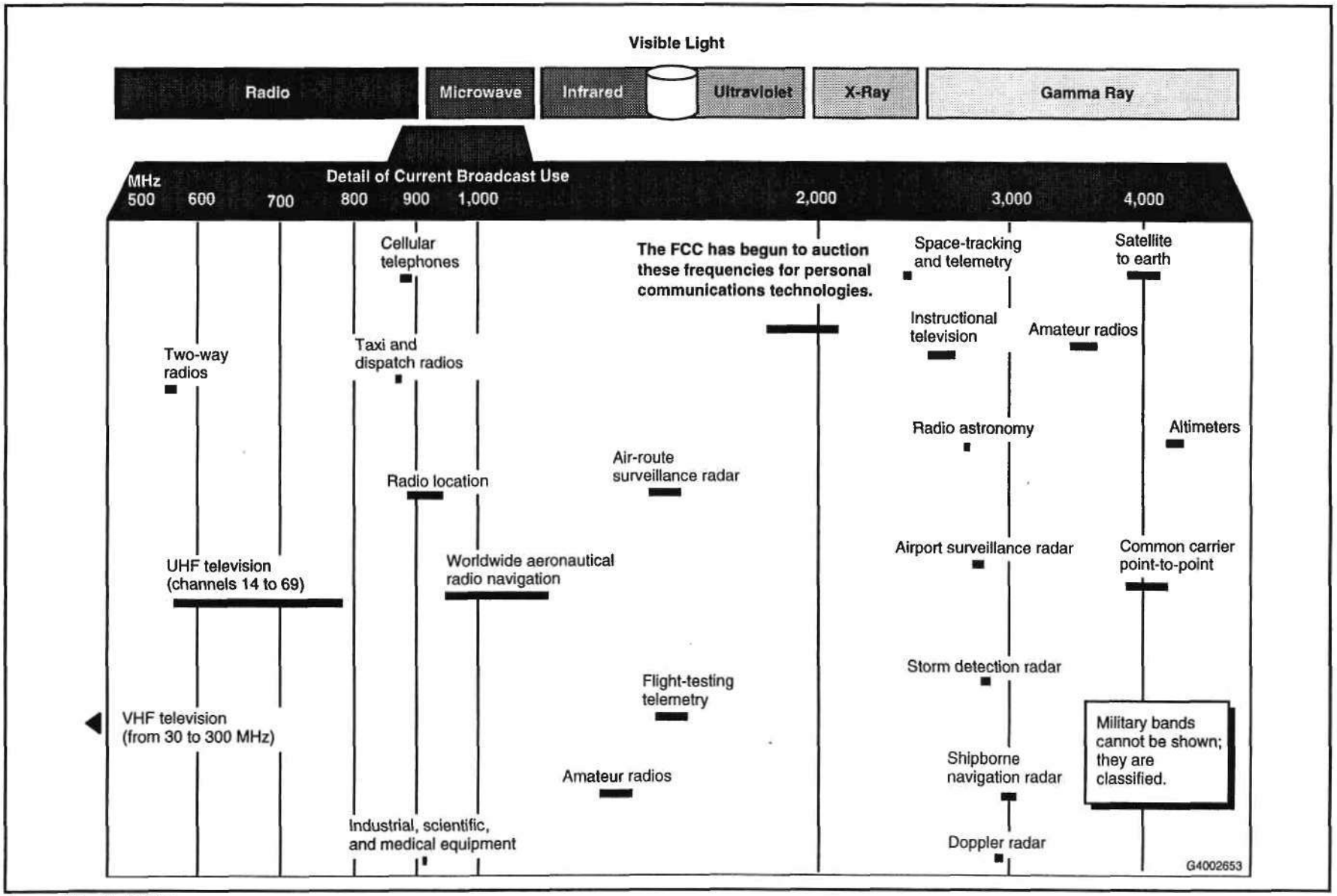
Figure 5-12
Broadband PCS Spectrum Plan



Source: Federal Communications Commission

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Figure 5-13
The Wireless Spectrum



Source: *New York Times*

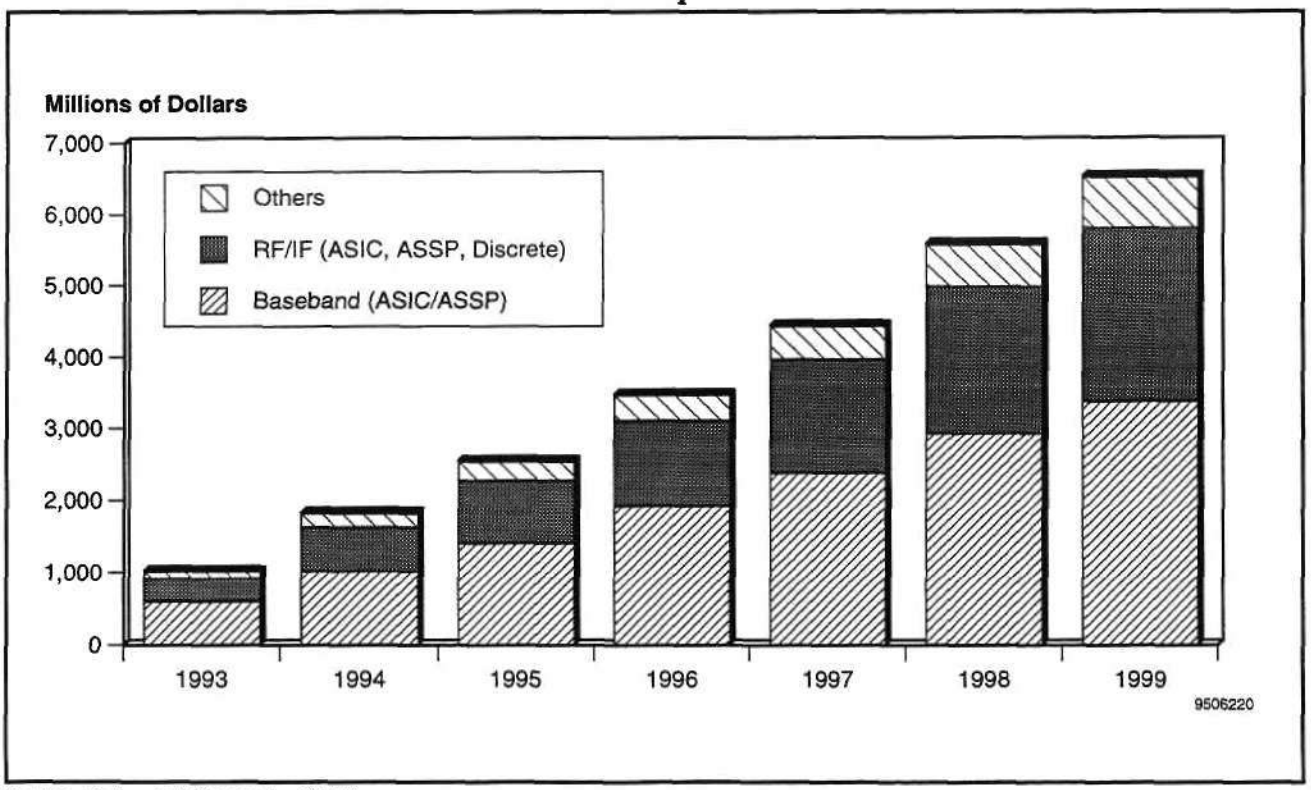
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Semiconductor Opportunities

Figure 5-14 and Table 5-15 show the worldwide cellular/PCS telephone handset semiconductor market forecast. Specific IC opportunities for digital cordless, cellular, and PCS telephones include:

- 3V versions of all activities
- Thin QFP packages for PCMCIA cards for PDAs
- Speech and baseband CODECs
- Speakerphone circuits
- TDMA/CDMA modulators
- CDPD/Mobitex modem/packetizer (for data communications)
- Phase locked loops/prescalers
- RF power/low-noise amps (902 to 928 MHz, 1.8 to 1.9 GHz)
- IF IC and discretes (oscillators, amps, frequency detection, and filters)
- 12-/24-bit MCU (with LCD driver)
- Voice recognizer (DSP based)
- Memory (EEPROM-serial, SRAM-optional, Flash)
- Various integrations of these

Figure 5-14
Worldwide Cellular and Broadband PCS Telephone Handset Semiconductor Market



Source: Dataquest (November 1995)

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Table 5-15
Worldwide Cellular and Broadband PCS Handset Semiconductor Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Analog								
Semiconductor Content ($)	43	42	42	43	43	43	45	1.4
Semiconductor Market ($M)	700	1,052	1,225	1,309	1,179	1,059	1,060	0.1
Baseband (ASIC/ASSP) ($M)	431	664	773	822	768	690	660	-0.1
RF/IF (ASIC, ASSP, Discrete) ($M)	201	291	339	365	308	277	300	0.6
Others ($M)	67	97	113	122	103	92	100	0.6
Digital/Dual-Mode								
Semiconductor Content ($)	215	150	120	104	92	78	70	-14.1
Semiconductor Market ($M)	338	822	1,395	2,282	3,441	4,779	5,767	47.7
Baseband (ASIC/ASSP) ($M)	173	359	642	1,106	1,616	2,242	2,719	49.9
RF/IF (ASIC, ASSP, Discrete) ($M)	116	324	527	823	1,278	1,775	2,134	45.8
Others ($M)	50	139	226	353	548	761	914	45.8
Total Cellular								
Semiconductor Content ($)	58	61	64	69	71	68	64	1.0
Semiconductor Market ($M)	1,038	1,874	2,619	3,591	4,620	5,838	6,827	29.5
Baseband (ASIC/ASSP) ($M)	604	1,023	1,414	1,928	2,383	2,932	3,378	27.0
RF/IF (ASIC, ASSP, Discrete) ($M)	317	615	866	1,188	1,586	2,053	2,434	31.7
Others ($M)	100	190	264	357	468	600	710	30.2

Source: Dataquest (November 1995)

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Chapter 6
Pagers (One- and Two-Way)

Market and Production Trends

New technologies and services have revitalized the pager market, with pager subscriptions growing at a record pace as shown in Table 6-1 and Figure 6-1. Worldwide pager production is forecast to grow by 11.3 percent CAGR during the next five years (see Table 6-2 and Figure 6-2). Table 6-3 shows the North American pager production forecast. Pagers have moved from serving as simple "beepers" to playing a role in future PCS markets delivering text messages, providing limited two-way messaging, and offering nationwide coverage. There were more than 70 million pager users worldwide by the end of 1994. The number of pager subscribers worldwide is growing at a strong pace, with soaring subscriber populations in the Asia/Pacific region. U.S. subscriptions to one-way pager services grew by a record-breaking 7.5 million in 1994 and are expected to grow another 7.5 million in 1995 (see Figure 6-3). Shipments of one-way alphanumeric pagers in North America are forecast to grow by 37.2 percent CAGR through 1999 as pager subscribers take advantage of new services.

Most traditional paging services cover only local or regional areas. The 10 largest paging service providers controlled almost 45 percent of the U.S. market in 1993. National paging service providers are making significant gains, with about 5 percent of pager subscribers using nationwide services. The big three of the nationwide paging networks are SkyTel, MobileComm, and PageNet.

Perfectly timed to build on the rising swell of subscribers in the paging market, two rounds of auctions for narrowband PCS licenses in the United States were completed during 1994. The winners of these auctions are shown in Table 6-4. By September 18, SkyTel had announced the availability of the first nationwide two-way paging service. Several new competitors are expected to enter the market during 1996. The new services that will be enabled by narrowband PCS technology include two-way messaging, acknowledgment paging, enhanced voice messaging (mobile answering machine), facsimile transmission, and e-mail communications. Figure 6-4 provides an illustration of how new advanced messaging networks will operate. While traditional paging services are predicted to reach 50 million subscribers by 1999, demand for narrowband PCS services will add another 11 million subscribers to the overall pager market by then. Also, Canada is already proceeding with plans for similar services. American Paging and Upper Canada Communications have entered into an agreement to coordinate development of narrowband PCS services. This alliance has gained approval from the FCC and Industry Canada to construct and operate transmitters that will allow it to develop a North American network using matching frequencies. Table 6-5 and Figure 6-5 show the forecast for the North American paging market.

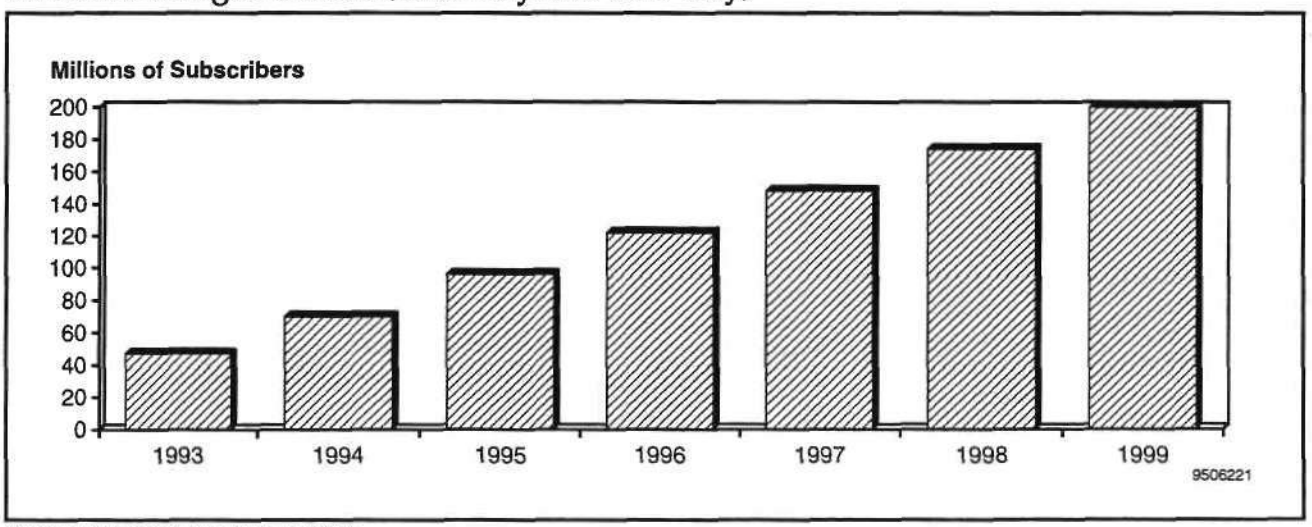
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Table 6-1
Worldwide Pager Market (One-Way and Two-Way)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Subscribers (M)	47	70	96	122	148	174	200	23.4
Units (K)	19,630	30,043	38,806	44,099	48,750	51,141	52,603	11.9
Factory ASP ($)	76	74	71	70	73	76	76	0.6
Factory Revenue ($M)	1,489	2,210	2,766	3,103	3,540	3,883	3,982	12.5

Source: Dataquest (November 1995)

Figure 6-1
Worldwide Pager Market (One-Way and Two-Way)



Source: Dataquest (November 1995)

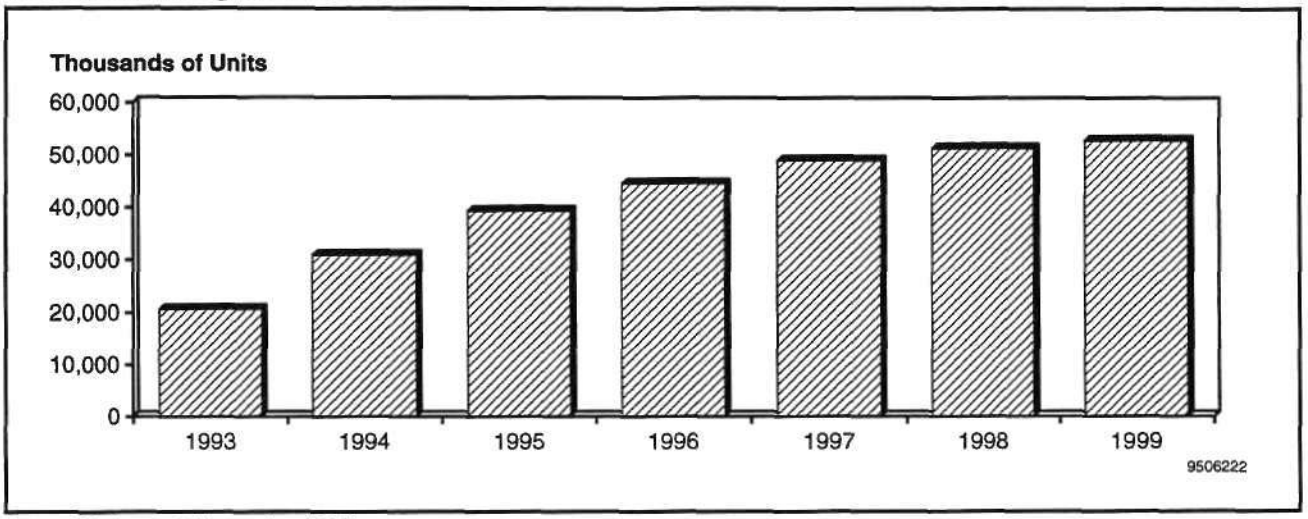
Table 6-2
Worldwide Pager Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	20,672	30,919	39,336	44,564	48,989	51,287	52,768	11.3
Factory ASP ($)	76	74	71	70	73	76	76	0.6
Factory Revenue ($M)	1,568	2,275	2,804	3,135	3,558	3,894	3,994	11.9
Semiconductor Content ($)	14	13	13	13	14	14	15	2.3
Semiconductor Market ($M)	285	404	515	593	665	738	774	13.9

Source: Dataquest (November 1995)

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Figure 6-2
Worldwide Pager Production



Source: Dataquest (November 1995)

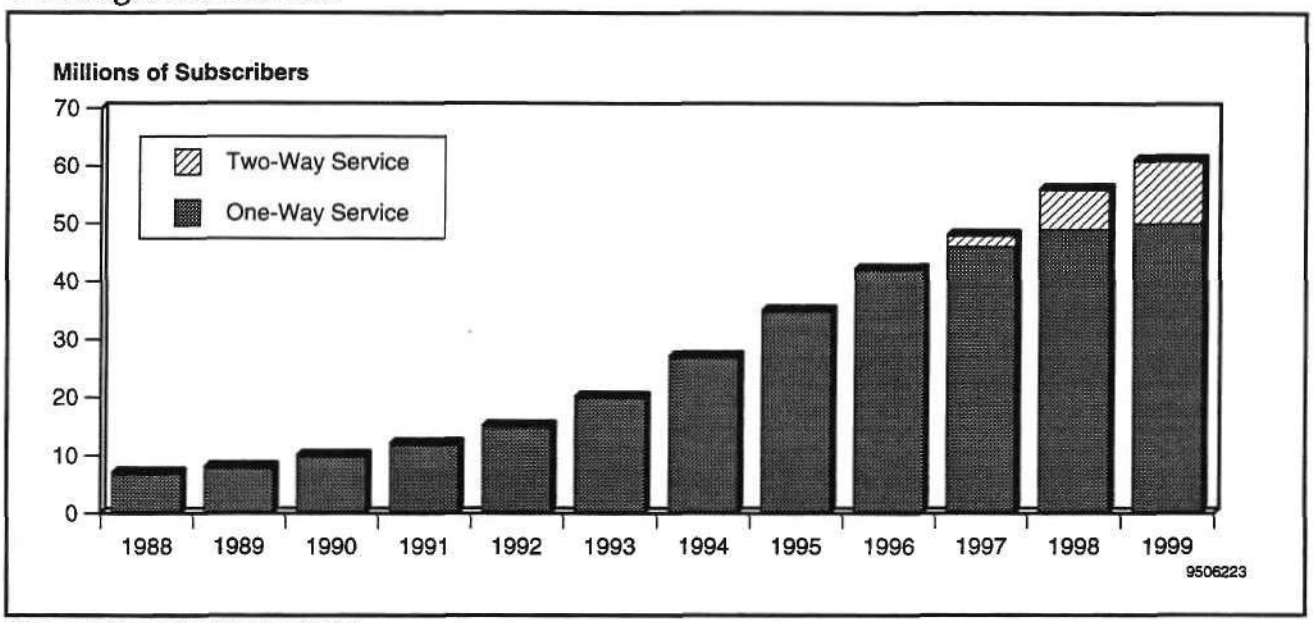
Table 6-3
North American Production of One-Way and Two-Way Pagers

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
One Way Pagers								
Units (K)	7,517	11,720	13,363	14,088	12,295	10,780	10,665	-1.9
Factory ASP ($)	78	75	74	73	74	77	81	1.5
Factory Revenue ($M)	588	878	989	1,029	910	833	860	-0.4
Semiconductor Content ($)	12	12	12	13	13	14	14	3.1
Semiconductor Market ($M)	90	141	160	176	160	146	149	1.2
Two-Way Pagers/ Narrowband PCS								
Units (K)	-	3	41	327	2,122	4,878	5,046	347.9
Factory ASP ($)	-	193	192	179	167	155	151	-4.8
Factory Revenue ($M)	-	1	8	59	354	755	761	326.3
Semiconductor Content ($)	-	18	18	20	21	22	22	4.3
Semiconductor Market ($M)	-	0	1	6	44	105	112	367.1
Total Pagers								
Units (K)	7,517	11,723	13,405	14,415	14,418	15,657	15,712	6.0
Factory ASP ($)	78	75	74	75	88	101	103	6.6
Factory Revenue ($M)	588	878	996	1,087	1,265	1,588	1,620	13.0
Semiconductor Content ($)	12	12	12	13	14	16	17	6.7
Semiconductor Market ($M)	90	141	161	182	204	250	261	13.2

Source: Dataquest (November 1995)

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Figure 6-3
U.S. Pager Subscribers



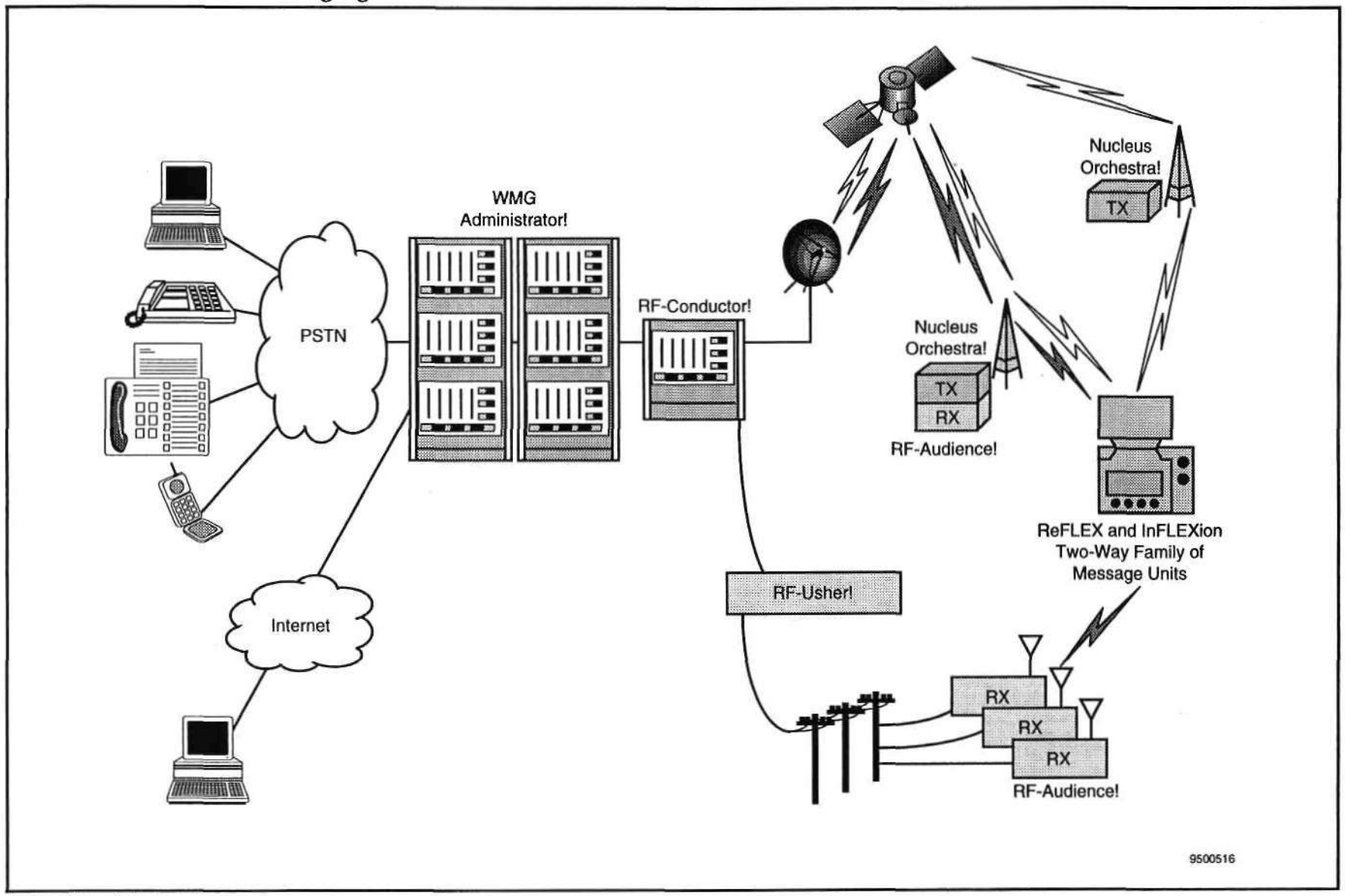
Source: Dataquest (November 1995)

Table 6-4
U.S. Narrowband PCS Auction Winners

National Licenses	Regional Licenses
PageNet	PageMart II (All Five Regions)
AT&T Wireless	PCS Development (All Five Regions)
SkyTel (MTel)	MobileMedia PCS (All Five Regions)
AirTouch Paging	American Paging (All Five Regions)
BellSouth Wireless	AirTouch Paging (Three Regions)
PageMart II	Adelphia Communications (Lisa-Gaye Shearing) (Three Regions)
	Benbow PCS Ventures (Two Regions)
	Ameritech Mobile Services (One Region)
	Insta-Check Systems (One Region)

Source: Dataquest (November 1995)

Figure 6-4
Motorola's Advanced Messaging Solution



Source: Motorola Inc.

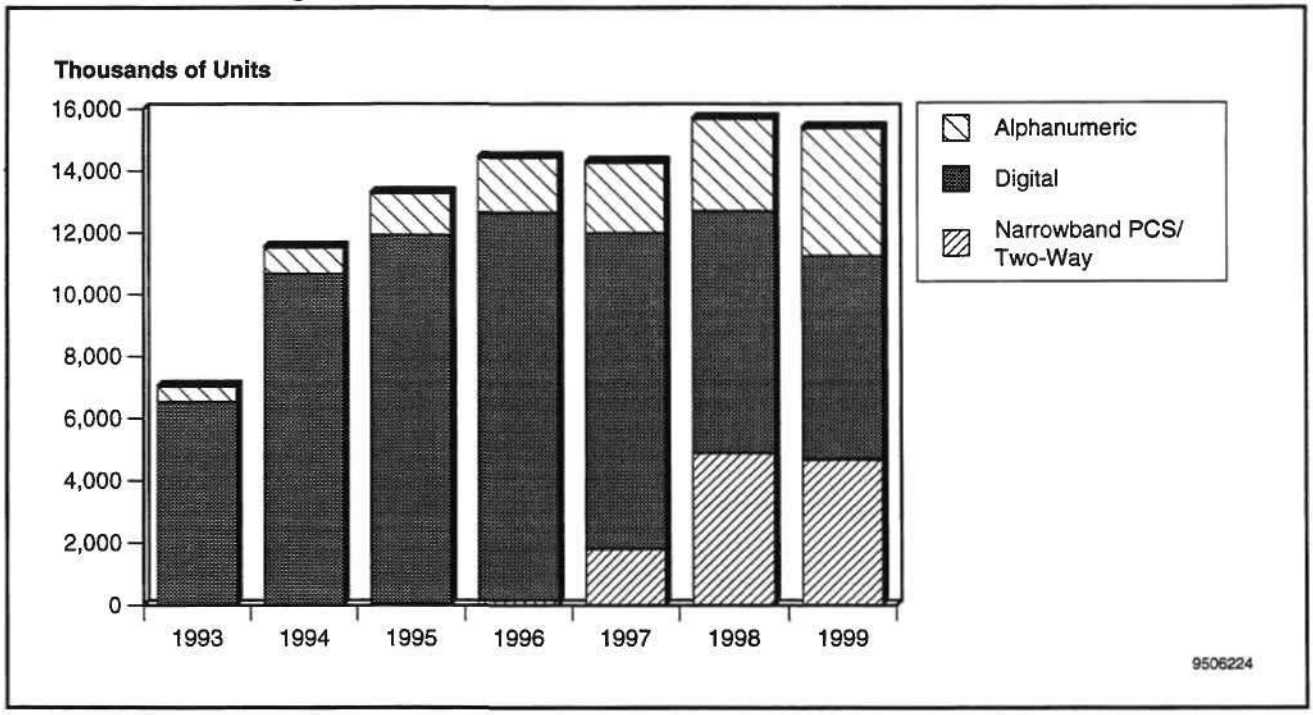
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Table 6-5
North American Pager and Narrowband PCS Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Market Revenue ($M)	557	866	988	1,072	1,228	1,589	1,576	12.7
Factory ASP ($)	79	75	74	74	86	101	102	6.4
Total Shipments (K)	7,069	11,548	13,291	14,430	14,277	15,687	15,393	5.9
Narrowband PCS/ Two-Way (K)	0	0	28	162	1,814	4,900	4,676	NM
Digital Shipments (K)	6,554	10,683	11,914	12,503	10,186	7,799	6,583	-9.2
Alphanumeric Shipments (K)	480	851	1,340	1,766	2,277	2,988	4,134	37.2
Tone-Only Shipments (K)	16	6	3	0	0	0	0	-100.0
Tone and Voice Shipments (K)	19	8	6	0	0	0	0	-100.0

NA = Not meaningful
Source: Dataquest (November 1995)

Figure 6-5
North American Pager and Narrowband PCS Market



Source: Dataquest (November 1995)

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Motorola is the dominant supplier of pagers to the North American market, with more than 60 percent market share. Most pagers sold in North America are produced in the North American region. In addition to Motorola, other major OEMs in the worldwide market include NEC, Uniden, Panasonic/Matsushita, Samsung, Hyundai, Goldstar, and Philips.

Motorola also developed some of the first two-way paging devices. The Tango pager, which will enable two-way messaging, is being used by SkyTel in its narrowband PCS service. Motorola's Tenor will provide enhanced voice messaging and act as a mobile answering machine. These pagers employ new protocols based on the FLEX technology developed by Motorola. The Tango uses ReFLEX technology and the Tenor is based on InFLEXion technology. Motorola has started to develop semiconductor partners to promote this technology and announced its first licensing agreement with Texas Instruments for the FLEX high-speed, one-way paging technology. Additional licensing agreements are expected in the future. Motorola is seeking to establish the FLEX family as a de facto protocol for pagers. However, AT&T, AT&T Wireless, and Ericsson have announced their decision to develop a competing technology. AT&T claims that details of its competing technology will be announced soon. AT&T would use this technology in the services it would provide with its nationwide license. Another alternative technology comes from Nexus Telecommunications Systems of Israel. The Nexus pagers would offer a lower-cost, lower-performance solution with its NexNet network. Nexus has already entered into agreements with American Paging to develop a service in the United States. Samsung has signed a nonexclusive licensing agreement to manufacture the two-way TAG-pager for Nexus.

At this point, Motorola has the advantage with strong momentum from 15 major U.S. paging companies adopting the FLEX protocol. FLEX has also been adopted by Bell Mobility and numerous service providers in Japan and Asia/Pacific, where much of the growth in the worldwide paging market will take place. Also AirTouch, MobileComm, Mtel, and PageMart have adopted the ReFLEX protocol, and PageNet has selected the InFLEXion protocol.

Feature and Technology Trends

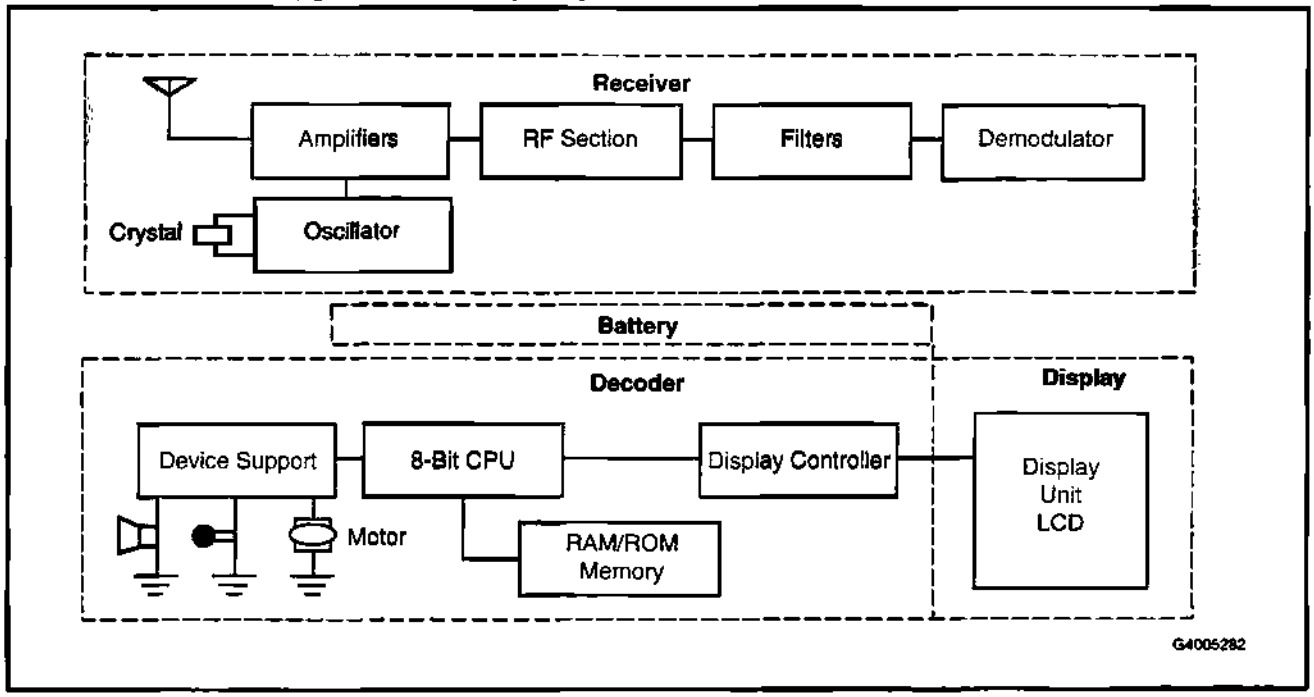
Pagers have changed dramatically in the past decade, taking advantage of microminiaturization, microprocessor advances, and extended battery life. Perhaps the most important feature of the new pagers is their small size. Credit card-size pagers are now available, and wristwatch pagers manufactured by Motorola and Swatch have also debuted. Figure 6-6 shows a block diagram of a one-way pager, which consists of the following modules:

- Receiver: includes the antenna, amplifier, and filter sections for amplifying and filtering the incoming RF paging signal
- Decoder: includes microprocessor and memory to decode, manage, and store messages
- Display: displays messages and other information
- Battery: provides power

Controls allow users to set parameters and access information.

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Figure 6-6
Block Diagram of Typical One-Way Pager



Source: Mtel Technologies

Some of the features offered by one-way pagers are:

- Numeric and alphanumeric paging
- Retaining and playing back received messages
- Vibration alert or buzzer alert
- Scrolling LCD display
- 24-hour built-in clock
- Time stamp
- Low-voltage alarm
- Canned messages

The new generation of two-way pagers will present new semiconductor opportunities for DSP products in the high-end devices and expand the consumption of memory and RF devices in this area.

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Chapter 7
Answering Machines

Market, Feature, and Production Trends

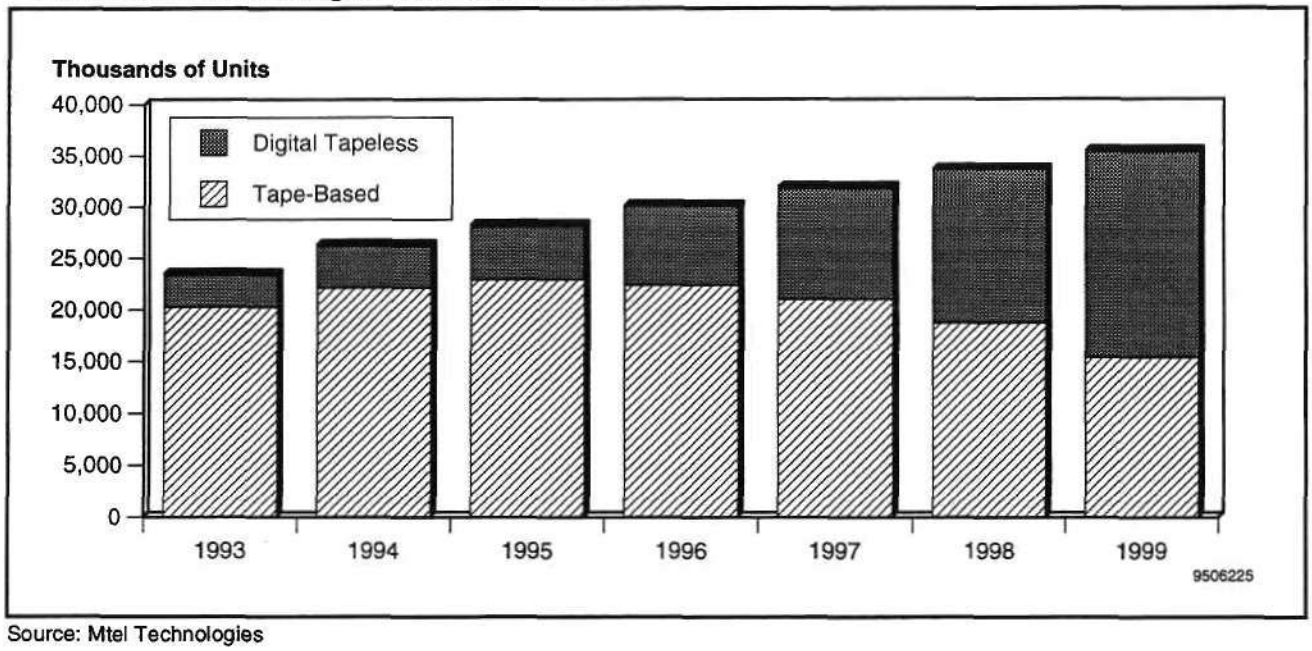
Worldwide answering machine production is expected to continue healthy growth during the forecast period, exceeding 35 million units by 1999 (see Table 7-1 and Figure 7-1). Less than 10 percent of the worldwide production of answering machines takes place in North America (see Table 7-2).

Table 7-1
Worldwide Answering Machines Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	23,470	26,273	28,194	30,099	31,901	33,655	35,431	6.2
Tape-Based	20,302	22,201	22,978	22,424	21,055	18,746	15,413	-7.0
Digital Tapeless	3,168	4,072	5,216	7,675	10,846	14,909	20,019	37.5
Factory ASP ($)	46	42	42	41	39	37	37	-2.9
Factory Revenue ($M)	1,074	1,115	1,197	1,230	1,247	1,254	1,295	3.0
Semiconductor Content ($)	9	10	11	12	12	13	12	5.4
Semiconductor Market ($M)	213	252	324	358	393	427	442	11.9

Source: Dataquest (November 1995)

Figure 7-1
Worldwide Answering Machine Production



Source: Mtel Technologies

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Table 7-2
North American Answering Machine Production

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	2,608	2,803	2,887	3,078	3,099	3,145	3,302	3.3
Factory ASP ($)	63	59	58	57	56	55	54	-1.7
Factory Revenue ($M)	164	166	168	176	172	173	180	1.6
Semiconductor Content ($)	19	20	19	18	17	16	15	-5.3
Semiconductor Market ($M)	50	55	54	55	52	50	50	-2.2

Source: Dataquest (November 1995)

Answering machines have become extremely popular in North America, as indicated by a penetration rate of 54 percent in the United States. The outlook for answering machines is for continued penetration, as implied in Table 7-3 and Figure 7-2. An estimated 52 percent of the answering machines are standalone, without a handset, and the balance is integrated with the handset. There is a strong trend toward removing the microcassette tapes, which are failure-prone and cannot be accessed randomly (for voice mailboxes). Digital answerphones took 17 percent of the market in 1994 and are predicted to take nearly 57 percent by 1999. The cassettes are being replaced by audio-RAM (ARAM) with CODECs and DSP-based chips for compression and filtering.

Another important trend with digital is that it is apparently replacing the phone company messaging service (which costs about $10 per month) with further features that the consumer desires, like mailboxes and reliability.

Another strong trend is toward cordless answerphones (analog transmission at 46 to 49 MHz). By most estimates they account for 24 percent of the market. Although currently at a price premium, cordless is expected to account for 50 percent of the market by 1997. By this time a substantial percentage of answerphones will be cordless and feature digital recording. We expect added features like LCDs and caller ID to penetrate answerphones at a similar rate as regular telephones. Besides Centrex-based services, the only other competition for answering machines comes from home computer-based fax/modem cards and standalone units capable of storing voice mail on a PC's hard disk. Microsoft recently proposed a standard software interface to help further catalyze interoperability of office equipment including telephone equipment.

Brand Share Leaders

Tables 7-4 through 7-9 show the unit and revenue brand share leaders for standalone, integrated corded telephone, and integrated cordless telephone answering machines in the U.S. market, respectively. Brand shares are provided for 1994 and for the third quarter of 1994 through the second quarter of 1995.

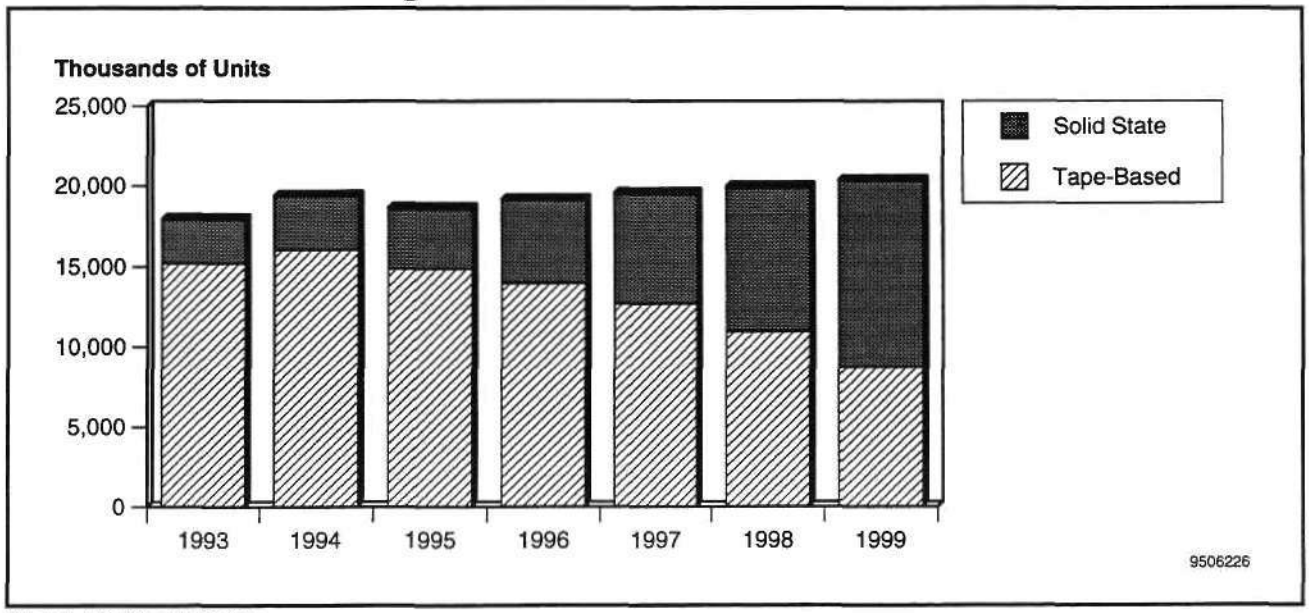
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Table 7-3
North American Answering Machine Market

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Market Revenue ($M)	1,091	1,085	977	951	920	898	897	-3.7
Factory ASP Overall ($)	61	56	53	50	47	45	44	-4.7
Factory ASP Tape-Based ($)	58	54	50	46	42	38	35	-8.3
Factory ASP Solid State ($)	77	66	63	60	57	54	51	-5.0
Total Units (K)	17,930	19,360	18,590	19,140	19,523	19,913	20,312	1.0
Tape-Based	15,241	16,069	14,872	13,972	12,690	10,952	8,734	-11.5
Solid State	2,690	3,291	3,718	5,168	6,833	8,961	11,578	28.6

Source: Dataquest (November 1995)

Figure 7-2
North American Answering Machine Market



Source: Mtel Technologies

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Table 7-4
U.S. Standalone Answering Machine Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	32.4	38.6
GE	17.7	15.2
PhoneMate	13.0	11.7
BellSouth	7.2	5.7
Panasonic	5.8	7.9
Conair	4.5	3.3
Unisonic	4.4	2.7
Radio Shack	4.1	4.8
Southwestern Bell	2.6	2.4
Spectra	2.1	1.4
Others	6.2	6.3
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 7-5
U.S. Standalone Answering Machine Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	35.3	40.4
GE	16.5	14.4
PhoneMate	11.8	10.7
BellSouth	7.9	6.7
Conair	4.9	3.8
Panasonic	4.7	6.5
Radio Shack	4.0	4.9
Unisonic	3.6	2.2
Southwestern Bell	3.5	3.2
Sony	1.9	2.6
Others	5.9	4.6
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

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Table 7-6
U.S. Answering Machine Integrated with Corded Phone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	28.8	32.9
GE	23.9	21.5
BellSouth	13.1	9.7
PhoneMate	11.0	11.1
Panasonic	6.5	8.5
Sony	4.1	5.0
Conair	2.4	1.3
Radio Shack	2.0	2.7
Southwestern Bell	1.7	1.9
Unisonic	1.1	0.7
Others	5.4	4.7
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 7-7
U.S. Answering Machine Integrated with Corded Phone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995

Brand	Unit Market Share	Revenue Market Share
AT&T	31.8	34.7
GE	23.7	21.7
PhoneMate	11.1	11.3
BellSouth	10.2	7.4
Panasonic	6.1	9.2
Sony	5.0	5.3
Conair	2.9	1.7
Southwestern Bell	2.7	2.7
Radio Shack	1.7	2.1
Unisonic	0.9	0.5
Others	3.9	3.4
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

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Table 7-8
U.S. Answering Machine Integrated with Cordless Phone Brand Share Leaders, First Quarter 1994 through Fourth Quarter 1994 (Percent)

Brand	Unit Market Share	Revenue Market Share
AT&T	23.2	24.6
Panasonic	22.5	25.1
Sony	12.0	13.3
BellSouth	12.5	10.1
PhoneMate	10.2	8.5
GE	7.1	6.3
Southwestern Bell	5.5	4.9
Sanyo	3.0	3.4
Cobra	1.0	0.7
Radio Shack	0.8	1.1
Others	2.2	2.0
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

Table 7-9
U.S. Answering Machine Integrated with Cordless Phone Brand Share Leaders, Third Quarter 1994 through Second Quarter 1995

Brand	Unit Market Share	Revenue Market Share
AT&T	24.3	26.4
Panasonic	19.1	21.6
Sony	13.3	14.6
PhoneMate	12.3	10.4
BellSouth	10.5	8.4
GE	7.4	6.5
Southwestern Bell	6.4	5.6
Sanyo	2.4	2.4
Radio Shack	1.2	1.5
Cobra	0.8	0.7
Others	2.3	1.9
Total	100.0	100.0

Source: The Scout Report®/The Polk Company

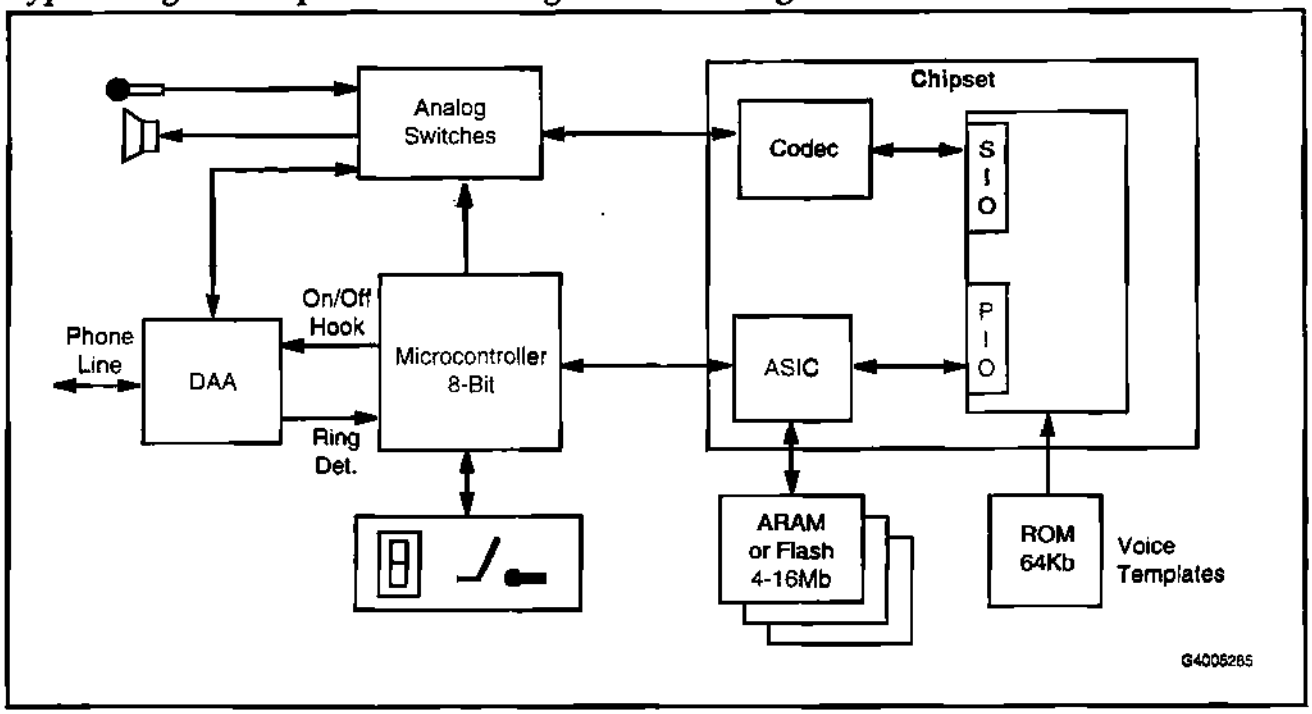
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Technology Trends and Semiconductor Opportunities

Cassettes in new answering machines are being replaced by ARAM, with CODECs and DSP-based chips for compression and filtering (see Figure 7-3). However, the volatile supply and pricing of ARAM has been frustrating to manufacturers and slowed market growth. Flash memory is now hitting price points at which it is beginning to be designed into answering machines instead of ARAM. Record times are typically being offered from 4 to 20 minutes. The length of recording time is dependent on the amount of ARAM used and the audio compression algorithm employed. Almost all answering machines are now using digitized outgoing messages of a few seconds stored on ARAMs. As described, answering machine semiconductor opportunities exist for:

- 12-bit CODEC (ADPCM or TrueSpeech)
- ARAM 4Mb to 16 Mb
- Tape transport control
- DSP-based combination of these

Figure 7-3
Typical Digital Telephone Answering Machine Design



Source: Dataquest (November 1995)

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Chapter 8
Satellite-Based Services and Specialized Mobile Radio

Satellite-Based Services

Satellite-based services (L2) would essentially be a cellular voice and data communications system using low-earth-orbit (LEO) satellites, which are 400 to 700 miles above the earth, medium-earth-orbit (MEO) satellites, which are 5,000 to 10,000 miles above the earth, or geostationary (or "fixed") satellites. More than twelve proposals are in various stages of obtaining approval and licensing from the FCC and from international bodies. Recently, two systems launched their first satellites into orbit and three other systems received FCC licenses. American Mobile Satellite Corporation launched its first geostationary satellite above North America and Orbital Communications launched the first two satellites of its planned system of 24 satellites. Motorola's Iridium, Loral and Qualcomm's Globalstar, and TRW's Odyssey all received FCC licenses for their systems. Constellation Communications and Mobile Communications with its Ellipso system are both actively pursuing licenses. Perhaps the most ambitious project that has been announced is the Teledesic system backed by AT&T (24 percent ownership), Bill Gates (30 percent ownership), and Craig McCaw (30 percent ownership). The system would deploy 840 satellites to ring the earth, with service planned to begin in 2001. Table 8-1 presents a summary of eleven proposed satellite systems.

While all of these systems have the use of satellites as a switching and transmission system in common, they can vary significantly in the types of service they plan to offer. For example, the Teledesic system would provide communications for videoconferencing, computer networking, and other services as part of the spectrum called the Ka-band. The system would not compete with the global pocket telephone satellite systems being built by Motorola, TRW, and Loral. Figure 8-1 presents a depiction of Motorola's proposed Iridium system. Motorola's Iridium and Loral's Globalstar would also target slightly different markets. The Iridium would seek deep-pocketed business travelers while the Globalstar system is targeting a general worldwide market. They also differ significantly in the architecture of their systems. The Iridium system would pass signals between its more complicated satellites while the Globalstar system would relay communications using ground stations, which are easier to maintain and modify. The TDMA and CDMA technologies are also competing in the satellite communications arena. The Globalstar and Odyssey systems use CDMA as the air interface, and the Iridium system will use TDMA technology.

American Mobile Satellite Corporation (AMSC), which is co-owned by Hughes, AT&T, and Singapore Telecom, launched its first satellite in the spring of 1995 to a geostationary orbit 23,000 miles above Lubbock, Texas. This system presents a good example of the type of service and hardware offered in a satellite-based system. AMSC plans to provide mobile voice and data applications for a variety of users including land mobile, maritime, aeronautical, and fixed-site markets. The satellite can support hundreds of thousands of subscribers and would provide dual-band satellite/

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Table 8-1
Proposal for Sattellite-Based Services

Company	Number of Satellites	Target Service*	Satellite/System Type	Comments
Orbital Communications	26 - 48	1995	Little LEO	Holds FCC license; two satellites in place and functioning
American Mobile Satellite Corporation	-	1995	Geostationary	Holds FCC license; one satellite in place and functioning
Motorola (Iridium)	66	1998	Big LEO	Received FCC approval
Loral, Qualcomm (Globalstar)	48	1998	Big LEO	Received FCC approval
TRW (Odyssey)	12	1998-99	MEO	Received FCC approval
Teledesic	840	2001	LEO	Working with FCC licensing and regulations; backed by AT&T, McCaw, and Gates
Constellation Communications	46	1996	-	Seeking FCC approval but denied initially for financing
Mobile Communications (Ellipso)	16	-	Little LEO	Seeking FCC approval but denied initially for financing
ICO Global Space Communications (Inmarsat-P)	12	2000	MEO	Offshoot of Inmarsat
VITA and CTA (GEMnet-VITAsat)	40	1995	-	Holds two satellites under Pioneer's Preference; Seeking 38 more licenses
Starsys (Starsys Global Positioning)	24	1997		

*Indicates start of initial service. Full-constellation deployment and full service would follow over four to five years, typically.
Source: Dataquest (November 1995)

SAMM-WW-MT-9505

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Figure 8-1
Motorola's Iridium: A Low-Earth-Orbit (LEO) Satellite Network

Source: Motorola Inc.

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cellular service for seamless coverage. AMSC's Skycell Satellite Roaming Service has agreements with 156 cellular carriers across the United States to be authorized service providers. Westinghouse Electronic Corporation's Series 1000 dual-band phones, expected to cost about $2,000, are available as units to be mounted in vehicles or in briefcases equipped with satellite dishes. Talk time will average $1.50 per minute, and customers will pay a $25-per-month access fee. The company plans to begin offering services in December 1995 to North American truck, ship, aircraft, and vehicle fleets. By 1997, it expects to offer services to cellular-phone users after a $600 million expansion. End-user terminals for cellular/satellite systems are expected to cost between $600 to $750 at introduction. This price would decline as the market begins to support volume shipments.

Some projections have placed the market for satellite-based services at $160 billion over the next decade, and this has lured more than $23 billion in combined proposals for satellite networks. There has been a race for financial backing. However, these systems are viewed as high-risk investments by the financial community because of fears that not all of the systems can be successful. Constellation Communications and Mobile Communications were denied licenses by the FCC because of concerns over financing. A recent $300 million bond offering from Iridium was pulled from the market when investors demanded a return that Iridium considered too high. Iridium has decided to pursue bank financing, which it believes it can obtain for around 14 percent instead of the effective 25 percent return that bond investors were seeking. In addition to technological hurdles, significant financial hurdles still stand in the way of the development of satellite communications.

SMR

Specialized mobile radio (SMR) frequencies are in both the 220-MHz and the 800-MHz ranges, compared with cellular frequencies, which are higher in the same 800- to 900-MHz band. Voice SMR services originally had been designated for private radio dispatch and fleet management; a lifting of FCC restrictions would allow reuse of the spectrum for cellularlike service. Leading the movement for the use of SMR for nationwide digital communication is Nextel Communications. Motorola has a 20 percent stake in Nextel, which it acquired in exchange for SMR licenses. Nextel, in return, is using Motorola equipment to deploy the network. Nextel's strategy is to acquire as many 800-MHz SMR licenses as possible, and in its efforts to do so, Nextel has allied with critical partners to gain access to technology and licenses nationwide. Nextel is converting the networks it has acquired from analog to digital TDMA systems. In 1995, Craig McCaw invested $1.1 billion in Nextel and received control over operations and corporate strategy. McCaw has already announced his plan to shift Nextel's focus from providing cellular/PCS services to a "focus on wireless work groups in the business segment." In one of his first moves, McCaw obtained a promise from Motorola to improve the Motorola Integrated Radio System technology, which has been renamed Integrated Dispatch Enhanced Network.

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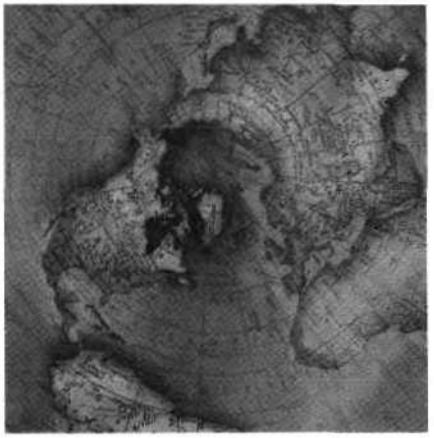
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Communications Application Markets—LAN, WAN, Voice, and Public



Market Trends

Program: Semiconductor Application Markets Worldwide
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Communications Application Markets—LAN, WAN, Voice, and Public



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Chapter 1
Introduction and Methodology

This document is the fourth in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The five areas are data processing, communications, consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- A listing of key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analyst: Gregory Sheppard

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Chapter 2
Local Area Networks (Cards, Hubs, and Internetworking Systems)

Market and Feature Trends

Tables 2-1 through 2-3 present market forecasts and accompanying semiconductor demand for LAN network interface cards (NICs), intelligent hubs, routers, bridges, asynchronous transfer mode (ATM) nodes, 100-Mbps and FDDI technologies, and wireless LAN nodes. Following are the primary trends:

- Large/medium-size office LAN desktop connectivity will continue to rise, reaching near 100 percent saturation in the United States and Europe by the end of the decade. Developing countries, small offices and business, and home offices will provide much of the new connectivity growth.
- LAN bandwidth demands will be driven by a variety of trends including increased use of applications servers, networking faxing, groupware (such as Lotus Notes), and multimedia-rich file transfer messaging (store and forward or conferencing).
- IS managers are under pressure to upgrade as they consider a variety of speed enhancing technologies for desktop connectivity and the backbone (see Figures 2-1 and 2-2), including:
  - Full duplex Ethernet (20 Mbps)
  - Iso-Ethernet (16 Mbps)
  - Switched Ethernet (10 Mbps)
  - Switched token ring (16 Mbps)
  - Fast Ethernet (100 Mbps)
  - 100 VG AnyLAN (100 Mbps)
  - FDDI/CDDI (100 Mbps)
  - ATM (25 Mbps to 622 Mbps)
- Ethernet will remain the dominant networking technology for the next two years although token ring will also experience substantial growth. The evolution of shared media hubs to the switches capable of dedicating full bandwidth to each desktop is giving both Ethernet and token ring extended market lives. 20-Mbps full-duplex Ethernet technology is also appearing in NICs, hubs, and switches.
- New high-speed technologies like 100-Mbps Fast Ethernet, 100 VG AnyLAN, and ATM are beginning to find use in premise network backbones. The market is expected to move rapidly to technology known as 10/100, which uses networking systems capable of both 10 Mbps and 100 Mbps. This allows a gradual integration to higher speeds to take place within the bound legacy installations.

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- FDDI is the most popular backbone technology today. Most hubs, LAN switches, and routers offer an FDDI "fat pipe" for high-speed transfer. FDDI will be challenged as a backbone technology in the future by both the 100-Mbps technologies and ATM. ATM is already finding early success in the so-called enterprise backbones switches.
- Isochronous or real-time networking demands for videoconferencing or voice over data are slowly emerging. ATM has the best prospects for long-term success for serving this kind of need. Iso-Ethernet does have some potential for addressing this need in the interim, allowing users to exploit existing cabling.
- PCI bus NICs are being designed in prolific numbers and should become mainstream within two to three years. 10-base-T will remain the predominant Ethernet variety. The trend is toward installing category 5 twisted-pair of fiber in most upgrades and new installations. Category 3 twisted-pair wire is the most common currently. PCMCIA card versions are enabling notebook computer connectivity and are expected to grow rapidly.
- PCs targeted at large businesses, like most workstations today, will have embedded LAN controllers designed onto the motherboard at an increasing rate.
- Intelligent shared media hubs are being replaced by LAN switches capable of dedicating full bandwidth (such as 10, 16, or 100 Mbps) to the desktop. In many cases, these LAN hubs or switches support one of the 100-Mbps FDDI, upgradable with routers and ATM functionality. Stackable hubs are gaining strong market acceptance as well.
- Two 100-Mbps technologies are doing battle for that market. Fast Ethernet (IEEE 802.3u) is backed by the Fast Ethernet alliance, whose members include 3Com, Cabletron, David Systems, Grand Junction, Intel, LAN Media, Lannet, National Semiconductor, SMC, Sun Microsystems, and Bay Networks. Fast Ethernet, or 100-base-T, as it's called, supports the traditional CSMA/CD protocol of Ethernet but requires different encoding schemes, depending upon the cabling used. The other technology is known as 100 VG-AnyLAN (803.12), and its constituency includes AT&T Microelectronics, Acctron, Alantec, Asante, Banyan, Bytec/NSC, Compex, D-Link, David Systems, Hewlett-Packard, IB, Katron, Microsoft, Novell, Optical Data Systems, Proteon, SMC, Ungermann-Bass, Wellfleet, and Zynx. Both of these standards are being implemented in a form allowing backward compatibility with 10-Mbps rates and token ring in AnyLAN's case.
- ATM is based in part on synchronous optical network (SONET)/ synchronous digital hierarchy (SDH) technology will emerge throughout 1995 and 1996. This technology employs 53-byte fixed-length cells that can operate from speeds as low as 25 Mbps to 155 Mbps and up to 2 Gbps in backbone and public transmission applications. Adopted initially by the hub/switch vendors, adapter cards for workstations and servers are also hitting the market. The main standards body is the ATM Forum, which works with interested players to ensure that local area networking (LAN), wide area networking (WAN), and public equipment will work with each other. ATM is viewed as the overarching technology network managers desire to have. So far, ATM is starting in the backbone of premise and public networks.

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- The remote LAN access market (via routers, modems, ISDN adapters, and so on) is proving to be very popular. Access to files at work, e-mail, and remote offices are the drivers.
- Radio-frequency (RF) versions employing spread spectrum technology operating in the ISM bands are expected to be the most popular, although infrared (IR) will find many point-to-point uses. Worldwide the 2.4-GHz band should become the most popular, with 902-MHz the most popular in existing vertical applications in the United States. Early market build will come from the rollover of users from proprietary solutions in the handheld data terminal market. Work on the IEEE 802.11 standard, which would govern wireless LAN interoperability, would have a flexible MAC layer (up to 20 Mbps) and three PHY layers, two spread spectrum, and an IR. Ratification of IEEE 302.11 is expected in mid-1996.

Table 2-1
Worldwide LAN Network Interface Card (NIC) Application Market

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	11,276	15,965	26,479	33,018	43,727	53,914	60,865	68,057	20.8
Ethernet	8,099	12,641	22,733	27,072	33,440	38,000	29,700	21,349	-1.2
Token Ring	2,281	2,685	3,161	4,300	5,200	5,800	6,000	5,900	13.3
10/100 Mbps (Fast Ethernet/AnyLAN)	0	0	27	1,128	4,560	9,500	24,300	39,650	329.9
FDDI	24	55	108	155	195	220	225	210	14.2
ATM (All Speeds)	0	0	8	35	105	250	520	850	154.3
Other (Arcnet, etc.)	872	584	442	328	227	144	120	98	-26.0
Factory ASP ($)	243	191	133	120	103	97	95	93	-6.9
Factory Revenue ($M)	2,745	3,050	3,516	3,962	4,504	5,230	5,782	6,329	12.5
Semiconductor Content ($)	55	43	29	28	25	24	25	25	-3.0
Semiconductor Market ($M)	618	686	774	911	1,081	1,307	1,503	1,709	17.2
ASIC/ASSP ($M)	531	590	667	786	933	1,130	1,299	1,476	17.2
Volatile Memory ($M)	37	41	46	55	65	78	90	103	17.2
Nonvolatile Memory ($M)	15	17	19	22	25	30	35	39	16.2
Others* ($M)	34	38	42	49	57	69	80	91	16.7
North America									
Unit Production (K)	3,744	4,765	6,767	8,883	9,462	10,761	11,110	11,911	12.0
Production Revenue ($M)	1,217	1,430	1,529	1,643	1,438	1,399	1,300	1,254	-3.9
Semiconductor Market ($M)	286	343	398	411	374	364	351	350	-2.5

*Others include standard logic, linear, discrete, and optoelectronic.
Source: Dataquest (October 1995)

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Table 2-2
Worldwide Hub (Shared Media and Switched) Application Market)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Ports (K)	9,552	20,090	31,521	47,069	61,272	78,260	94,846	106,888	27.7
Ethernet	7,420	16,087	27,100	41,569	53,208	63,850	70,235	72,342	21.7
Percent Switched	0	0	0.4	4.4	9.0	22.0	32.0	41.0	
Token Ring	2,074	3,856	4,120	4,411	4,609	4,794	4,842	4,793	3.1
Percent Switched	0	0	0	0.3	1.6	5.2	10.0	19.7	
10/100 Mbps (Fast Ethernet/AnyLAN)	0	0	105	729	2,770	8,117	17,095	25,908	200.9
FDDI	58	147	178	267	312	308	293	273	8.9
ATM (All Speeds)	0	0	18	93	372	1,190	2,381	3,571	188.1
Port Factory ASP ($)	170	122	116	103	100	97	94	91	-4.7
Factory Revenue ($M)	1,626	2,461	3,656	4,848	6,127	7,591	8,915	9,727	21.6
Semiconductor Content ($)	34	25	24	22	21	21	20	20	-3.5
Semiconductor Market ($M)	325	500	753	1,013	1,299	1,632	1,944	2,140	23.2
ASIC/ASSP ($M)	216	332	502	671	856	1,062	1,265	1,393	22.7
MPU/MCU ($M)	29	45	68	91	117	147	175	193	23.2
Volatile Memory ($M)	59	90	136	188	248	326	393	432	26.0
Nonvolatile Memory ($M)	7	10	14	19	23	29	33	36	20.5
Others* ($M)	15	22	33	44	55	67	78	86	20.9
North America									
Unit Production (K)	7,737	15,469	23,010	32,478	39,827	47,738	54,062	56,651	19.7
Production Revenue ($M)	1,317	1,895	2,669	3,345	3,983	4,631	5,082	5,155	14.1
Semiconductor Market ($M)	263	385	550	699	844	996	1,108	1,134	15.6

* Others include standard logic, linear, discrete, and optoelectronic.
Source: Dataquest (October 1995)

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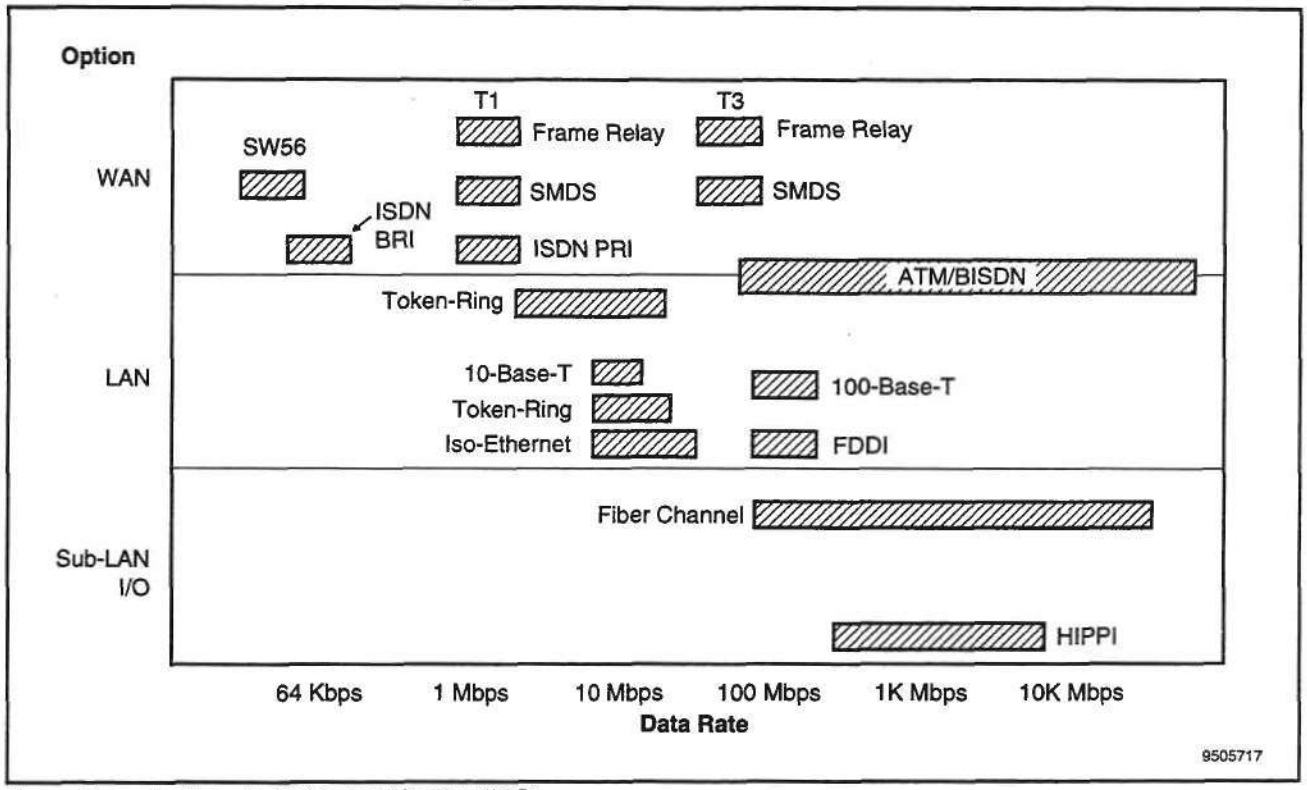
Table 2-3
Worldwide Internetworking Application Market (Routers, Bridges)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	171	243	421	691	1,078	1,522	2,107	2,587	43.8%
Routers	73	140	296	549	921	1,359	1,955	2,449	52.6%
Bridges	98	103	125	143	157	163	152	138	1.9%
Factory ASP Internetworking ($K)	9.6	7.7	7.2	6.3	5.3	4.7	4.1	3.9	-11.4%
Factory Revenue Internetworking ($M)	1,642	1,883	3,046	4,333	5,746	7,126	8,655	10,198	27.3%
Semiconductor Content ($)	1,348	1,100	1,042	940	853	796	739	749	-6.4%
Semiconductor Market ($M)	230	267	439	650	919	1,211	1,558	1,938	34.6%
ASIC/ASSP ($M)	146	164	255	359	489	618	763	930	29.5%
MPU/MCU ($M)	28	32	53	80	113	149	192	238	35.3%
Volatile Memory ($M)	30	40	79	130	202	291	405	523	46.0%
Nonvolatile Memory ($M)	16	19	33	52	75	102	131	163	37.7%
Others* ($M)	10	12	19	29	40	52	67	83	34.0%
North America									
Unit Production (K)	138	190	316	498	744	1,005	1,328	1,578	38.0%
Production Revenue ($M)	1,330	1,468	2,285	3,119	3,965	4,703	5,453	6,221	22.2%
Semiconductor Market ($M)	186	209	329	468	634	800	981	1,182	29.1%

* Others include standard logic, linear, discrete, and optoelectronic.
Source: Dataquest (October 1995)

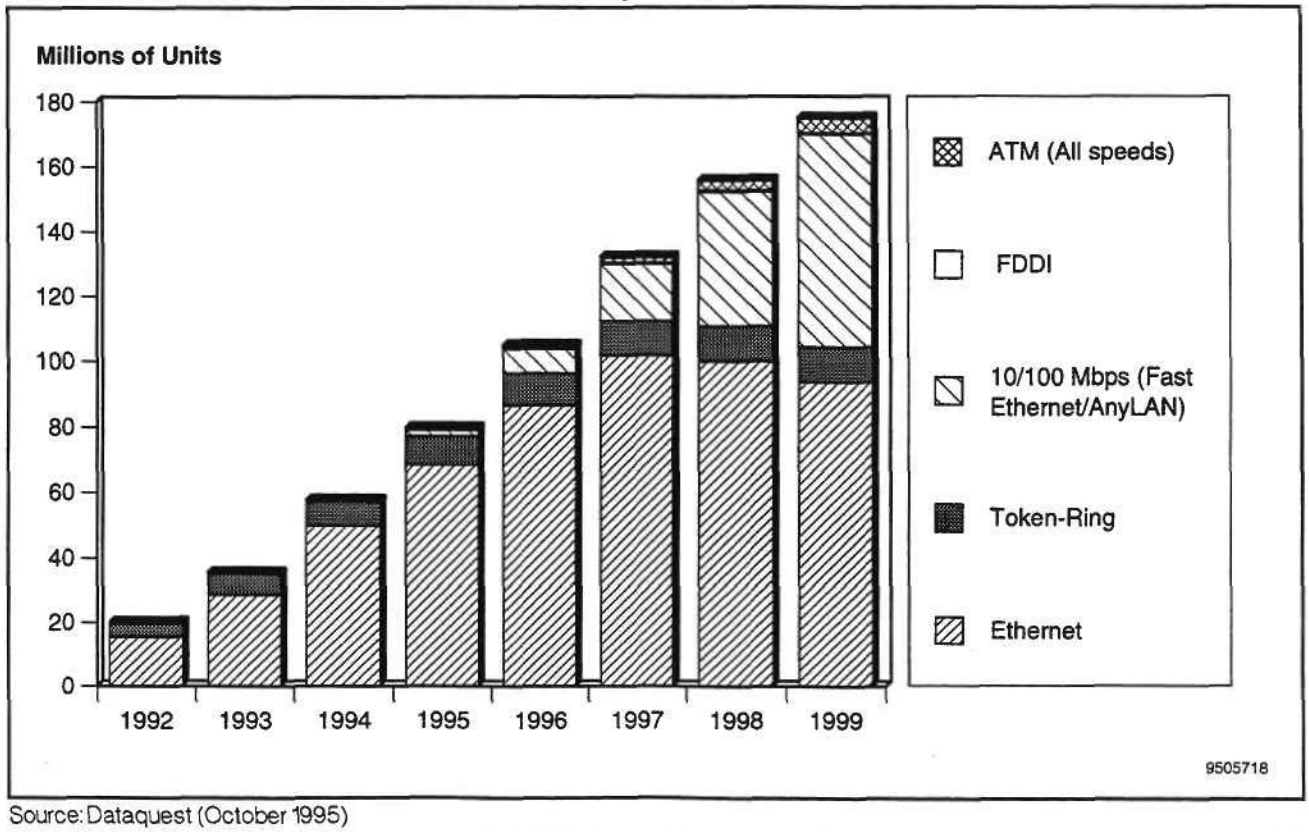
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Figure 2-1
Alternative Network Technologies



Source: Texas Instruments, Dataquest (October 1995)

Figure 2-2
Worldwide NIC and Hub/Switch Nodes by Standard



Source: Dataquest (October 1995)

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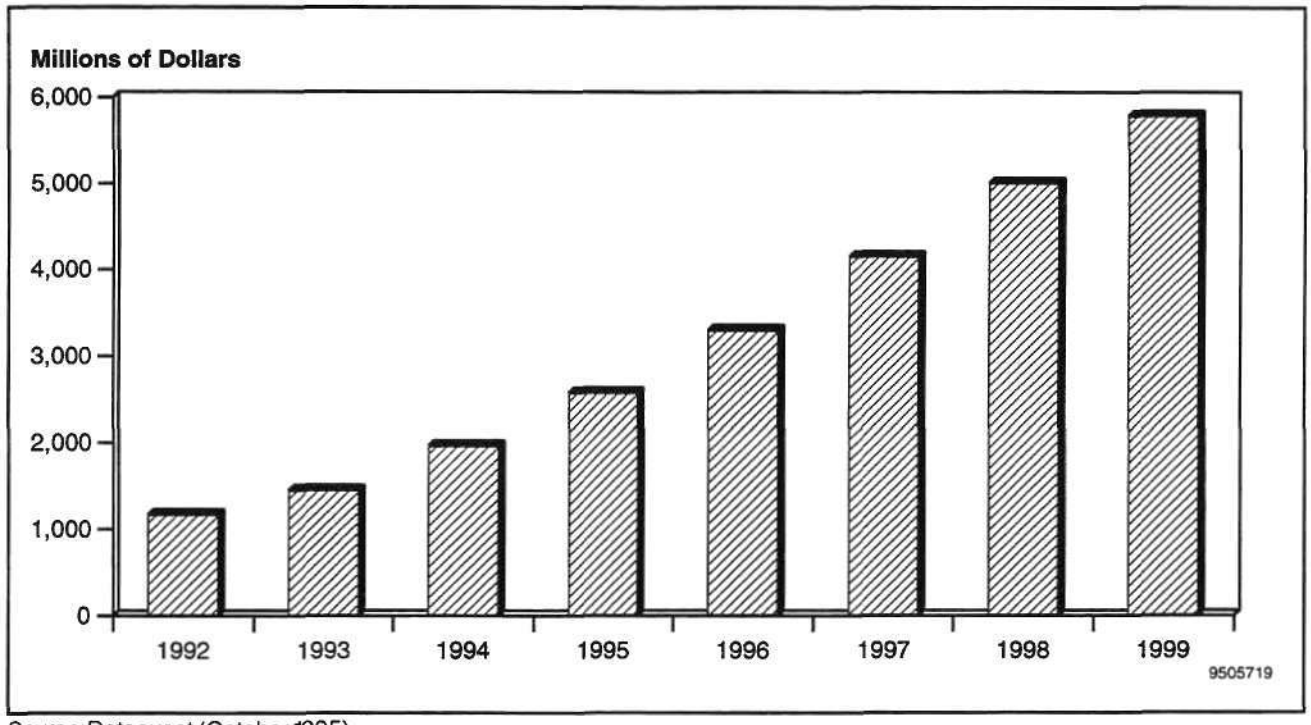
Semiconductor Opportunities

Refer to Tables 2-1 through 2-3 for the semiconductor application forecast in LANs. Figure 2-3 presents a forecast of overall networking semiconductor demand. Market growth is sustained by the increasing network connectivity, higher-speed upgrades, and the semiconductor-rich intelligence of hubs, switches, and routers. Key semiconductor opportunities are as follows:

- The standard LAN NIC architectures are rapidly heading toward one or two ICs that comprise the transceiver (coax, shielded twisted-pair, unshielded twisted-pair), the physical layer processing (encoding, among others), and MAC functions (for example, CSMA/CD features). Full duplex Ethernet at 20 Mbps is rolling out quickly. 3V varieties of 10-base-T controllers are needed for PCMCIA applications as well.
- Controllers and transceivers for both the Fast Ethernet and 100 VG AnyLAN are commencing market introduction.
- Figure 2-4 shows a block diagram for a typical, managed, intelligent hub (or switch). In this case the core architecture is based on 32-bit MPUs (i960, 68XXX MIPS, 29K. . .) along with 4MB of DRAM for processing management software. The I/O processor is a medium-performance, 32-bit MPU that off-loads the main MPU of that functionality. The ASIC (or ASSP in the future) performs the switching function for a switched hub version). The shared memory is 2 to 8MB of SRAM used to buffer the data. There is also as much as 4 to 6MB of flash/EPROM used for code storage. Routers have a similar architecture.
- More advanced standard NICs are incorporating features such as combining Ethernet and token-ring protocol processing, combining with SCSI host adaptation functions, with super I/O functions (serial/parallel, FDD, and IDE), and even with WAN functions such as modems or ISDN.
- Higher-performance NICs are using 1Mx16 DRAMs for buffering, and all NICs require some EPROM/flash/ICs for card hardware ID and plug-and-play compatibility.
- FDDI chipsets are further integrating to two to three chips. Both copper (CDDI) and low-cost fiber (LED) versions are gaining in popularity.
- ATM NICs are requiring both ASICs and standard parts. Key elements are transceivers (fiber and copper), physical layer processing (PHY), and the AAL/SAR layer-processing elements. The ATM Forum has defined the UNI and UTOPIA standards for the physical and bus interfaces, respectively.
- RF ICs and discretes covering the ISM bands will be needed, along with IEEE 802.11 controllers.

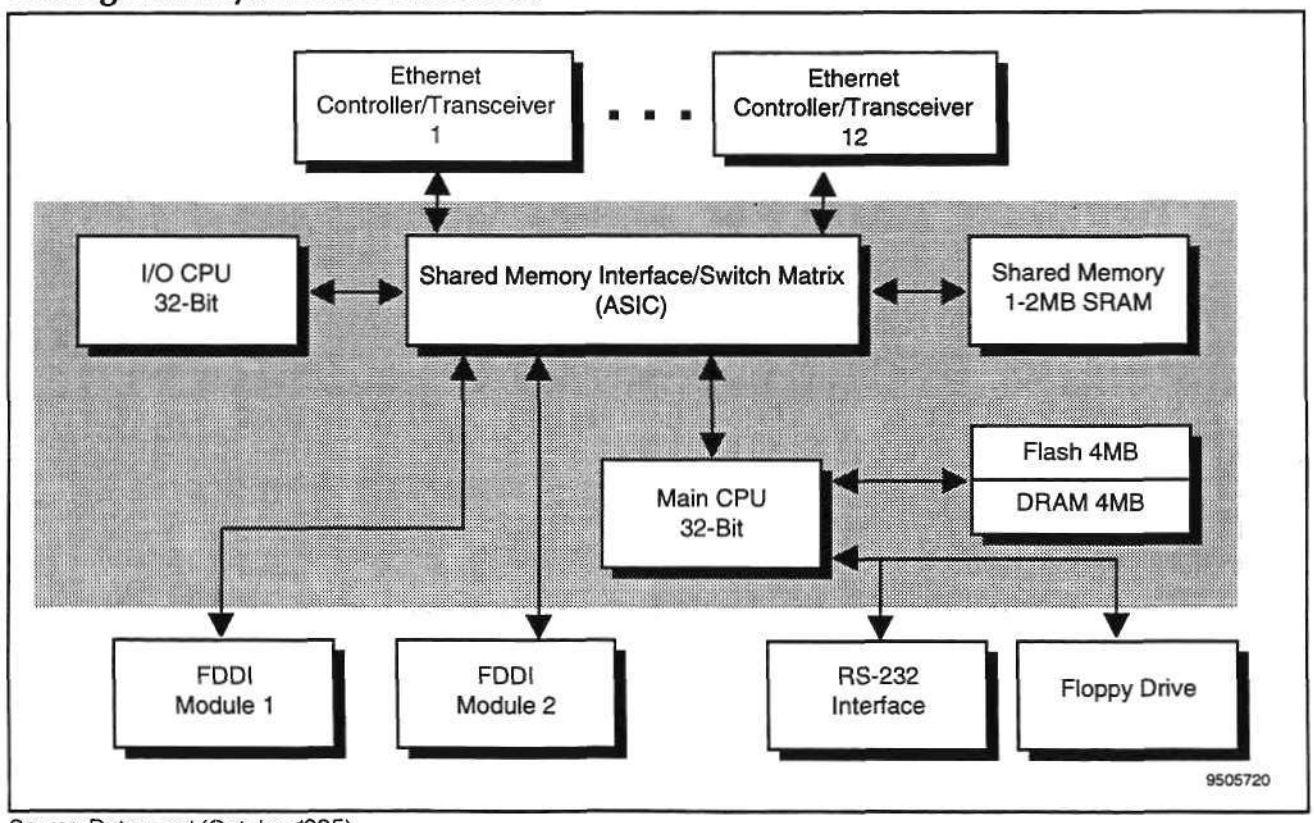
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Figure 2-3
Worldwide Networking Semiconductor Demand



Source: Dataquest (October 1995)

Figure 2-4
Intelligent Hub/Switch Architecture



Source: Dataquest (October 1995)

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OEMs

The following bullets present the key OEMs supplying LAN card, hub, and internetworking hardware.

Leading LAN card OEMs in rank order are as follows:

- 3Com
- Intel
- Standard Microsystems
- D-Link
- IBM
- Microdyne
- Compex
- Madge Networks
- CNET Technology
- Digital Equipment

Leading intelligent hub OEMs in rank order are as follows:

- Bay Networks
- Cabletron Systems
- Chipcom
- 3Com
- Hewlett-Packard
- UB Networks
- Digital Equipment
- IBM
- Optical Data Systems
- Networth

Leading Intranetworking (router) OEMs in rank order are as follows:

- Cisco Systems
- Bay Networks
- Shiva
- Digital Equipment
- 3Com
- CrossComm
- Cabletron Systems
- Gandolf Systems
- Ascom Timeplex
- Advanced Computer Communications

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Leading bridge OEMs in rank order are as follows:

- Gandolf Systems
- Cabletron Systems
- Combinet
- Develcom
- Digital Equipment
- Micom Communications

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Chapter 3
Wide Area Network (WAN) Systems, Modem, Fax, and Videoconferencing

Modems and Facsimile

Market and Feature Trends

The following captures the important market trend information concerning modems and fax machines:

- Modems
  - Table 3-1 and Figure 3-1 present the estimate for worldwide modem shipments in standalone versions, PC add-in card, and PCMCIA card versions. The data includes modem cards capable of fax and other advanced features such as voice mail, speaker phone, and simultaneous voice and data.
  - Near-term shipment growth is being driven heavily by a ramp-up in home modem use in the United States. Home use is for so-called home offices, remote access for work-at-home use, and the rapid rise in popularity of online services such as the Internet, America Online, and CompuServe.
  - PCMCIA card versions are gaining in popularity as notebook computer users desire gaining access to e-mail and databases while not in the office.
  - Growth in many European and other regions continues to be limited by government-controlled public telephone and telegraph (PTT) agencies, which dampen modem ownership. The United Kingdom is an example where privatization of the British Telecom and less restrictive premise equipment ownership is spurring modem sales. The relatively higher availability of basic-rate ISDN lines (and other digital connections) in Europe and Japan is also limiting the growth of modems that operate on analog lines.
  - V.22bis (2400-bps, two-wire, and full duplex) was the most popular standard worldwide in 1993. During 1994, it was surpassed by V.32bis modems (14.4-Kbps and lower, two-wire, and full duplex) in 1994 as prices come down. V.32bis should remain the dominant standard until after 1997, when V.34 (28.8-Kbps) becomes dominant.
  - V.34 (also known as V.Fast) was ratified as a standard and has become an International Telecommunications Union (ITU) standard. The demand for transferring larger, multimedia-rich files is causing users to upgrade to the higher throughput rates. Remote access to office LANs is also driving demand.
  - Most modems now support error correction (MNP 2-4 and V.42) as well as data compression (MNP 5 and V.42bis). There is also a strong trend to add plug-and-play functionality to PC modem cards so they can be installed without concern for the system configuration. Other evolving features include call discrimination, which can distinguish the types on incoming calls, caller ID support, answering machine emulation, business audio I/O, MNP 10 for more robust cellular communication, and universal "worldwide" standards support for call progress and handshaking, among others.

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- An industry group comprising Intel, U.S. Robotics, Rockwell, Creative Labs, and Hayes is creating a standard known as digital simultaneous voice data (DSVD). This protocol, vying for ITU standard status, allows the simultaneous use of a phone line for both voice and data transmission.
- The trend is toward most modems supporting V.17 faxing (14.4-Kbps) in addition to V.29 (9.6-Kbps) and other fax speeds. There also is a trend toward supporting the EIA/TIA-578 Class 1 standard, which extends the "AT" command set allowing the PC application software control over advanced fax functions.
- Telephony (data and fax modem) functions could become more standardized as Microsoft Windows Telephony API (TAPI) feature is issued as a standard feature in Windows 95. This would not only support the plug-and-play rollout but would simplify application developers' jobs by creating a standard software interface capable of using a multitude of modem features.
- Cable modems that can push data at speeds approaching 1 Gbps are being developed by companies such as General Instrument (with Intel), Scientific-Atlanta, and Motorola. Cable modems will help enable the push by cable companies into the telephone/data transmission services area.
- ISDN basic rate (BRI) (56/64-Kbps full duplex plus a data channel, 2B+D) has been rolling out in Europe and Japan for many years. There is renewed interest in the United States recently because Pacific Bell has introduced a residential ISDN service for $22 a month. This was done in conjunction with large online service providers that want to deliver multimedia-rich services to the home. Because of digital and speed advantages, the number of ISDN lines installed is expected to grow to over 10 million worldwide by 1999.
- Intel is soliciting industry interest in its native signal processing (NSP) approach. This would entail using software algorithms to displace many of the digital functions found in a modem system or chipset.

■ Fax machines

- Table 3-2 presents the fax machine forecast. Unit growth is slowing as market saturation nears in most of the developed countries. Developing countries and home offices in countries such as the United States are the main growth opportunities for fax machines.
- The trend toward plain paper machines continues as they lower in price relative to direct thermal transfer. Plain paper should be the majority of shipments by 1996.
- Laser/LED marking engines for plain paper machines are ramping quickly as a percentage of the market. The combination of good printing performance and cost-effectiveness will propel ink jet technology promoted by HP, and Canon should become the volume leader by 1998.
- Network faxing is becoming a reality with client/server fax software that allows users to send and receive documents directly from their PCs as an adjunct to e-mail or perhaps in its absence. The same is true with home PCs. These latter trends are serving to limit the growth of standalone machines capable of scanning.

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- Numerous efforts are under way to push integrated faxing, printing, scanning, and copying technology. Several integrated systems are on the market, targeted at small office/home office users.
- Group 4- or ISDN-based faxing continues to be relegated to a small fraction of the market as line availability, cost, and lack of user interest limit demand. Color fax remains a very small consideration.

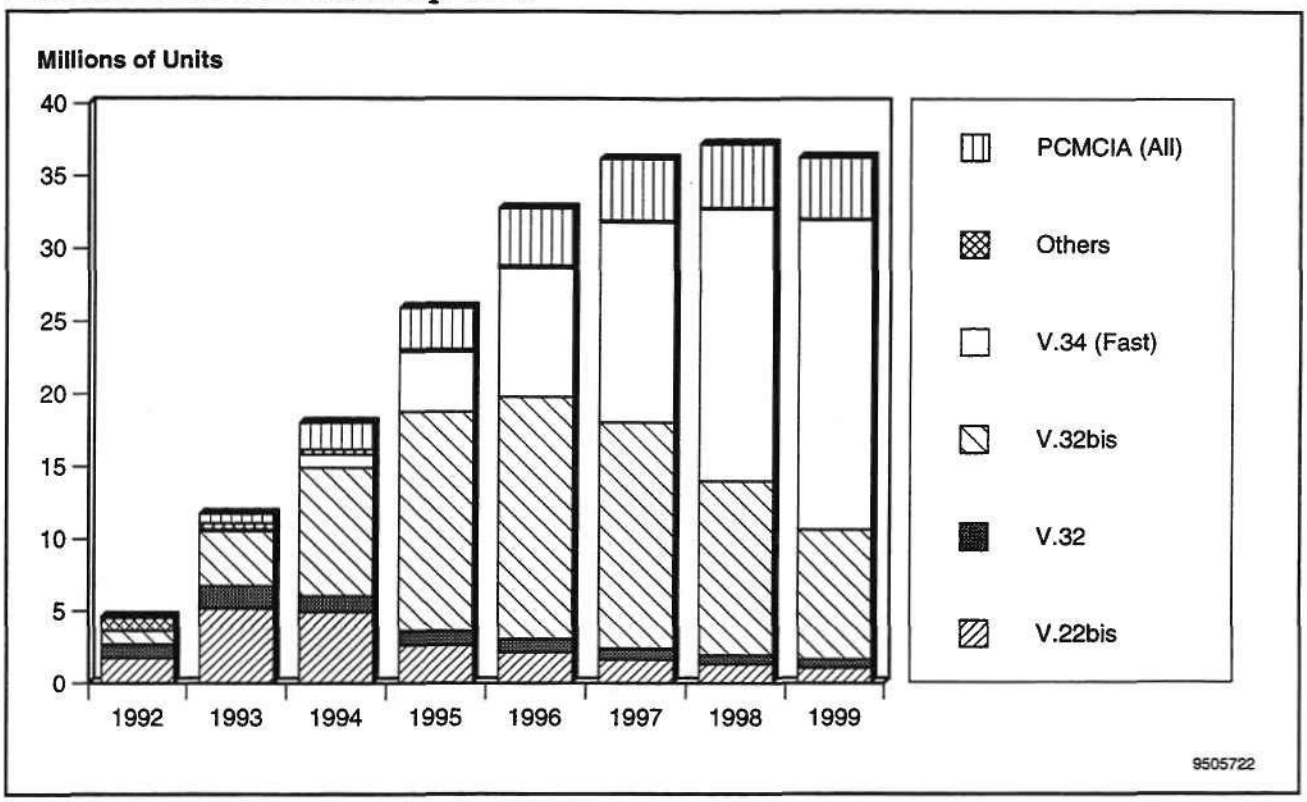
Table 3-1
Worldwide Modem* Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	4,556	11,722	17,972	25,897	32,752	36,171	37,192	36,291	15.1
V.22bis	1,779	5,186	4,960	2,657	2,167	1,652	1,330	1,085	-26.2
V.32	944	1,563	1,103	989	937	776	630	585	-11.9
V.32bis	943	3,798	8,873	15,136	16,695	15,615	12,056	8,985	0.3
V.34 (Fast)	16	104	913	4,136	8,873	13,790	18,758	21,354	87.9
Other	874	455	363	211	163	126	92	92	-24.1
PCMCIA (All)	0	616	1,761	2,768	3,918	4,213	4,327	4,190	18.9
Factory ASP ($)	307	152	132	128	118	111	105	101	-5.2
Factory Revenue ($M)	1,399	1,782	2,372	3,315	3,865	4,015	3,905	3,665	9.1
Semiconductor Content ($)	63	42	40	36	34	33	32	31	-5.0
Semiconductor Market ($M)	286	492	719	932	1,114	1,194	1,190	1,125	9.4
North America									
Unit Production (K)	1,595	3,868	5,571	7,510	8,843	9,043	9,298	9,073	10.2
Production Revenue ($M)	490	588	735	961	1,043	1,004	976	916	4.5
Semiconductor Market ($M)	100	162	223	270	301	298	298	281	4.8

* Includes all types plus those with fax capability
Source: Dataquest (October 1995)

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Figure 3-1
Worldwide Modem Unit Shipments



Source: Dataquest (October 1995)

Table 3-2
Worldwide Fax Machine Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	5,692	7,208	8,723	9,879	10,604	11,161	11,476	12,070	6.7
Factory ASP ($)	641	626	571	519	477	457	464	459	-4.3
Factory Revenue ($M)	3,646	4,513	4,977	5,128	5,062	5,095	5,321	5,536	2.2
Semiconductor Content ($)	79	88	87	82	79	79	83	83	-0.9
Semiconductor Market ($M)	452	634	759	810	838	882	953	1,002	5.7
MPU/MCU ($M)	41	57	68	73	75	79	86	90	5.7
Volatile Memory ($M)	32	44	61	65	71	75	86	90	8.2
Nonvolatile Memory ($M)	14	19	19	20	21	22	24	25	5.7
Modem ($M)	72	101	118	126	126	132	138	145	4.3
ASIC/ASSP ($M)	99	146	182	203	218	238	267	281	9.0
Logic/Analog/ Discrete ($M)	167	228	266	275	276	282	295	311	3.2
Optoelectronics ($M)	27	38	46	49	50	53	57	60	5.7
North America									
Unit Production (K)	211	258	328	384	423	441	420	439	6.0
Production Revenue ($M)	200	199	226	252	270	272	267	261	2.9
Semiconductor Market ($M)	17	21	27	31	34	35	34	35	5.3

Source: Dataquest (October 1995)

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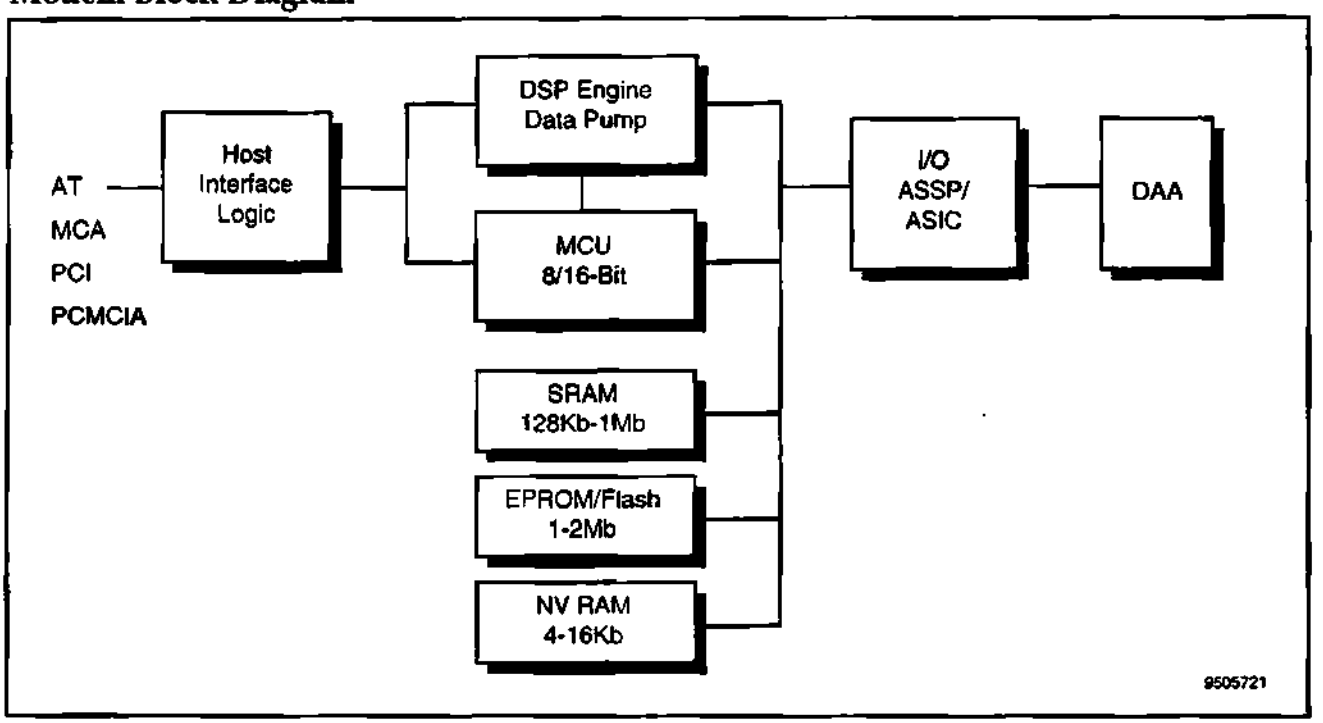
Semiconductor Opportunities

Modems (Data/Fax and Standalone/Card)

Figure 3-2 presents a block diagram of a typical modem capable of data, fax, and voice handling. Key chip opportunities in this application include:

- CMOS DSP-based chipsets (ASSP, ASIC, or pDSP) for implementing the various standards, with V.34/V.17 being the eminent opportunity. These chipsets would need to support many of the feature trends noted earlier. Ultimately, predominantly 3V versions will be needed. Mbps versions will be required for emerging cable (coax) versions.
- For PC card/PCMCIA versions there will be a migration toward PCI and PCMCIA bus interfaces that support plug-and-play Microsoft versions.
- There will be 128Kb to 1Mb of SRAM (trend toward 35ns or faster) for V.42 compression, among others.
- There will be 1 to 2Mb of flash or EPROM for control code storage.
- There will be 4 to 16Kb of EEPROM or NVRAM for power-down configuration storage.
- There will be RS-232 drivers and receivers, and optoisolators. Future interface alternatives include Geoport (Apple) support.

Figure 3-2
Modem Block Diagram



Source: Dataquest (October 1995)

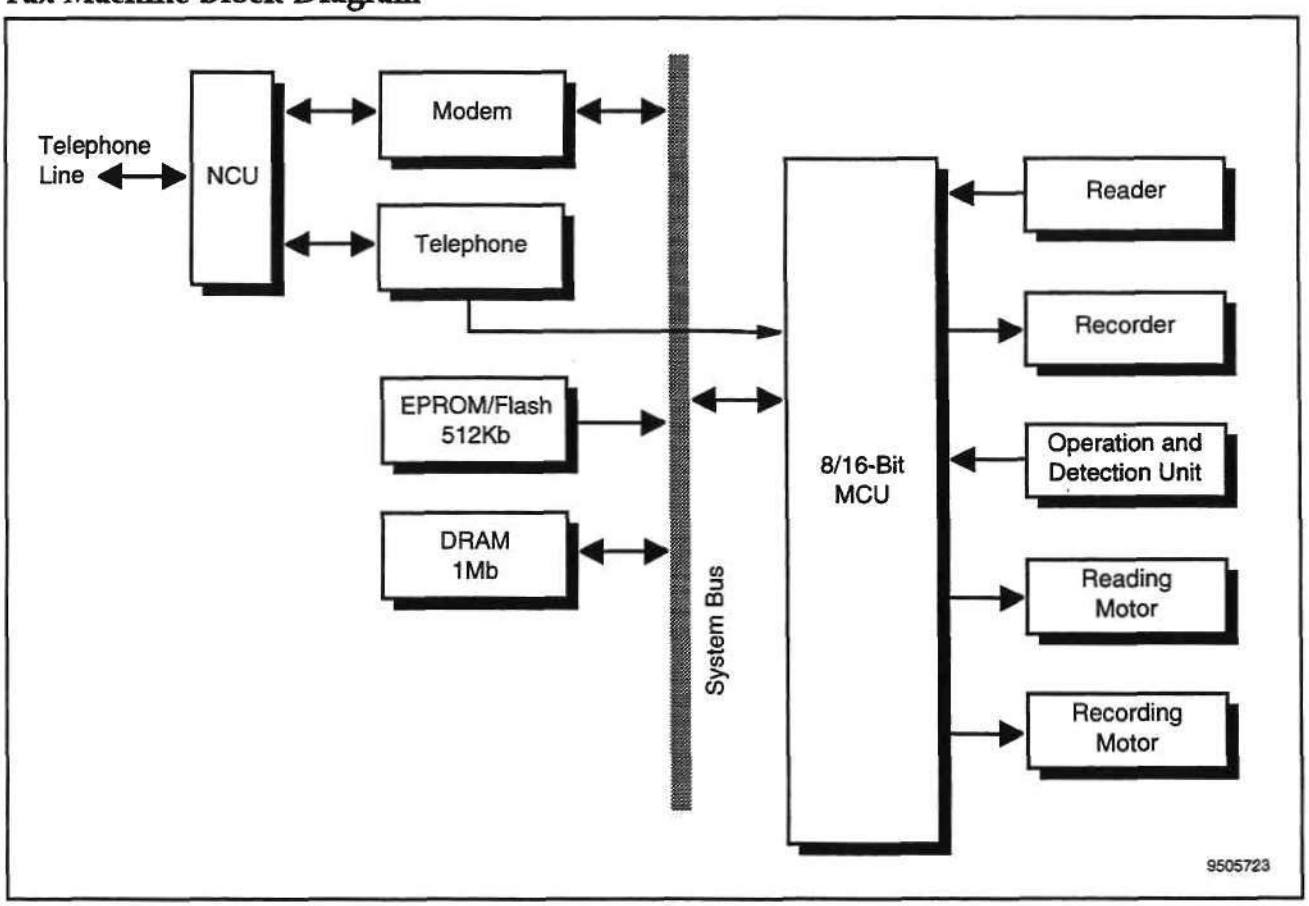
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Fax Machines

The trend toward more digital controls continues. Figure 3-3 shows a generic block diagram. Highlights in this segment are as follows:

- New fax modem chips supporting V.17 and earlier specifications – standard telephony functions including dialer and tape answering machine controls; ISDN versions require an S-interface controller, an LAP-D controller, and a rate adapter
- Memory requirements for DRAM page buffer 1Mb (predominantly) to 4Mb and flash/EPROM code storage for 0.5 to 1Mb
- 8-bit MCU (predominantly) through to 16- or 32-bit MPU to support advanced processing features, plus standard telephony/motor/sensor/front panel control
- Motor drivers, linear CCD (8 pixels/mm or greater), and CCD support circuitry

Figure 3-3
Fax Machine Block Diagram



Source: Dataquest (October 1995)

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OEMs

The following bullets list the leading brand names in modems in fax machines. The modem market tends to be dominated by U.S. companies, whereas the fax machine market is dominated by Japanese companies. It should be noted that ASCII of Japan and GVC of Taiwan are cited as large modem OEMs producing for several of the leading brands.

Leading modem marketers in rank order are as follows:

- GVC Technologies
- U.S. Robotics
- Hayes Microcomputer
- Zoom Telephonics
- Practical Peripherals
- Boca Research
- Megahertz
- Motorola
- AT&T Paradyne
- Multitech Systems

Leading fax machine marketers in rank order are as follows:

- Sharp
- Panasonic/Matsushita
- Canon
- Muratec
- Toshiba
- Brother
- Hewlett-Packard
- Funai
- Samsung
- Ricoh

Digital WAN Equipment (T/E-Carrier, Cell/Frame Relay, ATM, and ISDN)

Market and Feature Trends

The following highlights some of the market trends in WAN equipment:

- Digital WAN equipment is increasingly being used to extend campus LANs across wide geographic areas. Newer WAN technology can support server and real-time video traffic in addition to voice and data. New technologies include a group of fast packet switching approaches including frame relay, switched multimega digital services (SMDS), and ATM. Figure 3-4 details some of the differences among these technologies.

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- Key digital WAN equipment includes T/E-1&3 carrier multiplexers, fractional and sub-T1 multiplexers, cell switches (ATM and SMDS), frame relay switches and access devices (Frame Relay), X.25 PADs and switches, and ISDN terminal adapters.
- Table 3-3 presents the outlook for digital WAN systems and derived semiconductor demand. The fastest-growing segments are ISDN adapters, T3 multiplexers, and fast cell/frame relay switches.
- Although technically not a new WAN technology, ISDN is expanding rapidly in Europe and Japan and is beginning to grow in the United States. Demand for basic rate (128Kb full-duplex) for the desktop or home and primary rate (1.5-Mbps) for business and institutions is being served initially by adapter units and computer add-in cards. LAN internetworking equipment such as routers are also starting to support ISDN interfaces. ISDN basic rate service is available for under $30 per month in the United States. The availability of ISDN-capable lines, reasonably priced services, and adapters rapidly heading to less than $300 in price is stimulating demand. The most pervasive use of ISDN to date appears to be the displacement of switched 56- to 64-Kbps services to support desktop videoconferencing, Internet and remote access.
- Frame relay is rapidly becoming the dominant WAN Service in the United States and Europe. Its cost-effectiveness is converting users from other services like Switched 56, X.25, and even T1 leased lines.
- As files get longer and the traffic richer with multimedia content and the need for isochronous connections (real time) for videoconferencing expanding, the demand for speed is expected to increase. The ATM/SDH rate of 155 Mbps is positioned to be a popular speed to serve the WAN market. T3/E3 is gaining some ground as an intermediate speed feature.
- Another alternative known as SMDS is based on the IEEE 802.6 MAN standard. This technology has not proved attractive to end users as ATM is perceived as a better long-term solution.
- Overall it appears as though narrow band ISDN (128-Kbps) and ATM could become the principal digital WAN technologies in operation by the year 2000. X.25 should slowly fade away and Frame Relay and SMDS will find some "large" niche use in the meantime as offered by certain service providers.

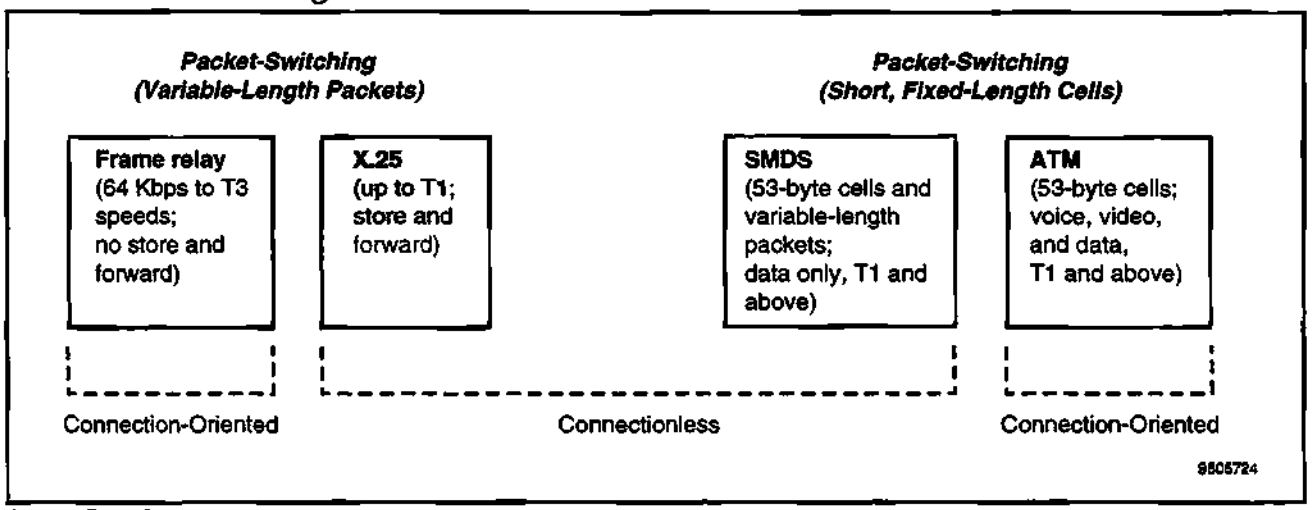
Semiconductor Opportunities

Principal digital WAN chip opportunities include:

- T-Carrier ICs and ASIC library elements (transceivers, framers, and mux, among others)
- S/T and U interface, LAP-D, rate conversion controllers for ISDN adapter cards
- HDSL line controllers
- ATM standard ICs and ASIC elements: transceivers (copper/fiber), physical interface (UNI, Saturn, and Utopia), AAL (5/1) and SAR, switching elements, and content addressable memory
- Volatile and nonvolatile memory: 4- to 64MB per switch

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Figure 3-4
Fast Packet Switching



Source: Data Communications

Table 3-3
Worldwide Digital WAN Equipment Application Market Estimates

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	850	1,120	1,442	1,891	2,373	2,888	3,566	26.1
Time Division Multiplexers	185	204	209	216	223	233	243	3.6
64 Kbps and Below	87	67	62	57	52	48	44	-8.0
T-1/E-1 and Below Muliplexers	69	108	117	126	136	147	159	8.0
Backbone Multiplexers	29	29	30	33	35	37	40	7.0
Inverse Multiplexers	9	19	27	43	61	79	86	35.3
DSU/CSUs	472	532	585	644	689	723	759	7.4
ISDN Adapters (Standalone, Cards)	122	238	456	776	1,125	1,512	2,075	54.2
X.25 PADS	62	66	68	70	70	69	65	-0.2
Cell/Frame Relay Access/Switches	0	61	97	143	205	273	338	40.8
Factory ASP ($)	2,618	2,582	2,467	2,294	2,194	2,073	1,931	-5.6
Factory Revenue ($M)	2,224	2,891	3,556	4,339	5,206	5,987	6,886	19.0
Semiconductor Content ($)	275	284	296	298	307	311	309	1.7
Semiconductor Market ($M)	234	318	427	564	729	898	1,102	28.2
North America								
Unit Production (K)	680	885	1,125	1,456	1,780	2,137	2,603	24.1
Production Revenue ($M)	1,779	2,284	2,774	3,341	3,905	4,431	5,026	17.1
Semiconductor Market ($M)	187	251	333	434	547	665	804	26.2

Source: Dataquest (October 1995)

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OEMs

Principal OEMs supplying digital WAN equipment in rank order are as follows:

- Newbridge Networks
- Ascom Timeplex
- NET
- Micom
- Tellabs
- Telco
- Cray Communications
- Stratacom
- Motorola
- AT&T
- Cascade

Videoconferencing

Market and Feature Trends

Videoconferencing comprises room systems fixed in place, roll-about systems based on movable carts, desktops based primarily on PCs, or workstation-based enhancements with add-in cards and a camera/microphone input. Video telephones are primarily consumer-targeted items with lesser capability. The following comprises some of the principal market and product feature trends:

- In general this market continues to gain notoriety as efficient, downsized companies turn to videoconferencing as a means of improving internal productivity and customer communications. This technology is finding great use in vertical markets such as telemedicine, teletraining, and tele-education, where limited professional personnel can be more effectively used.
- Room systems have served much of the need until recently when roll-about systems became popular. In general these systems are integrated with the main elements: the video/audio compression/decompression (codec), displays, cameras, speakers, microphones, computer interfaces (for presentation, graphics, and scanned images), remote control units, and multipoint control units for three-way or more conferences. Perhaps the most defining element is the software, which manages user interface, the computer interface, and the telephone network.
- Room/roll-about systems are feature-rich and typically allow 640 x 480-pixel resolutions at 30 frames per second (depending upon the type of line leased). Most of the recent entries by the established videoconferencing players support the ITU H.320 standard, which is an open standard specifying various protocol, formatting, and compression features. The established videoconferencing vendors continue to sell proprietary approaches, while also supporting the interoperable H.320 standard. H.320 uses the H.261 real-time, compression standard, whereas Compression Labs, for example, uses its proprietary CDV algorithm.

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- Key to establishing a videoconferencing link is that various telephone lines can be used. Most high-performance setups use a T1/E1 (1.5- to 2-Mbps) or fractional T1 (384-Kbps) link to transfer the video, audio, and support data and control signals. Because these lines are expensive to lease, lower-performance conferencing systems operate over switched 56-Kbps or ISDN basic rate lines (128-Kbps).
- The latest incarnation of videoconferencing is the enhancement of the PC or workstation into a personal conferencing system. This system today generally requires two add-in boards (including an ISDN or modem connection), a camera, a speaker, and a microphone. Systems capable of 320 x 240 video at 15 frames per second can cost $2,500. Prices should drop to less than $1,000 per seat as volumes develop (or vice versa).
- Desktop videoconferencing should be aided by an initiative established by Intel and Microsoft that brings a standard telecommunications applications interface to Windows/Chicago (Windows 95), known as TAPI. This, along with the display control interface (DCI) capability that supports multiple software and hardware codecs, should aid in the ease of software development and interoperability. H.320 is clearly heading toward being the most heavily supported desktop videoconferencing standard.
- Video phones continue to offer the consumer marginal frame rate performance relative to the price. Higher-performance versions operating at V.34 and ISDN basic data rates will improve their performance and appeal dramatically before the end of the decade. H.324 is a proposed ITU standard using the V.34 interface.
- Table 3-4 presents a forecast of videoconferencing systems and the accompanying semiconductor demand. The basic underlying assumptions include continued growth in the high-performance systems as user needs continue to expand. Desktop systems are expected to take two to three years to develop into significant volume as user familiarity, the price per seat, performance, interoperability, and software applications issues are worked out. Another large issue concerns the bandwidth of a telephone line. However, competitive ISDN service for less than $30 per month plus declining prices on the traditional WAN services (T1 and fractional T1) will help lower acquisition barriers.

Semiconductor Opportunities

Figure 3-5 presents a block diagram of typical videoconferencing system. Key semiconductor opportunities are noted as follows:

- Real-time, symmetrical, codec ICs; key standards include H.261, Indeo, and various other proprietary algorithms
- ITU G.711 and 772 (ADPCM) audio codecs; the TrueSpeech speech compression licensed by the DSP Group and supported by Microsoft could become popular for videoconferencing as well
- Digital video and audio ICs (data conversion, color space, scaling, mixing, amplification, filtering, and A/V synchronization)
- 1 to 8MB of DRAM (plus EDO and synchronous varieties) or VRAM for buffer
- V.34 modems, ISDN (S/T and LAP-D), T1/E1 or fractional T1 functions, and LAN controller
- ASIC integration variations of those listed using CMOS and some BiCMOS or bipolar technology

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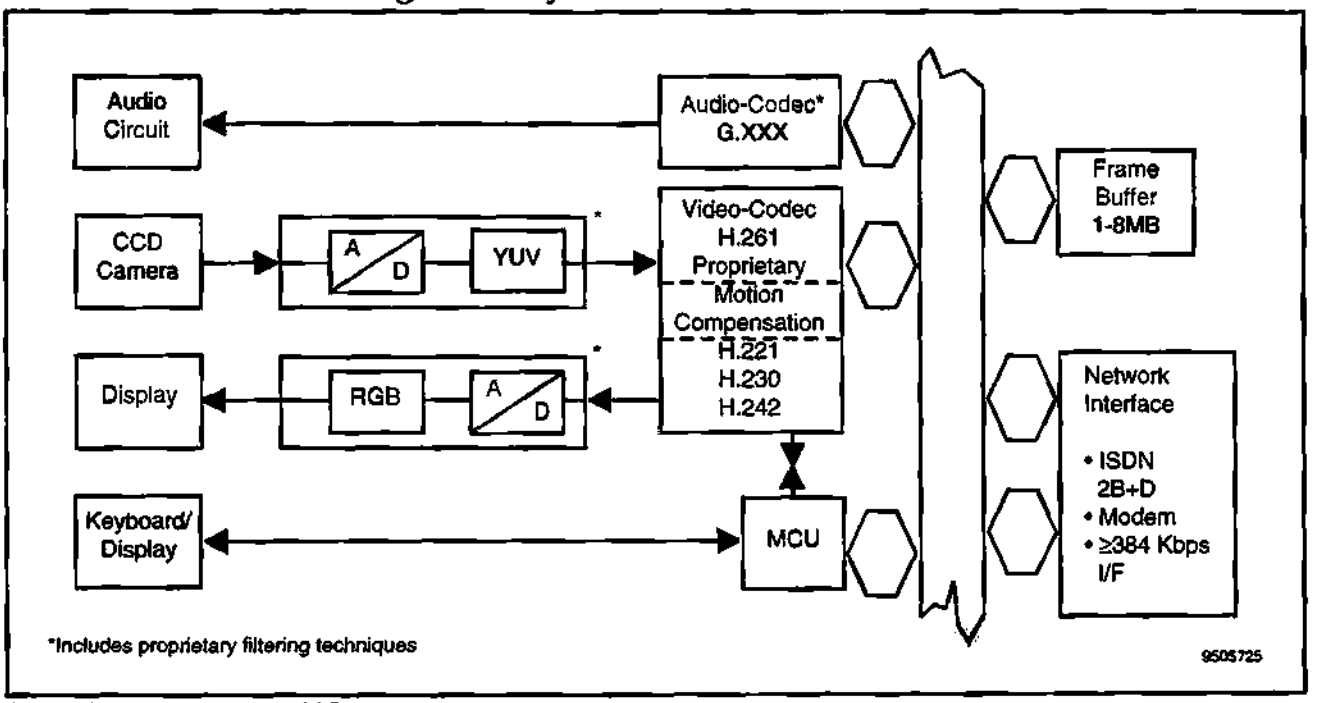
Table 3-4
Worldwide Videoconferencing/Phones Application Market

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Conferencing									
Units (K)	12	36	87	133	197	411	891	1,905	85.3
Room/Roll-About	6	8	13	17	21	24	25	24	12.0
Desktop	6	28	74	115	176	387	867	1,881	91.2
Factory ASP ($K)	27	13	6	6	4	3	2	1	-26.0
Factory ASP Room/ Roll-About ($K)	49	42	32	27	23	21	19	17	-11.8
Factory ASP Desktop ($K)	5.1	4.8	1.7	2.4	1.9	1.5	1.2	1.2	-6.5
Factory Revenue ($M)	331	467	548	738	818	1,077	1,508	2,657	37.1
Factory Revenue Room/ Roll-About ($M)	299	331	424	462	483	497	468	400	-1.2
Factory Revenue Desktop ($M)	32	136	124	276	335	580	1,040	2,257	78.7
Phones									
Units (K)	53	83	97	157	271	429	914	1,827	79.9
Factory ASP ($)	1.10	0.90	0.65	0.54	0.48	0.44	0.37	0.30	-14.3
Factory Revenue ($M)	56	75	63	85	130	189	338	548	54.2
Semiconductor Content ($)	592	455	365	341	264	211	153	137	-17.8
Semiconductor Market ($M)	39	54	67	99	123	177	277	513	50.1
MPU/MCU ($M)	3	4	5	7	9	12	19	36	50.1
Memory ($M)	5	6	7	11	14	19	30	56	50.1
ASIC/ASSP ($M)	27	38	48	71	88	127	198	367	50.4
Logic/Analog/ Discrete ($M)	4	5	7	10	12	17	27	50	49.8
Optoelectronics ($M)	0	1	1	1	1	2	3	5	50.1
North America									
Unit Production (K)	52	93	129	188	281	462	939	1,940	72.0
Production Revenue ($M)	310	422	428	535	569	696	960	1,603	30.2
Semiconductor Market ($M)	31	42	47	64	74	97	144	267	41.5

Source: Dataquest (October 1995)

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Figure 3-5
Generic Videoconferencing/Phone System



Source: Dataquest (October 1995)

OEMs

Leading videoconferencing/phone OEMs in rank order are as follows:

- Picturetel
- Compression Labs
- GPT
- VTEL
- Intel
- IBM
- AT&T
- Creative Labs (Share Vision)
- Hitachi
- NEC

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Chapter 4
Premise Switching and Call Processing Systems

Market and Feature Trends

Principal trends with voice communications equipment such as PBXs, key telephone systems (KTS), voice messaging (VM) systems, interactive voice response (IVR), and automatic call distribution (ACD) systems include:

- PBXs and KTSs will remain the central premise equipment in nonresidential voice communications. The other voice systems are typically used as adjuncts to PBXs. The main market attraction of these systems is for productivity purposes and thus they are very sensitive to capital spending cycles. They are enjoying a general upswing in the developed countries and new penetration in places such as eastern Europe, Latin America, and Asia.
- KTS phone systems are principally used by smaller companies with two or more lines. They typically do not require an access code, as PBXs do, but do provide various features such as holding (plus music) and intercom. In general KTSs are turning to digital processing as new models emerge. There are about as many KTS lines shipped as PBX lines. This market is very mature and is expected to remain flat over the forecast time frame.
- PBXs continue to add value by incorporating many new features, including:
  - Wireless options, with offerings emerging from many including Ericsson (CT-3), Spectralink, and Northern Telecom. DECT wireless technology is mentioned often as a solution for wireless offices.
  - Computer telephony integration (CTI) describes a general trend toward PBXs being modified to support LAN and WAN environments. Today many PBXs can connect to servers or intelligent hubs, with Novell's NetWare being the most popular network operating system. Microsoft and Intel are evangelizing the TAPI technology as a means of standardizing the software interface to telecom premise equipment.
  - Most PBXs can now optionally offer T1/E1 and ISDN primary and basic rate trunk line interfaces. Future other WAN features such as ATM, T3, routers, and modems are not out of the question as the PBX vendors attempt to do battle with the networking vendors.
  - PBXs will also trend to offer support for fax and audio/video store-and-forward as well as real-time support for videoconferencing.
- Voice message system unit growth will continue robustly into small businesses that do not have these systems yet but can afford them. These systems continue to offer more features including larger message capacity, thanks to lower disk drive prices. Some of the market continues to be absorbed by PBX systems integrating this functionality.
- IVR, as a newer technology, continues to emerge as it moves away from the United States into other markets. These systems continue to find good interest from almost any organization (banks and pension funds,

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among others) with customer or public support requirements for information that can easily be accessed with key telephone button strokes. Planned improvements include speech recognition.

- ACDs distribute phone calls to waiting agents (airlines, among others). They will continue to push into smaller operations willing to stay competitive. This function is also being absorbed by PBXs equipped with ACD software, but separate functionality remains a robust market.

Tables 4-1 through 4-4 present the worldwide market for these voice systems and their accompanying semiconductor demand.

Table 4-1
Worldwide PBX/KTS Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
System Units (K)	1,477	1,400	1,452	1,532	1,631	1,738	1,853	2,004	6.7
Lines/Stations (K)	23,009	24,204	26,134	27,670	29,525	31,511	33,849	36,420	6.9
Factory ASP ($K)	6	7	7	7	7	7	8	8	0.8
Factory Revenue ($M)	9,428	9,546	10,535	11,229	12,024	12,881	13,929	15,113	7.5
Semiconductor Content ($)	581	641	697	711	723	741	774	792	2.6
Semiconductor Market ($M)	858	897	1,011	1,089	1,178	1,288	1,435	1,587	9.4
ASIC/ASSP	515	538	605	654	704	769	848	938	9.2
Memory	120	135	162	180	200	219	251	278	11.4
MPU/MCU	77	82	93	100	110	120	135	149	9.9
Others	146	144	152	156	165	180	201	222	7.9
North America									
Unit Production (K)	443	406	407	414	424	434	445	481	3.4
Production Revenue ($M)	2,828	2,768	2,950	3,032	3,126	3,220	3,343	3,627	4.2
Semiconductor Market ($M)	257	260	283	294	306	322	344	381	6.1

Source: Dataquest (October 1995)

Table 4-2
Worldwide Interactive Voice Response System Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	8	12	20	26	34	44	56	72	29.4
Factory ASP ($K)	71	59	44	45	46	47	49	49	2.4
Factory Revenue ($M)	569	675	873	1,180	1,566	2,079	2,739	3,566	32.5
Semiconductor Content ($)	2,488	2,054	1,552	1,610	1,667	1,706	1,774	1,798	3.0
Semiconductor Market ($M)	20	24	31	42	56	75	100	130	33.2
North America									
Unit Production (K)	7	11	18	23	30	39	49	62	27.9
Production Revenue ($M)	529	621	795	1,062	1,393	1,829	2,383	3,067	31.0
Semiconductor Market ($M)	19	22	28	38	50	66	87	112	31.7

Source: Dataquest (October 1995)

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Table 4-3
Worldwide Voice Messaging Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	39	62	84	109	142	175	213	256	25.0
Factory ASP ($K)	28	22	21	22	24	24	24	23	2.4
Factory Revenue ($M)	1,101	1,337	1,735	2,422	3,349	4,226	5,147	5,979	28.1
Semiconductor Content ($)	1,819	1,429	1,431	1,552	1,676	1,737	1,764	1,730	3.9
Semiconductor Market ($M)	72	88	120	170	238	304	376	442	29.9
North America									
Unit Production (K)	37	56	74	95	121	145	174	205	22.4
Production Revenue ($M)	1,024	1,217	1,544	2,107	2,846	3,507	4,195	4,783	25.4
Semiconductor Market ($M)	67	80	107	148	202	253	306	354	27.1

Source: Dataquest (October 1995)

Table 4-4
Worldwide Automatic Call Distributor Application Market Estimates

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Units (K)	7	10	13	16	19	22	26	31	19.9
Factory ASP ($K)	88	74	71	75	75	77	76	73	0.6
Factory Revenue ($M)	644	727	884	1,167	1,421	1,705	1,959	2,261	20.7
Semiconductor Content ($)	2,647	2,226	2,192	2,334	2,406	2,458	2,515	2,407	1.9
Semiconductor Market ($M)	19	22	27	36	45	55	65	75	22.2
North America									
Unit Production (K)	5	7	9	10	12	14	16	20	18.1
Production Revenue ($M)	451	502	601	782	938	1,108	1,254	1,424	18.8
Semiconductor Market ($M)	14	15	19	24	30	35	41	47	20.3

Source: Dataquest (October 1995)

Semiconductor Opportunities

Semiconductor opportunities are as follows:

- Architecturally, PBXs are now bus-oriented (VME, among others), modular systems that allow for the easy upgrade of various voice, LAN, and WAN options.
- In general the trend is toward more memory as more processing and CTI features are added. PBXs today have 2 to 16MB of DRAM, which could double during the next five years. VM, IVR, and ACD systems have 2 to 10MB typically. All of these systems employ 1 to 4MB of EPROM/flash for control code and to support various power-down and backup modes. These systems also tend to be large users of FIFOs and other specialty memory.

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- 32-bit MPUs are used in PBXs, ACDs, IVRs, and VMs. Often multiple (two to four) processors are employed, divvying up various host and I/O functions. x386 appears to be the most popular, but 80960, 68K, and RISC CPUs such as the R3000 are making it into some designs. To manage individual or groups of line cards, 8-bit MCUs are often employed.
- Perhaps the largest opportunity is for line card circuits (for all the voice systems) and switch matrixes that manage either analog POTS phones, the digital phones (either ISDN or PCM), and PSTN interfaces for POTS, ISDN (BRI/PRI), and T1. Although many of these functions are standard ASSPs, many OEMs choose to use ASIC approaches. Many of these functions are appearing in CMOS or BiCMOS form, depending upon specific use. Specific functions and library functions include:
  - Slice Codecs/filters (uLaw, aLaw, PCM— 9.6 Kbps through 64 Kbps)
  - ISDN functions (S/T, U, LAP-D, and echo cancelers)
  - T1/E1 transceivers and framers
  - Cross-point switches
  - Various integrations of those listed, plus other features

OEMs

Leading PBX/KTS OEMs in rank order are as follows:

- AT&T
- ROLM/Siemens
- NEC
- Alcatel
- Bosch
- Philips
- Ericsson
- Toshiba
- Mitel
- Fujitsu

Leading interactive voice response systems OEMs in rank order are as follows:

- AT&T
- InterVoice
- Periphonics
- IBM
- Syntellect
- Brite Voice
- Stylus

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- Computer Communications ETC
- Voicetek

Leading interactive voice messaging system OEMs in rank order are as follows:

- Octel
- Northern Telecom
- AT&T
- Active Voice Technology
- ROLM/Siemens
- Applied Voice Technology
- Centigram
- Unisys

Leading automatic call distributor OEMs in rank order are as follows:

- AT&T
- Northern Telecom
- ROLM/Siemens
- Aspect Telecommunications
- Ericsson
- Rockwell
- EXECUTONE
- Philips
- Alcatel

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Chapter 5
Public Switching and Transmission Systems

Market and Feature Trends

Key equipment involved in the public switching and transmission markets are central office switches and fiber-optic and nonfiber-optic transmission systems consisting of primarily digital cross-connects, multiplexers, and repeaters. Transmission systems comprise the local telephone line (local loop), the trunk lines (conduits between switches), and the long distance lines. In the United States, there are separate, privately owned local (regional Bell operating companies—RBOCs—or Baby Bells) and long distance (AT&T and MCI, among others) telephone service companies that invest in this equipment. In most of the rest of the world, there is generally a single state-controlled PTT of telephone and data transmission services. There is a trend toward privatizing many of these, however, and Japan (NTT), the United Kingdom (British Telecom), and Mexico (Telephonos de Mexico) have sold majority stakes of their PTTs to investor interests.

The following describes key trends in the public switching and transmission markets.

- Principal new line shipments will occur in eastern Europe, China and the rest of Asia, and Latin America. Line shipments in the United States will decline throughout forecast period as the conversion to digital is completed and replacement economics takes over. Western Europe is also expected to slow growth in line shipments, while Japan has delayed much of its planned national fiber-optic rollout until the next decade. Tables 5-1 and 5-2 show a market forecast of public switching and transmission equipment and accompanying semiconductor demand.
- The traditional PTTs are under attack, however, especially in the United States. Companies known as competitive access providers (CAPs) are being allowed to compete for services. The most visible CAP contenders are the cable TV companies, which have plenty of bandwidth on their fiber/coax systems and can provide a host of traditional telecommunications services including data transmission for corporate users and videoconferencing. Pending deregulation legislation in the U.S. Congress could have the impact of sparing investment in local phone access and long distance services.
- The other major battle is for interactive, TV-based services to the home. The combatants are the telephone companies, cable TV companies, and a wave of new companies exploiting wireless links. At stake is a potential annual market worth $25 billion (in the United States alone) or more in interactively delivered services. Interactive services would include pay-per-view movies delivered individually to each home at any time, directories, extension education programs, and home banking and shopping. From a switching and transmission standpoint, these services will demand a new generation of high-bandwidth, two-way-capable delivery systems.

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- The major technical trend in public equipment is the conversion to digital techniques for transmission and switching and the increasing use of high-speed fiber-optics for transmission.
- There continues to be a significant increase in the number of ISDN lines in the United States, joining progress in Europe and Japan, as a new set of standards known as ISDN-1, -2, and -3 allow equipment from different manufacturers to be interoperable. Several U.S. RBOCs have recently started monthly basic-rate (128-Kbps full-duplex) ISDN services for less than $30 per month. These services support such features as videoconferencing and more sophisticated audio, video, and graphical interaction with the Internet, America Online, and other online services.
- Fiber-optic rollout is moving from the trunk lines between central office switches or cable TV headend equipment to being inserted in the local loop to the subscribers. This trend is known as fiber-in-the-loop or FITL. The most popular fiber transmission standard is known globally as SDH and in the United States as SONET. It is scalable from 155 Mbps, known as STS-12, to 2 Gbps or more.
- To support video-on-demand (VOD) and other high-bandwidth services, a technology that uses fiber optics to the last few hundred homes and then coax cables to the home itself is being developed. It is known as Hybrid Fiber-Coax (HFC). Figure 5-1 illustrates such a system.
- Key equipment used in fiber-optic transmission includes various types of multiplexers (add-drop, among others), repeaters inserted every few thousand feet to refresh the optical signal, optical line terminals that terminate optical signals at the switch, and optical network units (ONUs). Next-generation digital loop carrier (NGDLC) systems bring the fiber to the neighborhood and convert the optical signal to electrical for use on coax or twisted-pair. NGDLCs form the backbone of the hybrid fiber/coax systems being installed by the phone and cable TV companies.
- ATM and asymmetrical digital subscriber loop (ADSL) technologies are also scrambling to be chosen in next-generation broadband systems. ATM is a scalable, bandwidth-on-demand switching technology that employs a standard 53 bytes cells to move multimedia traffic. It is being tested by the service companies around the world, with large-scale rollout not expected to begin until 1996 at the earliest. ADSL is a DSP-based technology that stretches the bandwidth of traditional local loop twisted-pair technology to handle MPEG-2 (6-Mbps) bit streams delivering movies to the home. Developed by Bellcore, this technology is being evaluated as an alternative or bridge to fiber/coax delivery by companies in the United States and Europe. There is a possibility of several million ADSL nodes being shipped by the end of the century.
- Radio-in-the-loop (RITL) is also emerging as an alternative service providers for minimizing expensive infrastructure investment. This technique has been used by the cable TV community for years but is now also being used by the telephone companies in rural areas. Several of these systems operate in the microwave frequencies above 10 GHz. It is possible that radio could be used in as many as 5 million local loop lines by the end of decade.

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Table 5-1
Worldwide Central Office Switch Application Market

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Lines (K)	42,237	48,054	49,609	51,823	53,651	55,841	58,512	61,438	4.4
Factory ASP ($)	363	327	325	324	328	324	325	325	0.1
Factory Revenue ($M)	15,316	15,711	16,100	16,798	17,606	18,120	19,040	19,992	4.4
Semiconductor Content ($)	26	24	24	25	25	25	26	26	1.4
Semiconductor Market ($M)	1,118	1,163	1,207	1,277	1,356	1,413	1,504	1,599	5.8
North America									
Unit Production (K)	13,630	14,929	15,005	14,418	13,897	13,604	13,495	13,521	-2.1
Production Revenue ($M)	2,777	3,005	2,955	2,811	2,640	2,557	2,496	2,501	-3.3
Semiconductor Market ($M)	284	311	313	303	291	287	286	290	-1.5

Source: Dataquest (October 1995)

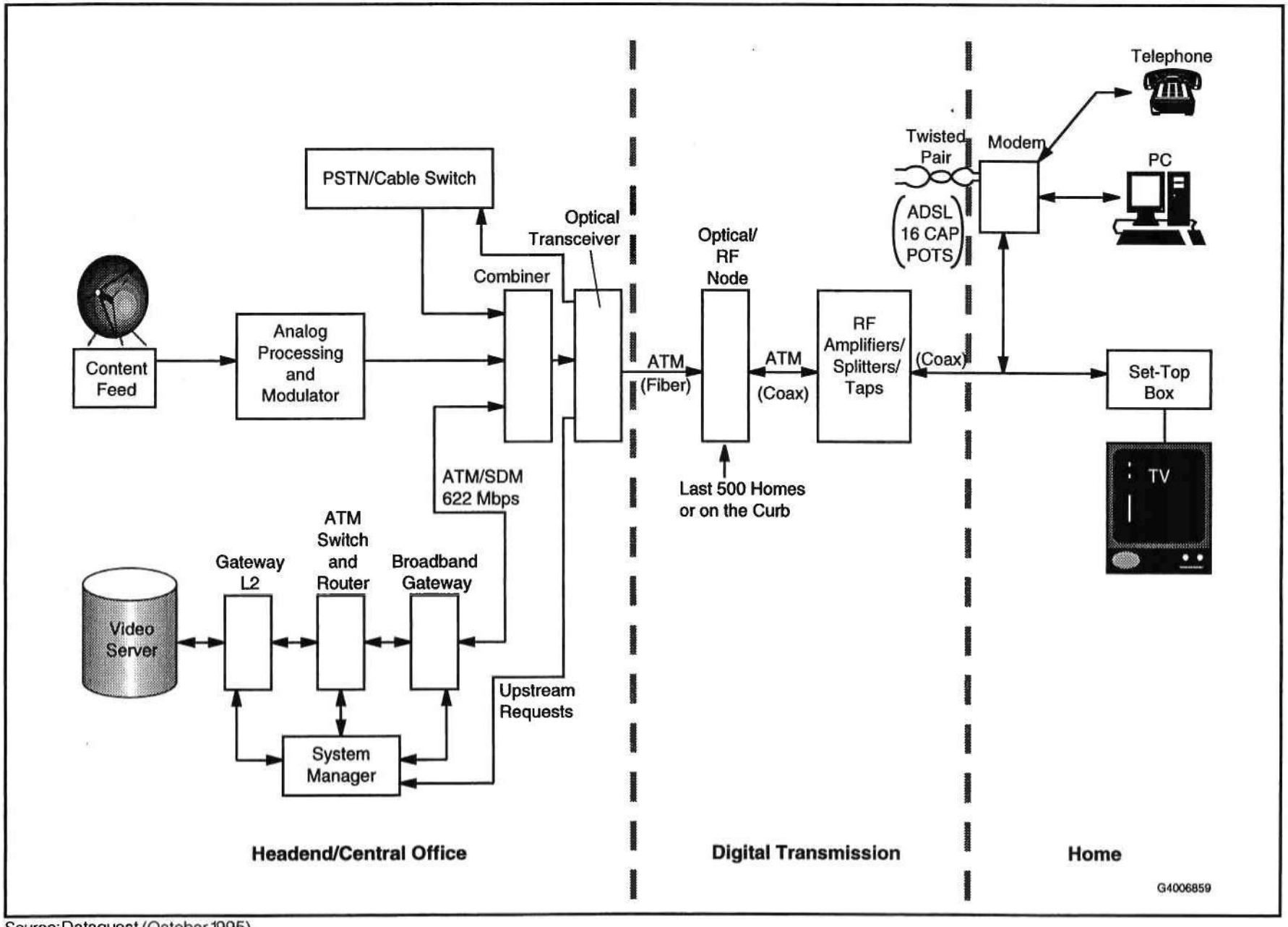
Table 5-2
Worldwide Public Transmission Equipment Application Market

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Factory Revenue ($M)	14,989	17,124	19,542	21,345	23,619	25,901	27,864	34,921	12.3
SONET/SDH Multiplexers	448	1,108	1,802	2,203	2,624	2,972	3,349	3,800	16.1
Non-SONET/SDH Multiplexers	2,551	2,192	1,933	1,418	1,005	759	528	286	-31.8
Digital Cross Connects	1,176	1,296	1,617	1,926	2,169	2,358	2,599	2,904	12.4
Local Loop	10,814	12,528	14,190	15,797	17,820	19,811	21,388	27,930	14.5
Semiconductor Market ($M)	1,109	1,284	1,485	1,644	1,842	2,046	2,229	2,794	13.5
North America									
Production Revenue ($M)	3,046	3,588	5,215	5,643	6,754	7,632	8,643	11,505	17.1
Semiconductor Market ($M)	225	269	396	435	527	603	691	920	18.4

Source: Dataquest (October 1995)

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Figure 5-1
Overall Cable/Telephone Multimedia Delivery



Source: Dataquest (October 1995)

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Semiconductor Opportunities

Tables 5-1 and 5-2 present a forecast of the semiconductor market from public switching and transmission applications. Key opportunities include:

- Standard line card circuits (see the PBX discussion)
- New line card circuits such as ISDN U interface and ADSL functions
- CMOS and BiCMOS ASIC libraries to support the building of switch matrixes, digital cross-connects, multiplexers, and optical network units; new technologies such as SDH and ATM need to be supported with framing, clock, multiplexing, protocol/adaptation processing, and switching macros
- High-speed SRAM, FIFO, and DRAM (for switch software)
- Standard transceiver and physical interface functions such as T/E courier SONET; laser-based optoelectronic transceiver modules will be needed in increasing quantities, as well as copper coax terminations
- 16- to 32-bit MPU, MCU for management and housekeeping

OEMs

Leading central office switch OEMs in rank order are as follows:

- Alcatel
- AT&T
- Siemens
- Ericsson
- Northern Telecom
- NEC
- AG Communications
- GPT

Leading transmission equipment OEMs in rank order are as follows:

- Alcatel
- AT&T
- Siemens
- NEC
- Ericsson
- Fujitsu
- Philips
- DSC
- Bosch
- Tellabs

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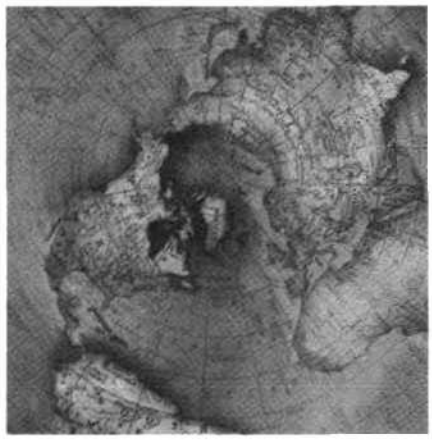
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Industrial and Military/Aerospace Application Markets



Market Trends

Program: Semiconductor Application Markets Worldwide
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Chapter 1
Introduction and Methodology

This document is the second in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, communications (two), consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- Key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analysts: Greg Sheppard and Dale Ford

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Chapter 2
Industrial Electronics Application Markets

Industrial and Medical Electronics Market Trends

Worldwide industrial and medical electronics production reached almost $104 billion in 1994, according to preliminary statistics compiled by Dataquest. This production drove an industrial semiconductor market of $10.1 billion over the past year. The early forecast calls for the industrial and medical electronics equipment market to grow by a 6.8 percent compound annual growth rate (CAGR) over the next five years. As in other electronics markets, the semiconductor content of industrial and medical equipment is growing significantly. This trend is driving a 13.5 percent forecast growth for the industrial semiconductor market from 1994 to 1999. This chapter reviews highlights of major subsegments in the industrial and medical electronics market, provides preliminary statistics and forecasts for equipment and semiconductor production, and lists key OEMs participating in the market. (The final forecast for this market will be released in the upcoming Electronic Equipment Production Forecast document.)

For purposes of definition, industrial systems include manufacturing controls, instrumentation, security and energy controls, medical electronics, and a host of nonconforming systems that involve electronic controls but do not fit into a particular category (for example, vending machines and traffic light controls, among others).

Major Industrial Electronics Trends

Highlights of the industrial electronics market are as follows:

- The bulk of this heterogeneous category is affected by capital spending outlays by business and government. This expenditure is expected to grow steadily throughout the five-year forecast because North America and Asia/Pacific are the most active producers and consumers.
- In general, these systems are converting to digital-based or digital signal processing of the real-world data they encounter.
- Security and energy management systems continue to diffuse into almost every structure or premise. Stiffer fire codes and rising crime rates are positively affecting demand for security, fire, and intrusion systems. About 18 percent of all U.S. households now have some type of electronic security system, according to manufacturers' estimates. This penetration rate has doubled since 1987 (see Table 2-1). Although professionally installed systems have dominated the home-security market, a new generation of do-it-yourself (DIY) security products has become common. Energy management is being positively affected by energy conservation measures. Many of these systems involve RF or IR wireless links to sensors. Most of the sophisticated systems employ PCs or PC motherboards as central control and logging units. The estimated 1993 worldwide production of home security systems was 4.1 million units.

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Table 2-1
U.S. Home Security Systems Market (Millions of U.S. Dollars)

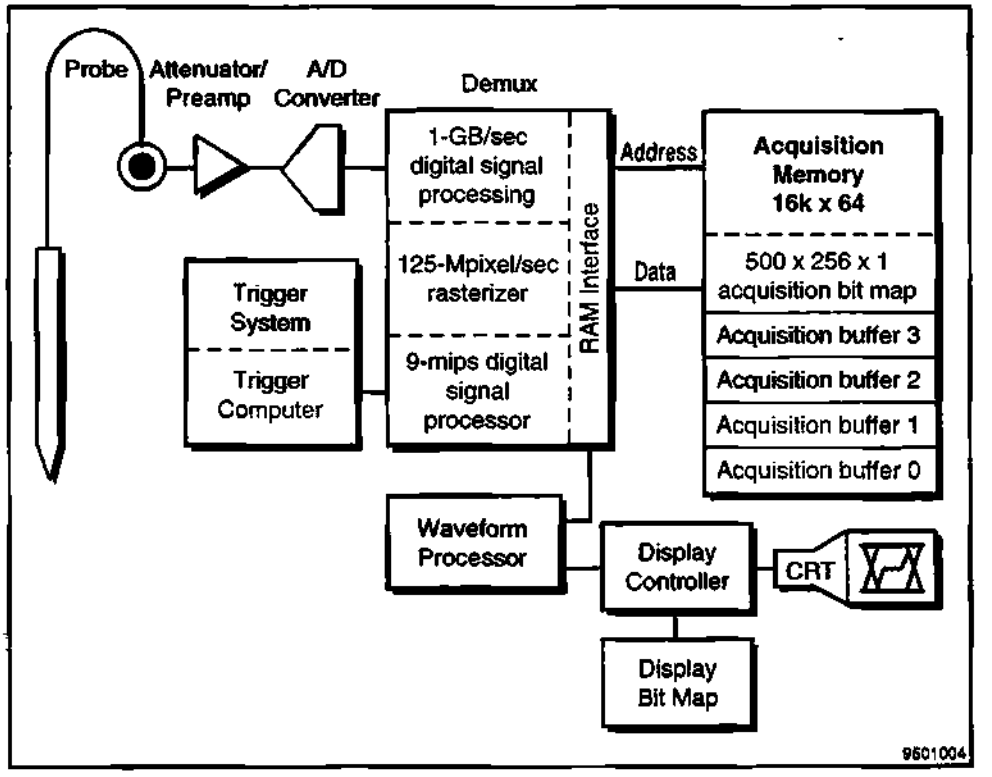
	Revenue
1988	900
1989	1,000
1990	1,150
1991	1,250
1992	1,250
1993	1,315
1998-1993 CAGR (%)	7.9

Source: U.S. Department of Commerce

- Electronics-based manufacturing systems continue to be employed and updated for productivity improvement purposes. There are two general types of manufacturing system: those oriented toward discrete manufacturing functions such as controlling a machine tool, and process or flow systems like those found in an oil refinery. Many of these systems are becoming architecturally anchored on standard industrial buses such as VME or Multibus II and even networks of PCs and workstations (or their motherboard forms). Future Bus and PCI bus are regarded as the high-performance industrial buses of the future. Common manufacturing systems include numerically controlled machine tools, programmable logic controllers, sensors, motors, and actuators such as solenoids. As economics warrant, sensors, motor controls, and actuators are converting to solid-state semiconductor technology. Most of these systems are custom-configured with production runs of less than 100.
- The booming North American machining and manufacturing market bodes well for industrial electronics equipment production. This is an industry that trails the economy, and after years of underinvestment by U.S. manufacturers there is now a pent-up demand for new equipment. U.S. factories are operating at 84 percent of capacity, their highest rate in more than five years. As a result, U.S. machine tool consumption rose 17 percent in 1994 and conveyor shipments likely topped 1993's $4.2 billion mark. This spending on industrial equipment is broad-based, from automakers to steel mills to soft-drink bottlers. Even if the U.S. market demand for industrial equipment eases in some sectors, export markets such as Asia and Latin America should pick up the slack for U.S. manufacturers. According to industry observers, the biggest challenge for industrial machinery makers in 1995 will be keeping up with demand.
- Driven by R&D, maintenance, and manufacturing requirements, electronic instrumentation continues to have new demands placed on it. Most of this equipment is highly specialized, performing a limited range of test and measurement functionality. Variations include oscilloscope, multimeters, and signal generators. Automatic test equipment (ATE) is perhaps the most semiconductor-intensive category. The ATE market is estimated at more than $3 billion, with about 2,000 systems shipped worldwide. Besides the trend to being digital-microprocessor based, much instrumentation is becoming portable as well, with PCMCIA slots for data storage cards. The Tektronix InstaVu digital oscilloscope shown in Figure 2-1 provides an example of the penetration of digital electronics in the test and measurement market. In the past,

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Figure 2-1
Acquisition-and-Display Architecture Speeds Oscilloscopes



Source: Tektronix Inc.

engineers have had to trade off the speed of an analog oscilloscope with the added functionality of a digital oscilloscope. The InstaVu oscilloscope employs a revamped acquisition-and-display architecture that allows it to display more than 400,000 acquisitions each second. This increased speed will allow it to compete with some of the fastest analog oscilloscopes.

Two high-volume industrial applications are solid-state lighting controls and electronically controlled utility meters. Highlights of these markets are:

- The lighting industry is going through a revolution driven by new technology that is forecast to fuel U.S. market growth for electronic ballasts to more than $1 billion by the year 2000, according to estimates by GE Lighting and Motorola Lighting. With only 3 percent penetration of the installed base of 1.5 billion electromagnetic fluorescent ballasts in the United States, the potential market for these more energy-efficient and economical electronic ballasts becomes more evident. As penetration of the electronic ballasts into the market reaches 50 percent, more than 102 billion kilowatt-hours of energy will be saved. This is enough power to run Disney World for almost a hundred years, and it would provide a savings of more than $8 billion per year in energy costs. Recognizing the economic benefits of building fewer power generation facilities, governments and utilities companies are providing significant financial incentives for companies to replace traditional lighting ballasts with the solid-state varieties. The combination of these incentives, reduced energy costs, and significantly improved life expectancy of

electronic ballasts has fueled dramatic growth in this market. Just six years ago, electronic ballasts represented only 3 percent of the annual total linear fluorescent ballast market, or only about $15 million in yearly sales. Today, electronic ballasts represent nearly half of the fluorescent ballast market, with $470 million in sales in 1994 (see Table 2-2). Key OEMs include: Philips (EBT), MagneTek, ABB, Siemens, General Electric, Etta Industries (United States), Motorola, and Lutron Electronics.

- Electronically controlled meters already are employed heavily in Europe, especially in the United Kingdom. These meters range in functionality from remote reading (wireless or wired) to being able to be controlled in brownout-type situations. Market estimates place electronic meter production at 5 million units a year now, with Schlumberger and General Electric being noted producers.

Medical Electronics

Some of the major industry trends and issues related to medical electronics are:

- The medical electronics industry is being transformed by a major shift in the marketplace. For decades, equipment sales were driven almost entirely by technological advances. Neither suppliers nor buyers worried about costs, which were passed on to insurance companies and patients. This model has collapsed with surprising speed as both insurance companies and national health policies are becoming more restrictive in the face of soaring health costs. One industry observer has explained that, "for health-care companies, it has become a race to see how fast you can squeeze yourself before your buyers squeeze you harder." In the U.S. private sector, the growth of health care costs has slowed from double digits in 1990 to just 2.6 percent from June 1993 to June 1994. This change has impacted the business plans of major equipment manufacturers. Companies such as Hewlett-Packard now routinely consult with insurers and health care buyers on what they are willing to pay for improvements in new equipment. In the past General Electric emphasized higher-ticket devices such as computerized tomography (CT) and magnetic resonance imaging (MRI), where it was the leader. It has now shifted resources to lower-cost lines such as the ultrasound market. GE has spent $100 million developing a $200,000 digital ultrasound machine that can be upgraded for future advances in 3-D imaging. GE previously had been a minor competitor in this market, which was dominated by companies such as Acuson. Within

Table 2-2
U.S. Electronic Ballast Market

	1989	1990	1991	1992	1993	1994 (Est.)	CAGR (%) 1989-1994
Unit Shipments (Thousands)	1,426	3,001	8,343	13,292	24,488	29,000	82.7
Revenue (U.S. $Millions)	39.8	69.3	180.0	274.6	446.5	469.8	63.8

Source: U.S. Department of Commerce, Dataquest (March 1995)

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the medical equipment industry there has also been a growing emphasis on so-called point-of-care technologies that can be used at home or wherever health problems occur. The deployment of lower-cost equipment into local clinics and homes is a trend that has helped elevate unit shipments. The total U.S. medical equipment market, electronic and nonelectronic, is expected to rise only 7 percent to $42 billion during 1995. Similar market trends in Europe are also impacting medical electronics manufacturers in countries such as Germany and France. Germany's 120 manufacturers of medical electronics suffered a 7.7 percent turnover decline to DM 5.9 billion in 1993. They do not expect recovery to occur before 1995. They blame the downturn on postponed investments by doctors and hospitals because of health care reform and the former East Germany not having a pent-up demand for replacement of medical electronics. French manufacturers expected revenue to remain flat in 1994 in spite of increased unit shipments. Streamlined budgets in French hospitals pushed prices down by 10 to 15 percent during 1992 and 1993. The tighter domestic markets and new lower-cost systems are driving companies to pursue development of new markets in places such as Asia and Latin America, where they are upgrading their health care infrastructures. For example, Thailand's imports of medical appliances and instruments have risen by an annual average of more than 15 percent since 1988. Imports supply 80 percent of the market for medical devices in Thailand. The U.S. trade surplus in medical products is expected to surge 28 percent to $6 billion by 1995. GE expected its sales in Asia to jump by 45 percent, to $1 billion, in 1994.

- In the wake of a number of incidents where wireless transmissions have interfered with life-critical medical instruments, the Food and Drug Administration (FDA) of the U.S. government has beefed up its regulation of microprocessor-controlled medical devices to ensure they can resist common sources of electromagnetic interference (EMI). A computer-assisted search of the FDA's database for medical devices reported 100 cases from 1979 to 1993 where EMI caused medical devices to fail or malfunction. Also, a handful of deaths that occurred during this time have been blamed on failure of equipment because of EMI. Most reports of dangerous incidents have focused on cellular phones and two-way radios. Some hospitals in the United States, Canada, and Europe have already banned cellular phones because of the EMI generated when they are held close to devices such as incubators, ventilators, and heart monitors. The problem could grow worse with the proliferation of a large number of wireless devices such as wireless modems and LANs. It is believed that most computers and personal communications services (PCS) devices are too low-powered to cause interference. The U.S. Federal Communications Commission (FCC) is evaluating the situation in order to develop an appropriate response. Meanwhile, vendors on both sides of the problem have taken preliminary steps to deal with this problem. The Cellular Telecommunications Industry Association (CTIA) has created a research center on electromagnetic compatibility at the University of Oklahoma, and the Association for the Advancement of Medical Instrumentation has formed an electromagnetic standards committee. Early solutions point toward better shielding of sensitive chips in medical electronics. New FDA design guidelines for medical devices should be released by mid-1995.

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- A backlog in device reviews by the FDA is having a significant, adverse impact on the U.S. medical electronics industry. The average FDA processing time for medical device reviews was 78 days in 1988. This grew to 126 by 1992, and the current average is 240 days. A survey commissioned by the American Electronics Association (AEA) and conducted by the Gallup Organization found that the FDA backlog has caused jobs to be moved offshore and is slowing private R&D investment in developing new products. Some key findings in this survey of 58 leading medical electronics manufacturing companies are: 74 percent said they changed business decisions because of the regulatory climate over the past two years; 55 percent had more products released outside the United States; 48 percent said they changed the focus of their R&D from breakthrough technologies to incremental technology improvements; 29 percent increased their investment in non-U.S. operations; and 17 percent relocated manufacturing operations overseas.
- During 1994 Eli Lilly divested some of its medical device and diagnostic business and Siemens sold its cardiac pacing business to St. Jude Medical:
  - Five of the nine companies that Eli Lilly spun off were combined to form a new public company known as Guidant. With a combined $800 million in annual sales, Guidant will comprise the Lilly companies Advanced Cardiovascular Systems, Cardiac Pacemakers, Devices for Vascular Intervention, Origin Medsystems, and Heart Rhythm Technologies.
  - Prior to the sale of its cardiac pacing business to St. Jude Medical, Siemens held 22 percent of the world heart pacemaker market, with annual sales of $350 million. Medtronic is the world leader with a 50 percent market share. St. Jude Medical has earned revenue of about $250 million from sales of its heart pacemakers in the past. Siemens claims to be the world's largest manufacturer of medical systems, with $5.03 billion turnover in 1993.

Product Developments

Selected highlights related to medical electronics product developments are:

- In another example of defense-related technologies benefiting commercial products, surgeons may eventually be able to perform complicated operations using technology borrowed from the U.S. Air Force called Computer-Assisted Minimally Invasive Surgery (CAMIS). The CAMIS system uses automatic target technology, similar to the technology used in smart bombs, to generate computer-enhanced, three-dimensional images on a helmet-mounted display that the surgeon wears while performing an operation. The three-dimensional images make it easier for the surgeon to view malignancies and normal tissue before and during operations. A team of companies, government agencies, hospitals, and universities has been formed to develop this technology. A Cleveland clinic has already used a preprototype device that uses similar technology. Two hundred CAMIS brain surgeries were performed with this device, resulting in a 30 percent reduction in postprocedure complications, length of hospital stay, and surgical costs. The actual operating time for a typical brain surgery was reduced from 3 hours to 1 hour. The development team hopes to have minimally invasive surgery systems available within five years.

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- Perhaps the most well-known medical electronic device is the X-ray machine, which still is a $4.5 billion global industry. Its newer, more expensive brethren – CT, MRI, and positron emission tomography (PET) – are penetrating hospitals slowly but surely, with world shipments in the hundreds of systems. An MRI system has been developed by GE that allows surgeons to operate while a patient is being scanned by the system. The new design removes the middle third of the MRI tube, leaving two magnetic doughnuts that a surgeon can operate between. Being able to monitor an MRI image of an organ while operating on it should help with procedures that require extreme precision, such as tumor removal. GE has invested $50 million in this project and hopes to market the new machines by 1997 at $3 million each.
- Ultrasound and its color upgrade continue to push into most clinics. Worldwide shipments of these systems are estimated at 20,000 units annually.
- A virtual reality training program developed by Virtuality Group and The Queen's Medical Center in the United Kingdom will allow future anesthetists to be trained without putting patients at risk. By using a head-mounted display, a user can enter a virtual reality world that presents an exact replica of a hospital's operating room with a patient in need of treatment. A handheld peripheral emulates hands and allows the student to pick the chosen treatment. Monitoring instruments reflect the success of the treatment.
- Fiber-optic-based endoscopic imaging and surgery is clearly revolutionizing how common ailments such as ulcers and knee injuries are treated.
- The medical electronics market may present a new opportunity for smart card technology. Medical electronic ID tags could be used to tag infants and patients, and to track patients' histories instead of a clipboard at the end of a bed. A number of companies are working on medical equipment solutions and expect the market to experience dramatic growth in 1995.
- In 1994, St. Jude Medical announced the first implantation of its new Trilogy DR+ pacemaker. It claims that this is the first pacing system to offer true "automaticity" – the ability of the pacemaker to automatically and intelligently adapt many of its settings based on information it collects and analyzes about the patient's heart and the heart's interaction with the pacing system.
- OrthoLogic has received 21 U.S. patents for methods using electromagnetic technology to stimulate growth factors in living tissue. Its first FDA-approved device using this technology is the $3,400 OrthoLogic 1000, a strap-on-device designed to heal fractures that have not mended more than 9 months past a break. It is now testing the SpinaLogic 1000, which is designed to heal bones after spinal fusion surgery.
- Home-based electronic thermometers, blood pressure meters, and glucometers (for diabetics) are helping people to help themselves. Pacemaker and defibrillators shipments worldwide annually total about 800,000 units.

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- Siemens Australia has developed a sophisticated hearing aid that uses digital signal processing (DSP) technology and can be programmed using a PC or a handheld programmer to incorporate adjustments related to the details of a particular patient's hearing loss. The new series of devices was planned for market introduction in early 1995. Resound, a U.S. company, is another OEM that focuses on applying DSP technology to hearing aids. It is estimated that 50 million people in the world could benefit from hearing aid technology. The world market for hearing aids is an estimated 3 million units and $1.2 billion annually.

Semiconductor Opportunities

Semiconductor opportunities are as follows:

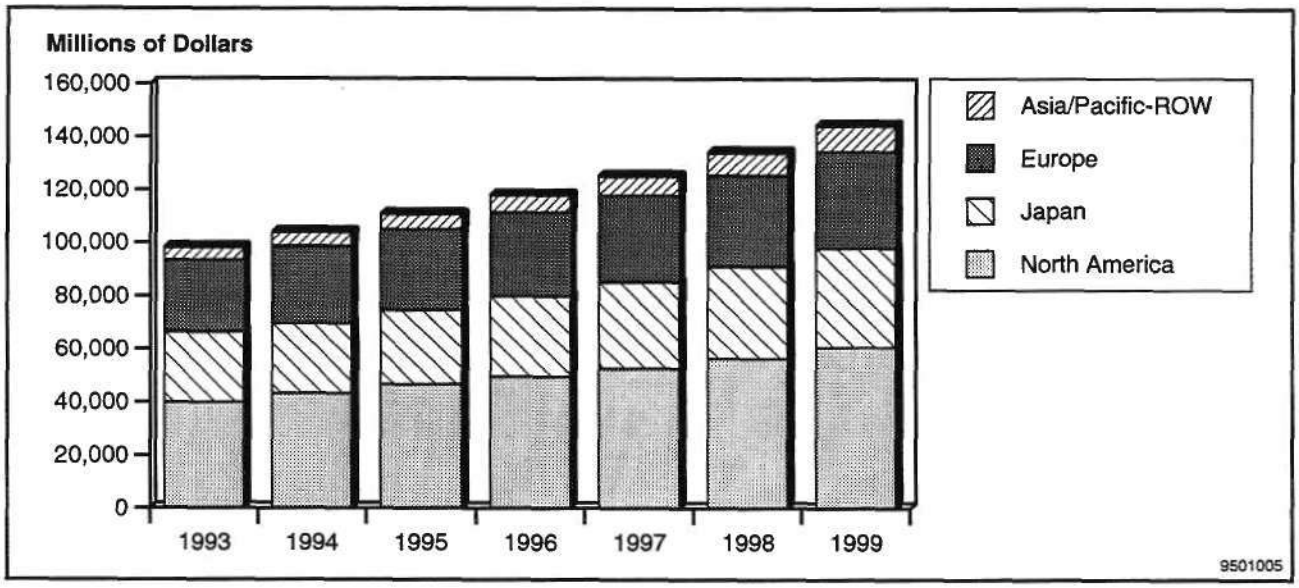
- Most industrial electronics companies view themselves as solution providers and turn to zero nonrecurring engineering (NRE) solutions as often as possible. Therefore, off-the-shelf motherboards, data acquisition boards, and power supplies are used as much as possible. Many industrial applications require industrial temperature range where 85°C temperature requirements need to be met.
- Power and smart-power semiconductor devices are used in abundance in industrial systems. The use ranges from low-voltage/current MOSFETs with TTL logic interfaces through to tens of amps/hundreds of volts motor control hybrids. The most common uses are for power supply and regulation, and for motor/actuator control.
- Precision analog devices including operational amplifiers, data conversion, and bus-oriented interface/transceiver devices are in demand. Solid-state pressure and position sensors are finding increasing use as their price comes down. CCD 2-D and linear arrays are used in imaging and scanning functions in increasing numbers. RF and IR devices are being used increasingly in the wireless factory.
- FPGAs and other complex PLDs are very popular in low-volume, custom, industrial applications. Gate arrays and cell-based ICs are used heavily in applications such as ATE.
- All varieties of MCU, 4- to 32-bit, are employed in the various control systems. MPUs are used in programmable logic controllers and the embedded PC and workstations that are becoming more common.
- LAN controllers on network interface cards are becoming more common on the factory floor. In addition to Ethernet and Token-Ring, the LON (sponsored by Echelon and Motorola) standard has made a presence on the factory floor.
- DRAM is finding increasing use in systems such as ATE, not to PC-based controllers. The ruggedness and speed of SRAMs remain preferred in many applications. Flash memory is taking over for most main steam control code storage applications as serial EEPROM continues to feed new uses. PCMCIA flash and SRAM cards already are being employed in many instruments for data logging.

Industrial Electronic Production and Semiconductor Market

Figures 2-2 and 2-3 and Tables 2-3 through 2-6 present the forecast for industrial electronics. Asia/Pacific and North America are expected to be

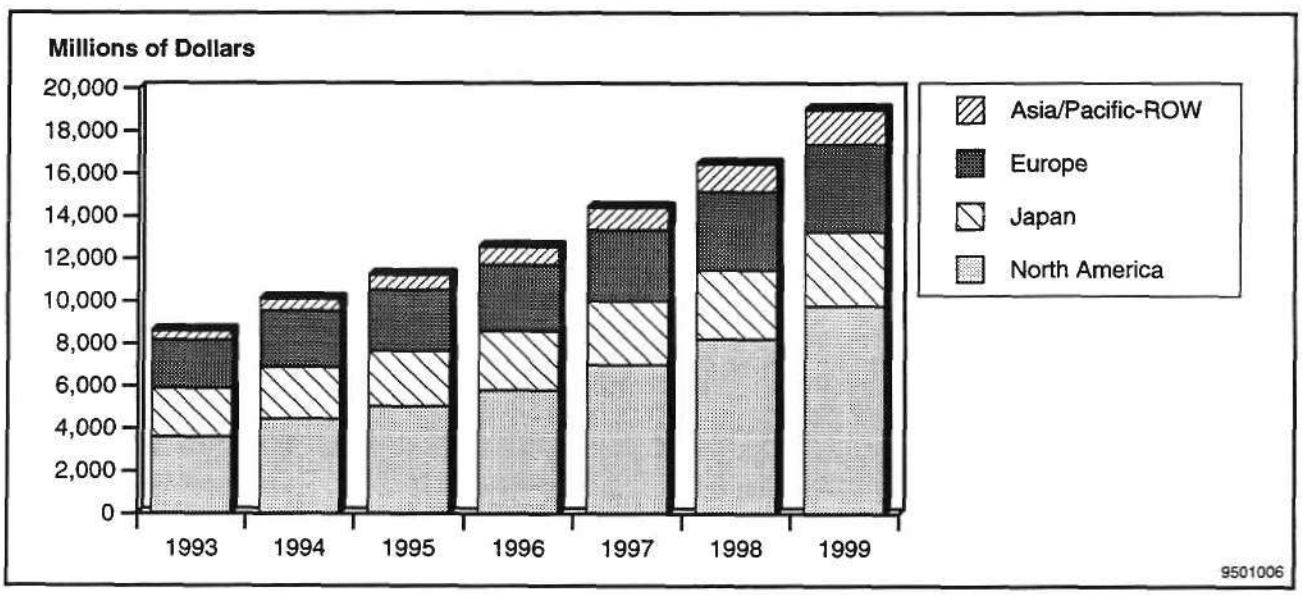
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Figure 2-2
Worldwide Industrial Electronic Production Forecast



Source: Dataquest (March 1995)

Figure 2-3
Worldwide Industrial Semiconductor Forecast



Source: Dataquest (March 1995)

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Table 2-3
Worldwide Industrial Electronics Production Forecast (Preliminary)
(Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
North America	39,937	43,374	46,645	49,675	52,800	56,524	60,840	7.0
Japan	26,477	26,342	28,048	30,356	32,347	34,648	37,285	7.2
Europe	26,976	29,051	30,313	31,555	32,807	34,601	36,626	4.7
Asia/Pacific-ROW	4,621	5,143	5,688	6,382	7,225	8,308	9,595	13.3
Total	98,012	103,910	110,693	117,968	125,180	134,081	144,346	6.8

Source: Dataquest (March 1995)

Table 2-4
Worldwide Industrial Semiconductor Forecast (Preliminary) (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
North America	3,617	4,467	5,053	5,823	7,024	8,243	9,795	17.0
Japan	2,282	2,427	2,594	2,790	2,993	3,225	3,491	7.5
Europe	2,284	2,674	2,898	3,122	3,363	3,706	4,104	8.9
Asia/Pacific-ROW	409	533	673	825	1,034	1,294	1,628	25.0
Total	8,592	10,102	11,218	12,560	14,413	16,467	19,017	13.5

Source: Dataquest (March 1995)

Table 2-5
Worldwide Industrial Electronics Production (Preliminary) (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Security and Energy Management	12,359	12,739	13,405	14,620	15,791	17,154	18,632
Manufacturing Systems/Instruments	55,659	59,268	63,211	66,895	70,605	75,681	81,821
Medical Equipment	14,545	15,637	16,712	17,873	19,005	20,232	21,538
Other Industrial	15,449	16,265	17,366	18,580	19,779	21,015	22,355
Total	98,012	103,910	110,693	117,968	125,180	134,081	144,346

Source: Dataquest (March 1995)

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Table 2-6
North American Industrial Electronics Production (Preliminary)
(Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Security and Energy Management	3,445	3,562	3,637	3,851	4,047	4,241	4,442
Alarm System	1,193	1,233	1,259	1,334	1,402	1,469	1,538
Intrusion Detection	669	680	681	708	730	750	770
Fire Detection	524	554	578	625	671	718	768
Energy Management	2,252	2,329	2,377	2,518	2,646	2,773	2,904
Manufacturing Systems/ Instruments	15,987	17,773	19,241	20,312	21,518	23,273	25,504
Semiconductor Production	2,171	3,105	3,530	3,542	3,752	4,505	5,676
Controls	6,035	6,469	7,003	7,550	8,071	8,599	9,159
Process Controls	2,575	2,778	3,030	3,289	3,540	3,796	4,069
Control and Processing Displays	4,872	5,062	5,288	5,511	5,704	5,893	6,087
Robots	334	359	389	420	450	480	512
Test and Measuring Equipment	8,472	9,175	9,891	10,554	11,256	11,989	12,768
ATE-Semiconductor Equipment	1,144	1,398	1,559	1,676	1,849	2,025	2,214
Other Test and Measurement	6,725	7,140	7,648	8,150	8,634	9,145	9,686
Nuclear Electronics	604	637	683	729	773	819	868
Medical Equipment	6,669	7,165	7,767	8,460	9,126	9,797	10,513
Diagnostic	1,998	2,153	2,350	2,571	2,793	3,025	3,275
Therapeutic	1,399	1,500	1,618	1,762	1,892	2,015	2,143
Patient Monitoring	1,061	1,154	1,261	1,380	1,500	1,627	1,765
Surgical Support	566	610	666	729	791	857	928
Irradiation Equipment	1,645	1,749	1,872	2,018	2,149	2,273	2,401
Other Industrial	5,365	5,699	6,109	6,497	6,853	7,223	7,613
Total	39,937	43,374	46,645	49,675	52,800	56,524	60,840

Source: Dataquest (March 1995)

the fastest-growing regions for industrial electronics production. Each region is experiencing strong spurts of capital investment. Asia/Pacific also is becoming more of a manufacturing site for more cost-sensitive systems. Europe and North America are still the top production locations for medical electronics equipment. Tables 2-7 through 2-10 povide historical statistics on U.S. industrial electronics production that provides a perspective on the size of the underlying markets.

Security and energy management electronics are forecast to be the fastest-growing categories, whereas manufacturing/instrumentation comprises about half of the overall dollar volume.

The fastest-growing chip category is microcomponent (MCU and MPU, among others), followed by memory. Discrete and analog combined comprised 54 percent of the worldwide semiconductor opportunity. Tables 2-11 through 2-14 present the forecast for semiconductor consumption in industrial/equipment markets.

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Table 2-7
U.S. Manufacturing Systems Production, 1992 (Excluding Semiconductor Production and Robots)

	Revenue ($M)
Controls	
AC full-voltage starters, contractors, reduced voltage controls, 1,000V or less	376.0
Motor control centers, 1,000V or less	318.2
Starters and contractors for squirrel cage and wound rotor and synchronous motors, more than 1,000V, air break and oil immersed	64.2
Pilot circuit devices, such as limit switches, interval timers, and photoelectric devices	366.1
Other general industry devices: push-buttons, rheostats and resistors, brakes, and synchronous motor starters	338.7
Metal mill	216.6
Crane and hoist controls	49.8
Adjustable speed drives	565.2
Numerical controls	1,758.3
Other controls and parts	1,640.2
Total Controls	5,693.3
Process Controls	
Temperature	554.8
Pressure, draft, and vacuum	395.6
Flow and liquid level	915.1
Humidity instruments	22.3
Continuous process gas and liquid analysis	422.2
Instruments for other variables (speed, viscosity, position, density, specific gravity, and sequence, among others), including mechanical types	104.3
Total Process Controls	2,414.3
Control and Processing Displays (Operate from Standard Transmitted Signals, Excluding Auxiliary Station)	
Electronic systems (unified architecture type):	
Controllers	180.9
Recorders	85.0
Indicators	28.5
Electronic systems (nonunified architecture type)	1,021.4
Multifunction process computers	538.8
Pneumatic system (excluding auxiliary station)	57.7
Annunciators	24.9
Physical properties testing and inspection equipment	938.7
Kinematic test and measuring equipment	167.2
Automatic regulating devices	661.0
Other process instruments	706.6
Parts of process instruments	325.4
Total Control and Processing Displays	4,736.1
Total Manufacturing (Excluding Semiconductor and Robot)	12,843.7

Source: U.S. Department of Commerce

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Table 2-8
U.S. Test and Measuring Equipment and Nuclear Electronics Production, 1992

	Revenue ($M)
Test and Measurement and ATE-Semiconductor Equipment	
AC watt-hour meters	148.9
Combined watt-hour and demand meters and time switch meters	124.8
Other integrating meters and instruments, and parts	152.4
Voltage, current, and resistance measuring equipment	260.2
Multimeters	142.0
Power and energy measuring equipment	94.3
Frequency measuring equipment	92.9
Waveform measuring or analyzing equipment	718.4
Signal generating equipment	385.0
Field strength and intensity measuring	229.6
Impedance and standing wave ratio measuring	40.6
X-Y plotters	7.0
Automatic testing and measuring equipment:	
Combination/group testing sets	509.8
Component part test sets:	
Semiconductors	874.2
Others	427.5
Others	257.4
Standards and calibration	184.2
Microwave test	31.2
Communications testing (excluding microwave)	670.4
Internal combustion engine analyzers	285.3
Associated devices for testing and measuring	267.1
Other testing, measuring, and analyzing	1,370.0
Total Test and Measurement and ATE	7,273.2
Nuclear Electronics	
Radiation detecting elements, including chambers, sold separately	82.4
Solid-state detectors sold separately	40.5
Nuclear monitoring instruments, including environmental, personal dosimetry, and medical monitors, stationary and portable	110.3
Sample flow counting systems	36.6
Scalers sold separately and special amplifiers for nuclear applications	8.3
Pulse analyzers, including nuclear spectrometers	18.8
Count rate meters	2.0
Measurement and control devices using beta, gamma, or neutron gauge technology	104.0
Input-output accessories for multichannel analyzers and nuclear power supplies	13.0
Nuclear instrument modules	52.0
Other nuclear radiation detection and monitoring instruments	113.6
Total Nuclear Electronics	581.5
Total Test and Measurement Equipment	7,854.7

Source: U.S. Department of Commerce

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Table 2-9
U.S. Medical Equipment Production, 1993

	Revenue ($M)	Units
Diagnostic Equipment		
Nuclear medicine (nuclear in vivo studies)	240.8	1,025
MRI, EEG, EMG	644.8	2,345
Ultrasound scanning	755.1	9,069
EGG	213.9	46,654
Audiological	10.3	
Endoscopic	21.7	2,405
Respiratory analysis	40.2	4,008
Other medical diagnostic	179.7	
Total diagnostic	2,106.5	
Patient Monitoring		
Intensive care/coronary care units, including component modules such as temperature, blood pressure, and pulse	549.9	
Prenatal and respiratory monitoring	52.2	
Other patient monitoring	504.6	
Total Patient Monitoring	1,106.7	
Therapeutic		
Ultrasound therapy	33.2	
Pacemakers	557.5	130,181
Defibrillators	375.5	44,946
Dialyzers	274.3	
Other medical therapy (except radiation therapy)	388.9	
Total Therapeutic	1,629.4	
Surgical Support		
Electrosurgical equipment	203.6	
Heart-lung machines (except iron lungs)	145.8	3,425
Blood flow systems	112.8	
Other surgical support systems	269.8	
Total Surgical Support	732.0	
Irradiation Equipment		
X-ray equipment		
Digital radiograpy	47.7	725
Conventional, dental, and CAT scan	1,013.3	17,874
Other X-ray	175.9	
Total medical X-ray	1,236.9	
Industrial and scientific X-ray equipment	106.7	1,482
Total Irradiation	1,343.6	
Total Medical	6,918.2	

Source: U.S. Department of Commerce

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Table 2-10
U.S. Other Industrial Electronic Equipment Production, 1992

	Revenue ($M)
Ultrasonic equipment: cleaners, drills, solderers, and welders	113.5
Trainers and simulators	1,234.9
Teaching machines and teaching aids	79.0
Scientific electronic equipment, n.e.c.	94.1
Laser systems and equipment, except communications	588.1
Other electronic systems, equipment, and subassemblies, n.e.c.	542.7
Industrial blank media and parts	549.4
Other industrial related	1,896.6
Total Other Industrial Systems	5,098.3

**n.e.c. = not elsewhere counted
Source: U.S. Department of Commerce

Table 2-11
Revenue from Worldwide Industrial Semiconductor Market by Type (Preliminary) (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	8,592	10,102	11,218	12,560	14,413	16,467	19,017
Total IC	6,190	7,440	8,375	9,554	11,211	12,998	15,226
Bipolar Digital	275	234	199	170	153	122	97
MOS Digital	4,263	5,285	6,044	6,978	8,329	9,735	11,482
MOS Memory	1,354	1,617	1,695	1,847	2,266	2,740	3,340
MOS Microcomponent	1,648	2,156	2,678	3,268	3,943	4,593	5,396
MOS Logic	1,261	1,512	1,670	1,862	2,120	2,402	2,745
Analog (Monolithic + Hybrid)	1,653	1,921	2,133	2,407	2,728	3,141	3,647
Total Discrete	1,951	2,163	2,317	2,465	2,639	2,875	3,159
Total Optical Semiconductor	451	499	526	541	563	594	632

Source: Dataquest (March 1995)

Table 2-12
Worldwide Industrial Semiconductor Market (Preliminary) (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Security and Energy Management	807	936	1,048	1,216	1,439	1,696	1,997
Manufacturing Systems/ Instruments	5,621	6,632	7,368	8,194	9,365	10,701	12,423
Medical Equipment	1,120	1,319	1,457	1,637	1,903	2,183	2,504
Other Industrial	1,045	1,215	1,346	1,513	1,706	1,887	2,093
Total	8,592	10,102	11,218	12,560	14,413	16,467	19,017

Source: Dataquest (March 1995)

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Table 2-13
North American Industrial Semiconductor Market by Type, All Semiconductors Shipped to North America for Use in Industrial Applications (Preliminary)
(Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Total Semiconductor	3,617	4,467	5,053	5,823	7,024	8,243	9,795
Total IC	2,945	3,697	4,201	4,899	6,018	7,139	8,571
Bipolar Digital	108	91	75	63	55	46	38
MOS Digital	2,125	2,742	3,151	3,715	4,651	5,543	6,683
MOS Memory	622	795	815	907	1,204	1,519	1,937
MOS Microcomponent	908	1,214	1,525	1,893	2,367	2,783	3,307
MOS Logic	595	733	811	914	1,080	1,240	1,440
Analog (Monolithic + Hybrid)	712	864	974	1,121	1,312	1,550	1,851
Total Discrete	544	620	686	742	804	879	972
Total Optical Semiconductor	127	150	166	182	202	224	252

Source: Dataquest (March 1995)

Table 2-14
North American Industrial Semiconductor Market (Preliminary)
(Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999
Security and Energy Management	291	344	382	447	546	641	751
Manufacturing Systems/Instruments	2,433	3,050	3,471	3,998	4,832	5,684	6,812
Medical Equipment	521	630	708	824	1,006	1,191	1,409
Other Industrial	373	442	491	554	640	726	823
Total	3,617	4,467	5,053	5,823	7,024	8,243	9,795

Source: Dataquest (March 1995)

Industrial Electronics OEMs

The industrial area is highly fragmented, with only a few large OEMs. The following sections list some of the more notable companies in the general industrial areas.

Security/Energy Management OEMs

The following is a sample of major companies participating in the security/energy management systems arena:

- Security
  - Alarm Device Manufacturing
  - Cerberus Pyronics
  - EyeDefinately Inc.
  - Honeywell Inc.
  - Johnson Controls Inc.
  - Simplex Time Recorder Co.
  - Wells Fargo Alarm Services

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- Energy
  - Carrier Corporation
  - Emerson Electric
  - Honeywell/Building Controls Division
  - Joy Technologies
  - Scientific Atlanta Inc./Control Systems Business Division
  - Solid State Systems
  - Trane Co.
  - Westinghouse/Energy Systems
  - Johnson Controls
  - Landis and Gyr
  - Robertshaw Controls
  - Lennox Industries

Manufacturing Systems OEMs

The following is a sample of the major companies participating in the manufacturing systems market:

- Semiconductor production
  - Anelva (sputtering, dry etch, molecular beam epitaxy, evaporation, and ECR)
  - Applied Materials (dry etch, silicon epitaxy, SACVD, PECVD, LPCVD, and ion implantation)
  - ASM Lithography (steppers, direct write, and maskmaking)
  - ASM International (diffusion, LPCVD, PECVD, and silicon epitaxy)
  - Canon (projection aligners, steppers, contact/proximity, resist processing equipment, and optical CD/wafer inspection)
  - Dainippon Screen (resist processing equipment, wet process, and rapid thermal processing)
  - Eaton (ion implantation, resist processing equipment, dry etch, dry strip, and diffusion)
  - Hitachi (direct write and maskmaking, steppers, dry etch, dry strip, ion implantation, and optical CD/wafer inspection)
  - Lam Research (dry etch and high-density plasma CVD)
  - Nikon (steppers and optical CD/wafer inspection)
  - Silicon Valley Group (resist processing equipment, diffusion, LPCVD, steppers, and projection aligners)
  - Tokyo Electron Limited (resist processing equipment, diffusion, LPCVD, dry etch, MOCVD, and rapid thermal processing)
  - Ulvac (sputtering, evaporation, ion implantation, molecular beam epitaxy, LPCVD, dry etch, dry strip, and MOCVD)
  - Varian Associates (sputtering, ion implantation, molecular beam epitaxy, LPCVD, and rapid thermal processing)

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- Other manufacturing systems
  - Allen-Bradley (data acquisition, manufacturing process controls, programmable controls, machine tools/presses, and inspection equipment)
  - Bailey Controls Company (manufacturing process controls and other manufacturing control systems)
  - Cincinnati Milacron (manufacturing process controls, programmable controls for machine and factory process, FMS materials handling equipment, and machine tool accessories/tools)
  - Fisher Controls (manufacturing process controls)
  - Fisher & Porter Co. (manufacturing process controls)
  - General Electric (data acquisition/ID equipment, manufacturing process controls, and programmable controls for machines and factory processes)
  - Johnson controls (manufacturing process controls)
  - Leeds & Northrup Co. (manufacturing process controls, programmable controls for machines, and other material handling/shipping equipment)
  - Measurex (sensor systems)
  - Modicon (data acquisition/ID equipment, manufacturing process controls for machines, and programmable controls for machines and factory processes)
  - Texas Instruments (manufacturing process controls)
  - Westinghouse (data acquisition/ID equipment, manufacturing process controls, other manufacturing control systems, and machine tools/presses)
- Robotics
  - Adept Technology
  - ASEA Brown Boveri Robotics Inc.
  - Automatix Inc.
  - Cimflex Teknowledge Corporation
  - Fisher Scientific Group
  - GE Factory Automation
  - Graco Robotics
  - Intelledex

Adept Technology, ASEA Brown Boveri, Cimflex Teknowledge, and GE Factory Automation also produce vision systems.

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Instrumentation OEMs

The following is a sample of the major companies participating in the electronic instrumentation category:

- Automatic test equipment
  - Advantest
  - Asia Electronics
  - Credence
  - GenRad
  - Hewlett-Packard
  - LTX
  - Megatest
  - Minato
  - Schlumberger
  - Tektronix
  - Teradyne
- Electrical test instruments
  - Analogic Corporation (oscilloscopes)
  - Ametek Inc. (infrared analyzers, calibrators, data logging/acquisition, flow measuring equipment, and level measuring equipment)
  - EG&G (data recorders, oscilloscopes, detection equipment, seismograph measuring equipment, geophysical measuring equipment, flow measuring equipment, frequency measuring equipment, and spectrometers)
  - Fisher Controls (electronic function controls)
  - Gould (computer-related analyzers, oscilloscopes, data logging/acquisition equipment, data recorders, and waveform analyzers)
  - Hewlett-Packard (oscilloscopes, bar code readers, analyzers, counters/timers, data recorders, multimeters, power measuring equipment, and spectrophotometers)
  - John Fluke (oscilloscopes, analyzers, counters/timers, and voltmeters)
  - LeRoy Corporation (oscilloscopes)
  - IFR Systems (oscilloscopes)
  - Millipore/Chromatography Division (scientific instruments and counter/recorders)
  - Nicolet (oscilloscopes and mass spectrometers)
  - Schlumberger (indicators, power measuring equipment, electrical measuring equipment, geophysical measuring equipment, oscilloscopes, analyzers, and data logging/acquisition equipment)

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- Teledyne (chemical/physical analyzers, infrared analyzers, other analyzers, calibrators, energy fuel retrieval equipment, geophysical equipment, seismograph measuring equipment, and voltmeters)
- Tektronix (oscilloscopes, analyzers, and calibrators)
- Tracor Inc. (analyzers, data recorders, detection equipment, spectroscopy equipment, and spectrophotometers)
- Westinghouse (data recorders, detection equipment, and electronic function controls)

Medical Electronics OEMs

Table 2-15 shows a sample of major companies participating in the medical electronics arena.

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Table 2-15
Medical Electronic Equipment Manufacturers

Diagnostic	Therapeutic	Patient Monitoring	Surgical Support	Irradiation Equipment
Abbott Laboratories	3M/Hearing Health	3M Healthcare	3M Health Care	ADAC Laboratories
Acuson Corporation	Abbott Laboratories	Baxter Healthcare Corporation	Abbott Laboratories	Dentsply International
Advanced Technology Laboratories	Avecor Cardiovascular Inc.	Bio-Rad Laboratories	Advanced Technology Laboratories	Diasonics Inc. (OEC Medical Systems)
ATZ Interspec Cardiology	Baxter Healthcare Corporation	Braemar Inc.	AMSCO International Inc.	E-Z-EM Inc.
Becton Dickinson and Company	Biomet Inc.	Critikon Inc.	Baxter Healthcare Corporation	Eastman Kodak
Bio-Rad Laboratories Inc.	Chiron Corporation	Datascope Inc.	Becton Dickinson and Co.	Fischer Imaging Corporation
Corning	COBE Laboratories Inc.	Fisher Scientific	Biomet Inc. (AOT)	GE Medical
Diasonics	Guidant (Eli Lilly Spin-Off)	Hewlett-Packard	C.R. Bard Inc.	Hewlett-Packard
E-Z-EM Inc.	Hewlett-Packard	ICN Biomedicals Inc.	CAE Link Corporation	Philips Medical Systems
E.I. du Pont de Nemours and Co.	Mallinckrodt Medical	Mallinckrodt Medical Inc.	Chiron IntraOptics	Picker International
Eastman Kodak/Health Sciences	Medtronic Inc.	Marquette Electronics Inc.	Cordis Corporation	Siemens Gammasonics Inc.
GE Medical Systems	Puritan-Bennett Corporation	Nellcor Inc.	Datascope (Boston Scientific Corporation)	Toshiba America
Hewlett-Packard	SpaceLabs Medical	Ohmeda	Datascope Inc.	
Hitachi	St. Jude Medical Inc.	Siemens Medical Systems	Guidant (Eli Lilly Spin-Off)	
Mallinckrodt Medical	Techmedica	SpaceLabs Medical	Intermedics Inc.	
Marquette Electronics Inc.	Varian		Mallinckrodt Medical Inc.	
Miles Inc./Agfa Division			Medtronic	
Ortho Diagnostic Systems Inc.			Ohmeda	
Philips Ultrasound			Puritan-Bennet Corporation	
Picker International Inc.			Siemens Medical Systems Inc.	
Siemens Medical Systems			St. Jude Medical Inc.	
Thermedics			Stryker Instruments	
Toshiba America			Sulzermedica USA	
Varian Associates			Zimmer Inc.	

Source: Dataquest (March 1995)

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Chapter 3
Military and Civil Aerospace Electronics Application Markets

Military/Aerospace Market Trends

Military/aerospace market trends highlights are as follows:

- Continued overall decline in defense spending across the board from the NATO countries in response to the ending of the cold war. Table 3-1 presents the U.S. defense budget as broken out into its constituent parts. Perhaps the most indicative of spending on electronics is the procurement line, which shows an ongoing decline. Spending on electronics is expected to see some growth in the United States after 1995 as new initiatives take hold.
- There is weaker demand for military wares out of traditional export markets in the Middle East, but growing demand with the Asia/Pacific countries as they become more self-reliant.
- Remaining defense procurement spending will be electronic-intensive as existing platforms (aircraft, ships, and ground equipment) are upgraded with new electronic systems to extend their operational lives. Equipment such as radar, electro-optics, and electronic warfare will be needed.
- Emphasis will be placed on maintaining security in world hot spots such as the Persian Gulf and Yugoslavia, and for humanitarian missions such as in Somalia. New systems will be required for this role, including mobile communication and computers, satellite surveillance, and small-scale command, control, communications, and intelligence C(3) *I* systems.
- It is believed that the end of the Coordinating Committee for Multilateral Strategic Export Control (CoCom) will help create opportunities for sales of so-called dual-use technologies to former Soviet bloc countries. Many electronic systems and chips were once banned from sale.

Table 3-1
U.S. Defense Budget (Billions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1994-1997
Military Personnel	81.2	76.0	70.8	70.5	68.7	67.5	NA	NA	NA	-1.6
Operations and Maintenance	93.7	89.2	88.0	92.9	91.9	90.6	NA	NA	NA	1.0
Procurement	62.9	52.8	44.5	43.3	39.4	43.5	NA	NA	NA	-0.7
RTD&E	36.6	37.8	34.8	36.2	34.3	32.7	NA	NA	NA	-2.0
Construction	5.3	4.6	6.0	5.0	6.6	4.5	NA	NA	NA	-9.0
Housing	3.7	3.9	3.5	3.3	4.1	4.3	NA	NA	NA	7.0
Others	-1.3	2.9	1.4	1.0	0.9	0.2	NA	NA	NA	NM
Total	282.1	267.2	249	252.2	246.0	242.8	249.7	256.3	266.2	-0.8

NM = Not meaningful
NA = Not applicable
Source: U.S. Department of Defense

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- NASA, ESA, and Japanese space programs continue to grow, despite tough fiscal environments for government budgets. The space station Freedom (as recently downscaled) will be the single largest space project during the next decade, requiring an estimated $8 billion to $10 billion in electronics systems in space and on the ground.
- There are at least a half dozen commercial proposals to launch arrays of satellites to provide global and local cellular communication to areas such as Asia, Africa, and eastern Europe. Besides this, several direct broadcast satellite systems are planned to provide interactive services and HDTV reception. The Japanese government has perfected the H-2 rocket to launch civilian payloads in competition with NASA, ESA, and private interests.
- A slowdown in worldwide passenger miles has delayed airline fleet upgrade and expansion plans. A recent spate of orders on Boeing and Airbus could be reversing that trend. Fly-by-wire (electronic) aircraft has become the norm on new aircraft such as the Boeing 777.
- There are ongoing decade-long projects to upgrade the world's air traffic control systems.

Military/Aerospace Electronics Market Trends

Electronics will continue to be turned to in spite of a decline in the national budgets for defense spending. As countries keep aging weapons and communications systems effective, they often turn to electronic-intensive upgrades to extend the operations' lifetimes. Table 3-2 lists key U.S. defense spending programs. Other key trends include the following:

- All electronics are supporting "low-intensity" conflicts where forces are airlifted into "policing" situations; satellite communications and intelligence, mobile low-power voice and data communication, handheld electronic/optically guided weapons; and cost-effective aircraft, highly mobile light armored personnel carriers, and smart "fire and forget" missiles and munitions.
- Finer-resolution optical sensors using derivatives of CCD technology will be needed.
- Commercial varieties of computers, computer boards, storage, and networking increasingly are employed as military/aerospace designers recognize their reliability and cost savings. DY-4, Radstone Technology, and Towcester are examples of aggressive military computer board suppliers.
- The U.S. Department of Defense will spend $580 million from 1994 to 1998 for flat panel R&D and R&D incentives. The Advanced Research Projects Agency (ARPA) is the lead U.S. agency coordinating flat panel work.
- Increasing emphasis will be placed on remotely controlled electronics platforms that save human lives such as unmanned aerial vehicles (UAVs) or unmanned underwater vehicles (UUVs).
- High visibility programs such as the F-22 and EFA projects will drive trends in areas such as software tools, data communication, radar and electro-optics, and electronic warfare systems.

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Table 3-2
Major U.S. Defense Program Spending (Procurement and RTD&E)
(Millions of U.S. Dollars/Units)

	1995		1996		1997		
	$M	Units	$M	Units	$M	Units	Prime Contractor
Aircraft Programs							
RAH-66 Comanche	525	0	374	0	499	0	UTC/Boeing
Longbow AH-64	249	0	362	24	407	36	
V-22	497	0	712	0	589	0	United Technologies
F/A 18 C-F	2,639	24	2,271	24	3,912	36	McDonnell Douglas
B-2 Stealth Bomber	891	0	1,240	0	770	0	Northrop
C-17 Airlifter	2,987	6	2,697	8	49	0	McDonnell Douglas
F-16	202	0	408	0	146	0	General Dynamics
F-22	2,466	0	2,415	0	2,557	4	Lockheed
Missile/Weapon Programs							
SADARM	72	0	88	0	277	753	To be determined
AAWS-M Javelin	162	374	172	858	169	942	Texas Instruments/ Martin Marietta
ATACMS	154	148	149	150	104	100	Loral Vought
Longbow Hellfire	78	0	198	364	264	1,050	
AMRAAM	501	516	542	640	571	578	Hughes/Raytheon
Standard	275	202	276	230	264	215	Hughes/Raytheon
Tomahawk	463	217	480	217	526	217	Hughes/ McDonnell Douglas
Trident II	700	18	468	12	417	12	Lockheed
BAT	119	0	194	0	187	0	Northrop
Rolling Airframe	84	240	103	240	100	240	Hughes
TSSAM	524	48	520	114	566	133	Northrop
Navy Vessels							
DDG-51 AEGIS Destroyer	2,929	3	3,080	3	3,019	3	Bath/Ingalls
New Attack Submarine	266	0	1,060	0	1,075	0	To be determined
Space Systems							
DSP Satellites	459	0	386	0	249	0	TRW/Aerojet
DMSP Satellites	67	0	67	0	64	0	GE/Martin Marietta
GPS Satellites	247	5	159	4	168	1	Rockwell
Medium Launch Vehicle	132	3	177	3	240	6	McDonnell Douglas/ General Dynamics
MILSTAR SATELLITES	629	0	779	0	840	0	Lockheed
Space Boosters	1,264	0	1,280	0	1,326	0	Martin Marietta
Miscellaneous Electronics Programs							
AFATDS	100	477	74	292	77	424	
SINCGARS Radio	427	27,024	410	25,456	346	18,253	ITT/General Dynamics
GPS Terminals	427	15,463	487	16,279	555	15,824	Rockwell
JSTARS SYSTEMS	901	10	854	13	960	12	Grumman

Source: U.S. Department of Defense

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Semiconductor Opportunities

Semiconductor opportunities are as follows:

- Dwindling defense spending has forced many chip suppliers to rethink their participation in the market. In response to this, government procurement planners have begun to recognize commercial quality and procurement practices. U.S. procurement guidelines were changed during the year to prefer commercial off-the-shelf (COTS) when appropriate.
- U.S. military procurement is trending away from "mil-spec" for most purchases toward its use mainly in life/mission-critical applications. "Extended temperature" semiconductors now are being purchased heavily in Europe and by high-profile programs such as the Boeing 777, which uses fly-by-wire technology. Commercial-temperature-range products with plastic packages now also are being allowed in many programs.
- The Qualified Manufacturers Line (QML), or Mil-I-38535, is slowly becoming accepted for complex products such as ASICs and MPUs. The group monitoring military procurement procedures in the United States, DESC, now is allowing offshore assembly and test. Plastic-packaged QML certification also now is available to suppliers.
- Multichip module (MCM) technology continues to find increasing applications in high-performance signal processing and high-power applications. In the United States, a group known as the MCM Consortium has been awarded a $40 million contract to develop tools and processes to manufacture MCMs cost-effectively. Team members include: GM Hughes, Sandia National Labs, nChip, Polycon, Texas Instruments, IBM, Micro Module Systems, and Motorola.
- Radiation hardened (rad-hard) semiconductors will continue to be in demand. They generally are applied to space and strategic systems because their radiation-harsh environments can damage circuits and cause memory bit to change errantly. Total dose radiation of more than 100,000 rads generally is considered rad-hard. Silicon-on-insulator (SOI) and silicon-on-sapphire (SOS) are two common rad-hard process technologies.
- ASICs in all forms will continue to be emphasized. ASICs are the perfect technology for the design-intensive yet low-volume nature of most military/aerospace opportunities. Many ASICs also are used to consolidate logic and to replace parts that have been discontinued. Expect mixed-signal and DSP core-based designs to proliferate into many programs. FPGAs found early, big acceptance with military systems designers because of their relatively higher gate counts, design tool availability, and security for "classified" designs. FPGAs should continue to capture many of the new fewer-than-10,000-gate design wins. Gate arrays remain the most popular form of ASIC.
- SRAMs, flash memory, DRAMs, and specialty memories such as FIFOs continue to penetrate military/aerospace systems. As these systems become increasingly digitized and programmable, large arrays of memory are being required for standalone computers, displays, and embedded control systems (for example, aircraft flight computer). SRAMs remain preferable for most volatile applications; however, DRAMs are

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making a dent in many off-the-shelf and short-operational-life applications. Flash memory is perfect for many military uses, including many data and program applications that once were the province of EPROMs or EEPROMs. EEPROMs still find use in some performance-sensitive applications.

- Microprocessors, microcontrollers, and DSP (programmable and fixed function) such as memory continue to penetrate the heretofore analog domain of military/aerospace signal processing and control systems. Although most systems are quite content at the 8- and 16-bit levels, 32-bit CISC and RISC processors are finding their way into avionic, shipboard, and vetronic (vehicle) control modules. The drive toward using high-level languages such as Ada and C is amplifying this trend as well.
- Precision and power analog/discrete products forever will have a home in military products. As the signals that military/aerospace systems need to process get higher in frequency and data conversion accuracy exceeds 16 bits, new products are needed. Military/aerospace communications and electronic warfare will continue to need frequencies up into the tens of gigahertz and thus will need GaAs and millimeter wave amplifiers, mixers, and diodes, among others. Military/aerospace applications are prime candidates for smart-power linear and discrete elements that can connect to data buses and switch power monolithically. Hybrids will continue to be used as long as the performance/power envelope remains outside of the monolithic process for certain applications.

Military/Aerospace Electronic Production and Semiconductor Market

Figures 3-1 and 3-2, along with Tables 3-3 and 3-4, depict the global and North American demand for military/aerospace electronics and accompanying semiconductor demand. The North American market is expected to lag as defense spending gets hit harder, while security-conscious Europe and the newly industrializing countries of Asia will help offset that decline.

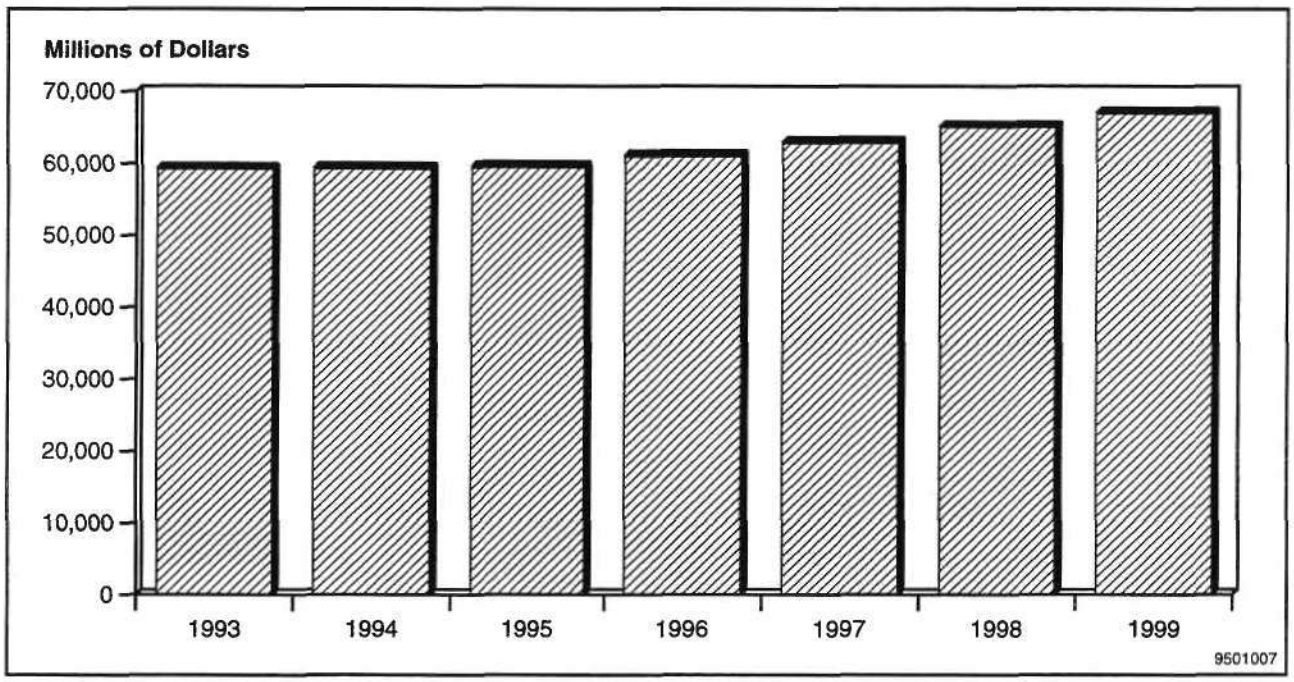
Radar and sonar systems are expected to fare better in the coming years, relative to missile and space systems, which are expected to take some heavy spending cuts. Overall rises in semiconductor content will allow semiconductor shipments to this market to grow faster than the equipment market itself. ASICs, memory, and microcomponents are expected to have above-average growth as digital/DSP controls become more dominant.

OEMs

Table 3-5 lists military/aerospace electronic companies and their product areas. There continues to be consolidation as companies such as Martin Marietta and Loral remain acquirers of divisions of other companies.

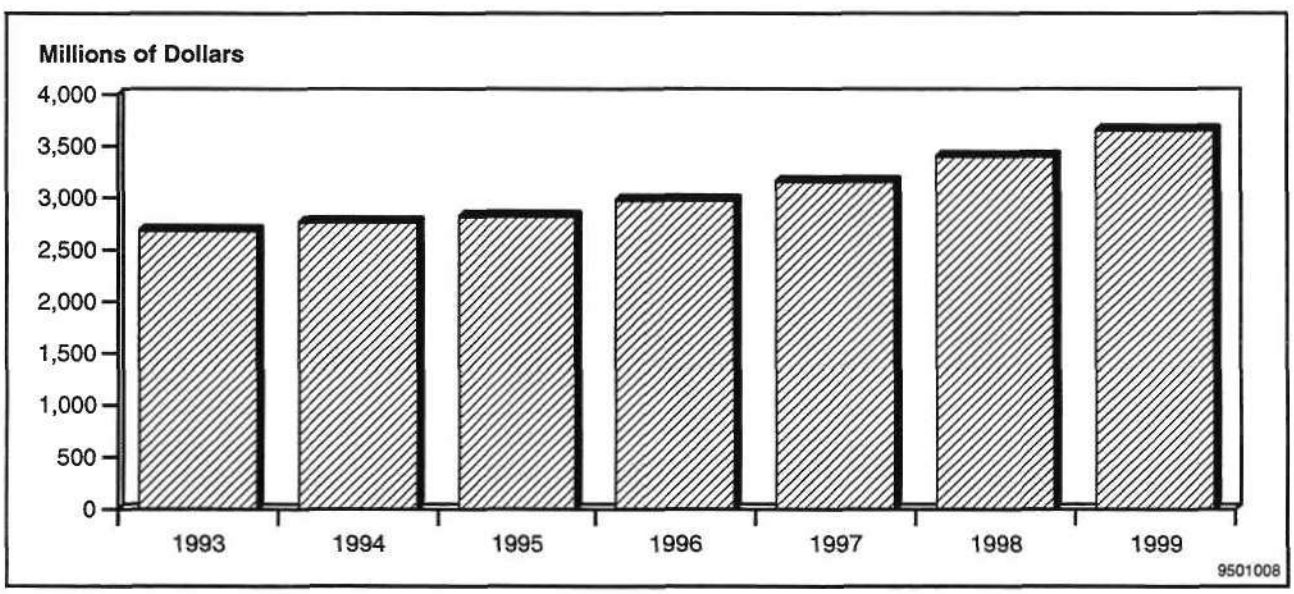
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Figure 3-1
Worldwide Military/Aerospace Electronics Production Forecast (Preliminary)



Source: Dataquest (March 1995)

Figure 3-2
Worldwide Military/Aerospace Semiconductor Forecast (Preliminary)



Source: Dataquest (March 1995)

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Table 3-3
North American Military/Aerospace Electronics Production (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total	31,284	29,668	28,698	28,932	29,466	30,018	30,585	0.6
Radar/Sonar/ Reconnaissance	13,291	12,627	12,122	12,303	12,611	12,926	13,249	1.0
Missile/Space	5,362	5,041	4,940	4,964	4,989	5,014	5,039	0
Navigation	4,761	4,618	4,572	4,618	4,687	4,758	4,829	0.9
Electronic Warfare	3,537	3,342	3,175	3,112	3,158	3,206	3,254	-0.5
Aircraft Flight Systems	3,015	2,749	2,611	2,637	2,690	2,744	2,799	0.4
Command, Control, Communication	1,318	1,291	1,278	1,298	1,330	1,370	1,415	1.8

Source: Dataquest (March 1995)

Table 3-4
North American Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	1,712.0	1,692.0	1,680.9	1,735.6	1,806.1	1,882.2	1,957.5	3.0
IC	1,364.0	1,348.0	1,341.9	1,386.6	1,446.1	1,509.2	1,571.5	3.1
Digital Bipolar	219.0	198.0	179.9	166.1	154.6	144.2	134.0	-7.5
Memory	21.0	17.5	14.0	11.0	9.0	7.0	5.0	-22.2
Logic	198.0	180.5	165.9	155.1	145.6	137.2	129.0	-6.5
Standard Logic/ Function	136.0	126.5	118.9	114.1	109.6	105.2	101.0	-4.4
ASIC/Custom	62.0	54.0	47.0	41.0	36.0	32.0	28.0	-12.3
MOS Digital	799.0	809.0	827.0	876.5	928.5	985.0	1041.5	5.2
Memory	268.0	273.0	283.0	300.0	319.0	340.0	359.0	5.6
DRAM	38.0	41.0	45.0	50.0	55.0	61.0	67.0	10.3
SRAM	110.0	110.0	113.0	122.0	131.0	141.0	149.0	6.3
≤64K (%)	36	30	25	20	12	10	9	
=256K (%)	44	40	36	28	20	15	10	
≤1M (%)	20	30	39	52	68	75	81	
EPROM	37.0	36.0	35.0	33.0	30.0	27.0	24.0	-7.8
ROM/PROM	22.0	22.0	21.0	19.0	17.0	16.0	14.0	-8.6
EE	36.0	35.0	34.0	34.0	35.0	36.0	37.0	1.1
Flash	4.0	9.0	14.0	21.0	29.0	37.0	45.0	38.0
Other/FIFO	21.0	20.0	21.0	21.0	22.0	22.0	23.0	2.8

(Continued)

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Table 3-4 (Continued)
North American Military/Aerospace Semiconductor Consumption (Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Microcomponent	193.0	197.0	202.0	214.5	228.0	240.5	254.0	5.2
MPU	54.0	55.0	56.0	61.0	66.0	71.0	77.0	7.0
8/16 Bit (%)	72	68	64	60	56	52	48	
32 Bit (%)	28	32	36	40	44	48	52	
MCU	17.0	16.0	16.0	16.5	17.0	17.5	18.0	2.4
4/8 Bit (%)	93	92	90	88	85	82	79	
16/32 Bit (%)	7%	8%	10%	12%	15%	18%	21	
DSP MPU	17.0	19.0	21.0	23.0	26.0	29.0	32.0	11.0
MPR/Functions	105.0	107.0	109.0	114.0	119.0	123.0	127.0	3.5
MOS Logic	338.0	339.0	342.0	362.0	381.5	404.5	428.5	4.8
Standard (S/MSI)	55.0	54.0	53.0	54.0	54.0	55.0	56.0	0.7
ASIC	283.0	285.0	289.0	308.0	327.5	349.5	372.5	5.5
Gate Array	140.0	139.0	139.0	147.0	155.0	163.0	172.0	4.4
Cell Based	69.0	70.0	72.0	77.0	82.0	87.0	93.0	5.8
Programmable Logic	50.0	54.0	59.0	66.0	74.0	83.0	91.0	11.0
Full Custom	12.0	10.0	7.0	5.0	3.0	3.0	2.5	-24.2
GaAs	12.0	12.0	12.0	13.0	13.5	13.5	14.0	3.1
ASIC % Rad-Hard/Space	13	14	14	15	15	15	15	
ASIC $ Rad-Hard/Space	43.9	47.5	47.9	54.3	57.2	60.7	64.3	6.3
Analog	346.0	341.0	335.0	344.0	363.0	380.0	396.0	3.0
Discrete	285.0	280.0	275.0	283.0	291.0	300.0	309.0	2.0
Optoelectronic	63.0	64.0	64.0	66.0	69.0	73.0	77.0	3.8

Source: Dataquest (March 1995)

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Table 3-5
Military/Aerospace Electronic Producers

Company	Airborne	Radar Ship/Ground	Sonar	Missile Weapon	Space	Navigation	Communication	Electronic Warfare
GM Hughes Electronics	X	X	X	X	X		X	X
Thomson-CSF	X	X	X	X	X		X	X
Martin Marietta	X	X		X	X	X	X	X
Raytheon		X	X	X			X	X
GEC Plessey	X	X	X	X	X	X	X	X
Lockheed		X	X	X	X			X
TRW					X	X	X	X
Unisys		X				X	X	
Rockwell	X			X	X	X	X	X
Texas Instruments	X			X		X		X
Litton	X			X		X	X	X
Honeywell			X	X	X	X	X	X
Westinghouse		X	X	X	X		X	X
Loral	X		X	X	X		X	X
ITT	X	X			X	X	X	X
Deutsche Aerospace		X	X	X	X	X		X
E-Systems					X	X	X	X
Northrop				X		X		X
General Dynamics				X	X		X	
Harris					X		X	
GTE							X	X
Ferranti	X	X			X	X		
Boeing	X			X	X			X
British Aerospace				X	X	X	X	X
Allied-Signal	X			X	X	X	X	

(Continued)

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Table 3-5 (Continued)
Military/Aerospace Electronic Producers

Company	Airborne	Radar Ship/Ground	Sonar	Missile Weapon	Space	Navigation	Communication	Electronic Warfare
Philips				X	X	X	X	
Thorn-EMI	X	X		X				
Mitsubishi	X	X	X	X	X	X		
Motorola				X	X		X	X
AT&T			X		X		X	X
Siemens	X	X					X	X
Sextant Avionique						X	X	
Smiths Industries					X	X	X	
Dassault Electronique	X	X		X	X			X
AIL Systems	X	X					X	X
Toshiba				X	X			
Emerson Electric	X	X				X	X	X
NEC					X	X	X	
Ericsson	X	X			X		X	X
McDonnell Douglas				X	X		X	
IAI/Elta	X	X	X	X	X	X		X
Racal						X	X	X
Grumman	X			X	X			
Selenia	X	X	X	X	X	X		X
Tadiran/Elisra							X	X
Matra				X	X			

(Continued)

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Table 3-5 (Continued)
Additional Principal Military/Aerospace Electronic Equipment Producers

Company	Electro-Optic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
GM Hughes Electronics	X	X	X	X	X	Semiconductors, microwave subsystems
Thomson-CSF	X	X	X	X	X	Semiconductors, microwave, CCD
Martin Marietta	X	X	X	X	X	Semiconductors
Raytheon			X			Semiconductors
GEC Plessey	X	X	X	X	X	Semiconductors, microwave subsystems
Lockheed	X	X	X	X	X	Semiconductors, microwave subsystems
TRW	X	X	X	X		Semiconductors, microwave subsystems
Unisys		X	X	X		
Rockwell	X	X	X		X	Semiconductors
Texas Instruments	X		X		X	Semiconductors, microwave subsystems
Litton	X		X			Microwave subsystems
Honeywell	X	X	X	X		Semiconductors
Westinghouse	X	X	X			Semiconductors
Loral	X	X	X	X		Semiconductors, microwave subsystems
ITT	X	X				Semiconductors, microwave subsystems
Deutsche Aerospace	X					
E-Systems				X		
Northrop	X	X	X		X	
General Dynamics		X		X	X	
Harris		X	X	X	X	Semiconductors, microwave subsystems
GTE	X					
Ferranti	X	X				
Boeing	X	X	X		X	
British Aerospace	X	X	X	X	X	
Allied-Signal		X			X	Semiconductors

(Continued)

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Table 3-5 (Continued)
Additional Principal Military/Aerospace Electronic Equipment Producers

Company	Electro-Optic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
Philips						Semiconductors
Thorn-EMI	X		X	X		Semiconductors
Mitsubishi		X		X	X	Semiconductors
Motorola		X	X		X	Semiconductors
AT&T	X	X	X			Semiconductors, microwave subsystems
Siemens		X	X			Semiconductors
Sextant Avionique		X	X			
Smiths Industries	X	X	X			
Dassault Electronique	X		X			
AIL Systems			X			
Toshiba Semiconductors						
Emerson Electric	X	X	X		X	
NEC			X			Semiconductors
Ericsson	X	X	X	X	X	Semiconductors
McDonnell Douglas	X	X		X		
IAI/Elta	X	X		X	X	
Racal	X	X	X			
Grumman		X		X	X	
Selenia	X					
Tadiran/Elisra			X			
Matra	X					

Source: Dataquest (August 1994)

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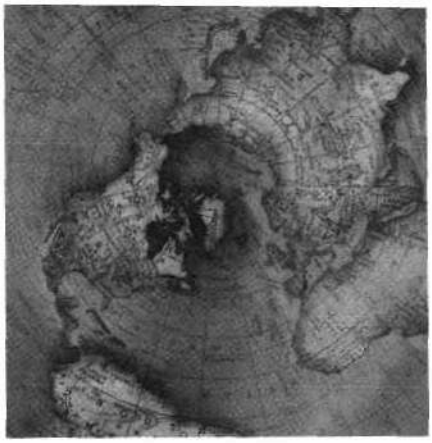
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Automotive Application Markets

Market Trends Report

Program: Semiconductor Application Markets Worldwide
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Automotive Application Markets



Market Trends Report

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Chapter 1
Introduction and Methodology

This document is the first in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, communications (two), consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- Key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analyst: Greg Sheppard

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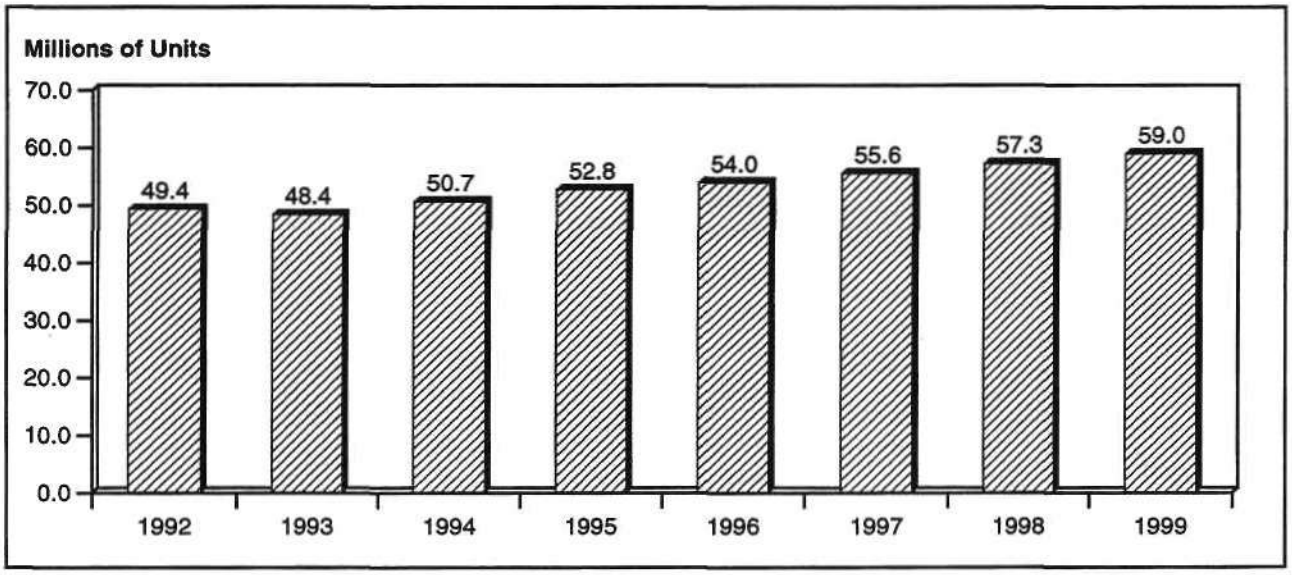
Chapter 2
Automotive Market Trends

Highlights of the automotive market are as follows:

- The hot U.S. market should slow down in 1995 and throughout 1996 as higher interest rates dissuade some buyers. The slowdown should not be as pronounced as those previously because of the replacement of older vehicles. The average age of vehicles on U.S. highways remains at an all-time high. The Canadian and German markets are expected to show some recovery this year as those economies bounce back. European auto production is expected to show a modest recovery overall throughout 1995 and 1996. Strong exports and a slowly recovering economy are expected to boost Japanese production. Figure 2-1 provides an outlook on global production; Table 2-1 shows actual production by region, and Table 2-2 provides an outlook for North American production.
- Japanese manufacturers and suppliers are continuing to move production out of Japan into the United States, Europe, and Asia as the high yen value and market demand for local manufacturing shape capital spending. Mercedes-Benz and BMW have announced movement of production to North America for that market as costs become prohibitive in Germany.
- The emerging countries of Asia are expected be the fastest-growing automotive producers in the coming decade. Companies such as Nissan and Volkswagen have been very aggressive in seeking joint ventures in such countries as China. The electronic module designs typically are licensed to Asian partners in such ventures.
- Government-mandated fuel economy (corporate average fuel economy, or CAFE, in the United States), emission requirements, and safety requirements will continue to become more restrictive in the developed countries and applied for the first time in developing countries. For applications in developed countries, this means that more electronics will be used that include integrating transmission control functions. For developing regions, it means employment of electronic engine controls for the first time.
- General Motors remained the top global producer in 1993 (and believed to be in 1994, too), followed by Ford and Toyota, buoyed by the strength of the U.S. market. The three major American producers were the only companies to grow last year (see Table 2-3).

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Figure 2-1
Worldwide Vehicle Production Forecast



Source: Dataquest (February 1995)

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Table 2-1
Worldwide Vehicle Production Forecast by Region

	1984	1992	1993	1993 Percentage Worldwide	Growth (%) 1992/1993
United States	10,924	9,778	10,890	22.6	11.4
Canada	1,878	1,983	2,239	3.9	12.9
Mexico	343	1,080	1,080	0.7	0
North America	13,145	12,841	14,209	27.1	10.7
Belgium	249	314	417	0.5	32.8
France	3,062	3,733	3,131	6.3	-16.1
Germany	4,045	5,194	3,991	8.4	-23.2
Italy	1,602	1,686	1,267	3.3	-24.9
Spain	1,308	1,782	1,542	2.7	-13.5
Sweden	432	357	337	0.9	-5.6
United Kingdom	1,134	1,540	1,496	2.3	-2.9
Europe	11,832	14,606	12,181	24.4	-16.6
Japan	11,393	12,449	11,228	23.5	-9.8
Australia	399	260	294	0.8	13.1
Brazil	865	1,095	1,422	1.8	29.9
Russia/CIS	2,209	1,598	1,589	4.6	-0.6
Korea	265	1,730	2,050	0.5	18.5
Others*	2,050	4,861	5,454	4.2	12.2
Total Worldwide	42,158	49,440	48,427	-	-2.0

*Includes China and at least 30 other producing countries
Source: Automotive News/Dataquest (July 1994)

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Table 2-2
U.S. and Canadian Auto and Truck Production (Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Automobiles	6,692	7,337	7,818	8,170	8,006	8,127	8,330	8,621	2.0
Trucks/Vans	5,065	5,829	6,844	7,220	7,148	7,255	7,473	7,772	2.6
Total	11,757	13,166	14,662	15,390	15,155	15,382	15,803	16,393	2.3

Source: Dataquest (February 1995)

Table 2-3
Top Worldwide Vehicle Producers (Thousands of Units)

	1992	1993	1993 Percentage Worldwide	Growth (%) 1992/1993
General Motors	7,097	7,299	15.1	2.8
Ford	5,500	5,700	11.8	3.6
Toyota	4,696	4,450	9.2	-5.2
Volkswagen	3,466	3,000	6.2	-13.4
Nissan	2,981	2,818	5.8	-5.5
Chrysler	2,033	2,348	4.8	15.5
Mitsubishi	1,832	1,875	3.9	2.3
Honda	1,883	1,827	3.8	-3.0
Renault	2,095	1,761	3.6	-15.9
Peugeot-Citroen	2,050	1,751	3.6	-14.6
Fiat	1,900	1,600	3.3	-15.8
Mazda	1,459	1,241	2.6	-14.9
Total	36,992	35,670	73.7	-3.6

Source: Automotive News/Dataquest (July 1994)

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Chapter 3
Automotive Electronics Market Trends

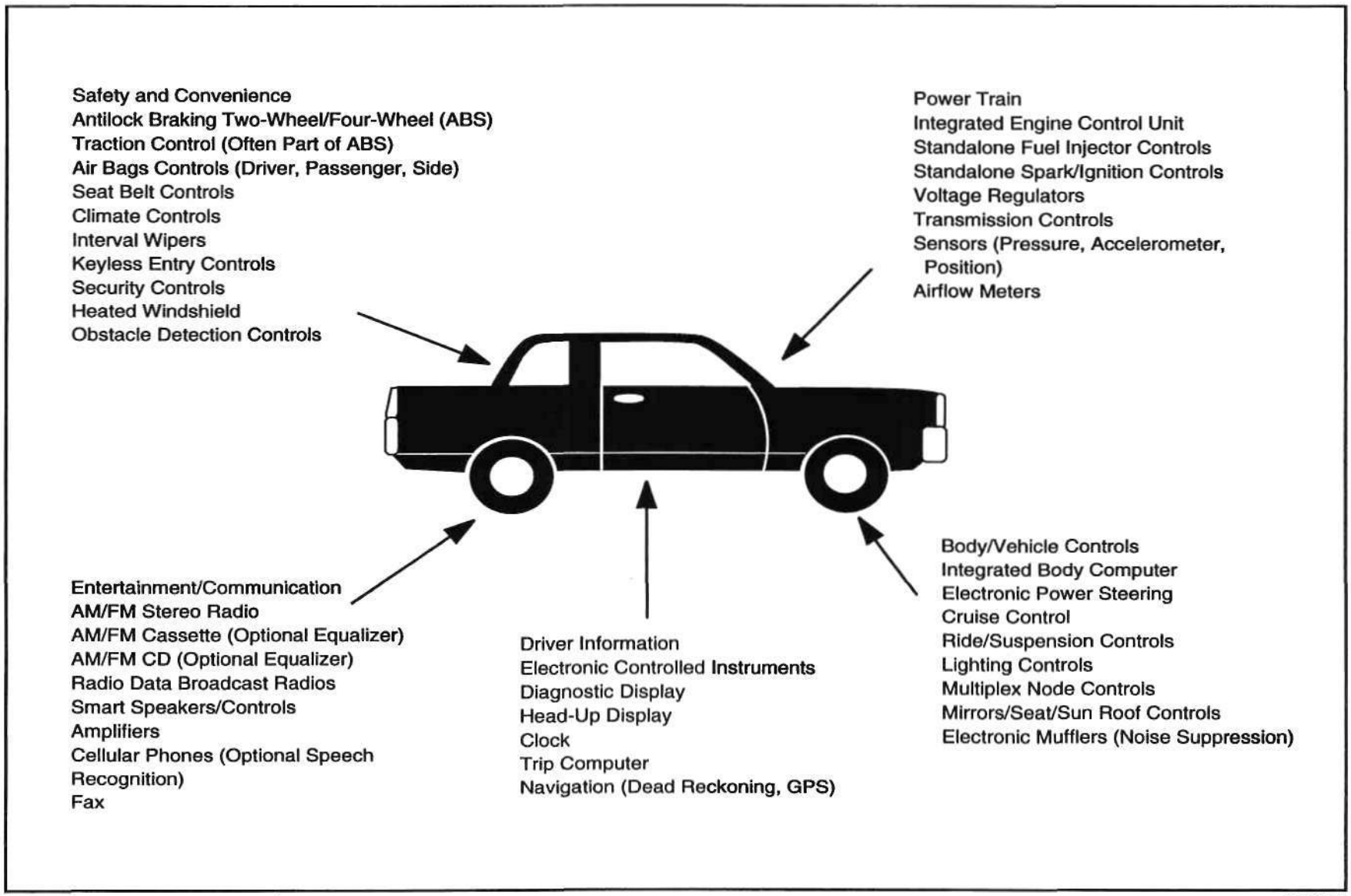
There is a continuing penetration of various electronic subsystems and controls into cars and trucks. Figure 3-1 shows the proliferation of electronic systems. Key factors driving the wave of electronic penetration continue to be public initiatives such as better fuel economy, lower emission, air bag safety, and a new one that standardizes the diagnostics/communications system. Consumer demand and product differentiation, as in most markets, contribute to the proliferation on options. Figure 3-2 shows that we estimate the average vehicle today to have about $565 of modules and systems; the figure will be $678 per vehicle by 1999. The average car can have a dozen modules (circuit boards), typically located in the passenger or engine compartment.

Highlights are as follows:

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming 6 modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the drive train area. A trend toward 32-bit MPU-based integrated modules is being stimulated by efficiencies needed for even higher corporate fuel economy requirements.
- Electronic-intensive antilock brakes and air bags controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (two wheels) to be used on high-end cars (four wheels). Driver-side air bags are becoming standard equipment on almost every vehicle. Passenger-side air bag versions now are entering the market. Side air bags are emerging as an option.
- Electronic suspension and steering are beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information, and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry, and light timers are proving to be popular options in an ever-security-conscious world.
- Personalization features such as memory seats, mirror, and radio settings now are popular on high-end modules.
- Entertainment systems are dominantly cassette-based today, with CD-based systems emerging at a modest rate. New digital compact cassette (DCC) and Mini Disc systems are beginning to find their way into 1994 vehicles. Intelligent/distributed speaker systems are becoming more common.

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Figure 3-1
Automotive Electronics: Standard Features and Options Proliferate

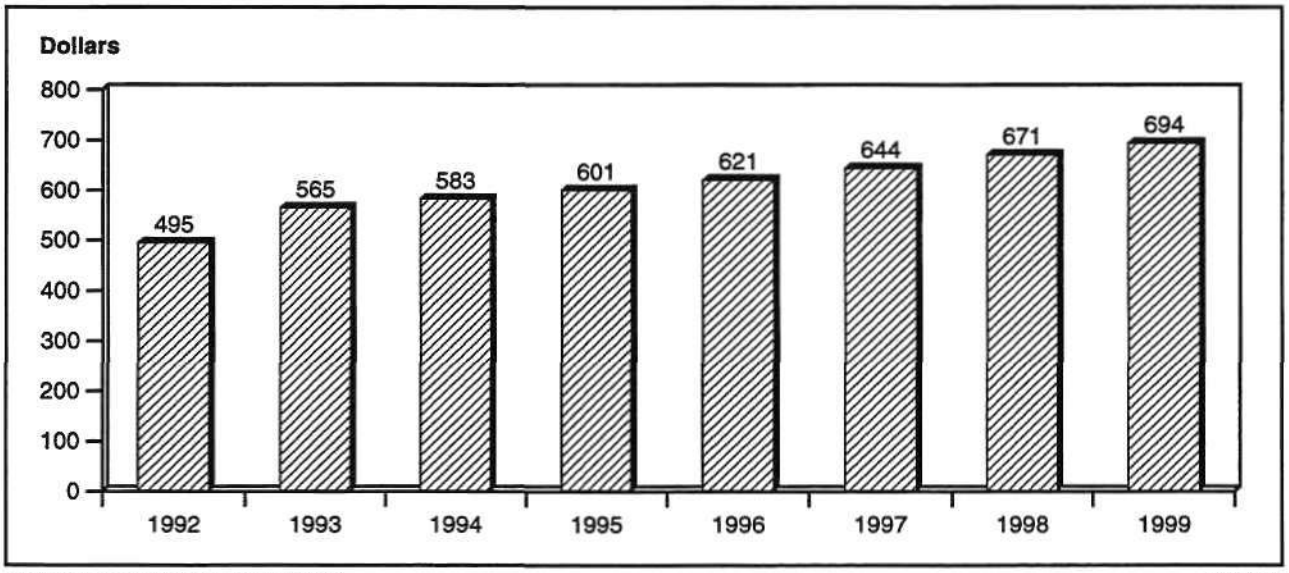


Source: Dataquest (February 1995)

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Figure 3-2
Electronic Module and System Content



Source: Dataquest (February 1995) G4003956

- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 has been adopted in the United States. This interface is heading toward serving as the communications link between modules. Europe is rolling out a standard called ISO 9141 and two proprietary standards known as CAN and VAN.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement for a 2 percent requirement on all vehicles sold in that state by 1998 (10 percent by 2003). Several manufacturers have chosen the a minivan test platform. The most critical challenge is creating cost-effective battery technology. Nickel metal hydride seems to be the leader at the moment. Electric vehicles currently cost about 50 percent more than do gas engine versions. Battery life averages about three years; it costs the consumer $3,000 to replace them. Hybrid approaches are being considered, including advanced flywheel technology.

Navigation, Communication, and Smart Highways

Highlights in the navigation, communication, and smart highways areas are as follows:

- Navigation systems based on dead reckoning and the Global Positioning System (GPS) are becoming very popular in Japan and are appearing in the United States and Europe. General Motors has introduced a $2,000 system that uses a PCMCIA card for the map database and a Motorola-based 68EC020 processor for GPS and dead reckoning processing (made by Zexel and Rockwell).

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- The Radio Data Broadcast System (RDBS) has been available in Europe for some time and now is rolling out in the United States. The system will alert the driver to traffic reports and will display radio station format and call letters.
- Intelligent vehicles that employ infrastructure-integrated navigation aids and collision avoidance systems, and that communicate with the highway system to optimize traffic flow, remain at least a decade off from broad-scale use. Japan has embarked on its Vehicle Identification and Communication System (VICS), which combines government and industry on devising ways to route vehicles efficiently over Japan's crowded highways. Japan has spent more than $1 billion in the past decade researching intelligent traffic management methods. To date Japan is the furthest along in the availability of navigational aides such as GPS receivers.

The $800 million Prometheus Program in Europe is an effort to devise a common way for smart cars and smart infrastructure to communicate with each other. Drive I and Drive II are other pan-Europe programs. Drive II, which started this year, also covers other modes of transportation, such as trains. Other European efforts include one in Manchester, England, that involves the use of 500,000 wireless smart cards for automatic toll collection on roads.

The major program in the United States is coined the Intelligent Vehicle Highway System (IVHS) and is underwritten by $659 million in Federal Highway Administration funding for several R&D contracts. Tests were just completed in Orlando, Florida, with a GM system known as TravTek that informed the driver of area attractions, weather, and road conditions. It could give voice-synthesized instructions on where to turn. The goal of IVHS program is to develop a standard technology for car-road navigation as well as vehicle control such intercar spacing and movement. A trade association known as IVHS America estimates that $200 billion could be spent on IVHS in the next 20 years in the United States alone.

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Chapter 4
Architecture and Semiconductor Opportunities

Figure 4-1 shows average worldwide and North American vehicle semiconductor content. Now at $103 of content in 1994, $135 is possible by 1999, given the expected pervasion of systems. Figures 4-2 through 4-4 show block diagrams of a typical integrated engine control unit, antilock braking controller, and a multiplex wiring system. In general all automotive opportunities can be characterized as cost-sensitive and quality-demanding. Almost all components will not get design-in consideration if they do not meet the parts-per-billion defect rate. Likewise, every chip must be cost-justified on an engineering trade-off basis, and the tremendous volumes involved allow the OEMs plenty of negotiating leverage. As design opportunities move into the engine compartment, it is not unusual to find temperature requirements approaching 150°C.

Controllers and Cores

4-, 8-, 16-, and 32-bit MCUs and MPUs in standalone configuration and ASIC cores are staples on most vehicles. These serve as the nerve center of the various modules, whose numbers can vary from 2 to 3 on low-end vehicles to 35 to 50 on high-end luxury cars. Companies such as Texas Instruments and Motorola have been successful at creating reconfigurable core libraries that place the MCU core, data conversion, ROM, RAM, and even power circuitry on the same chip. 8-bit is the most common variety for engine management and body functions, whereas the stereo system typically have been satisfied with 4-bit MCUs for tuning, among others. Future power train applications will use 32-bit controllers as 683xx and PowerPC have garnered design wins at many of the major OEMs.

ASICs

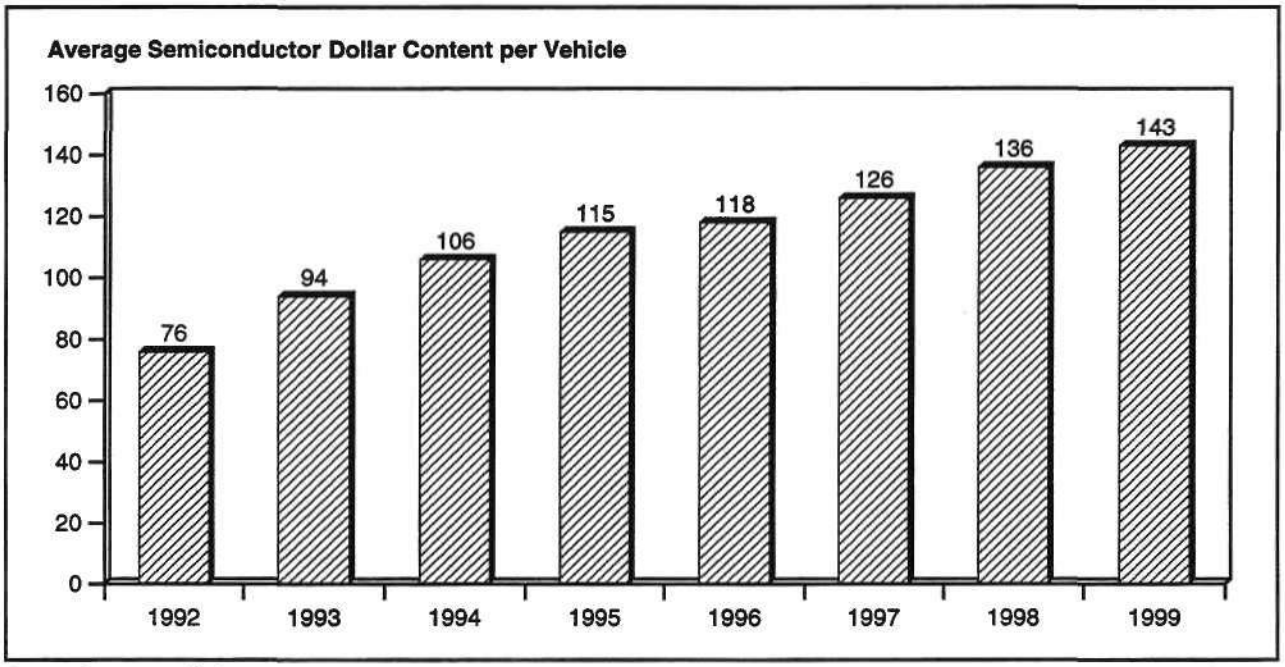
A substantial part of the circuitry surrounding the module-based MCU are CMOS, bipolar, or BiCMOS functions that multiplex and condition signal inputs and outputs. This principally is handled by ASICs and various standard analog functions such as op amps and comparators. The trend is toward integrating these functions on to the same ASIC chip as the processor core. In some cases the power driver circuitry also is being included.

Power

There is no lack of a need to switch and regulate 12/5V and control loads such as motors (windows, seats, antennas, and wipers), fuel injectors, actuators, and lights. Bipolar and MOSFET power transistors and power protection circuits are used by the dozens in each vehicle. Each module also generally has a voltage regulating device on it. The main voltage regulator (often a hybrid) and alternator diode are on every vehicle. Most power devices generally have to be able to accept 80V of "load dumping" energy. New outsourcing practices for items such as wiper motors are forcing the power circuits into the controlled items themselves. Electric vehicles of course will require a new genre of power chips that can handle 300V.

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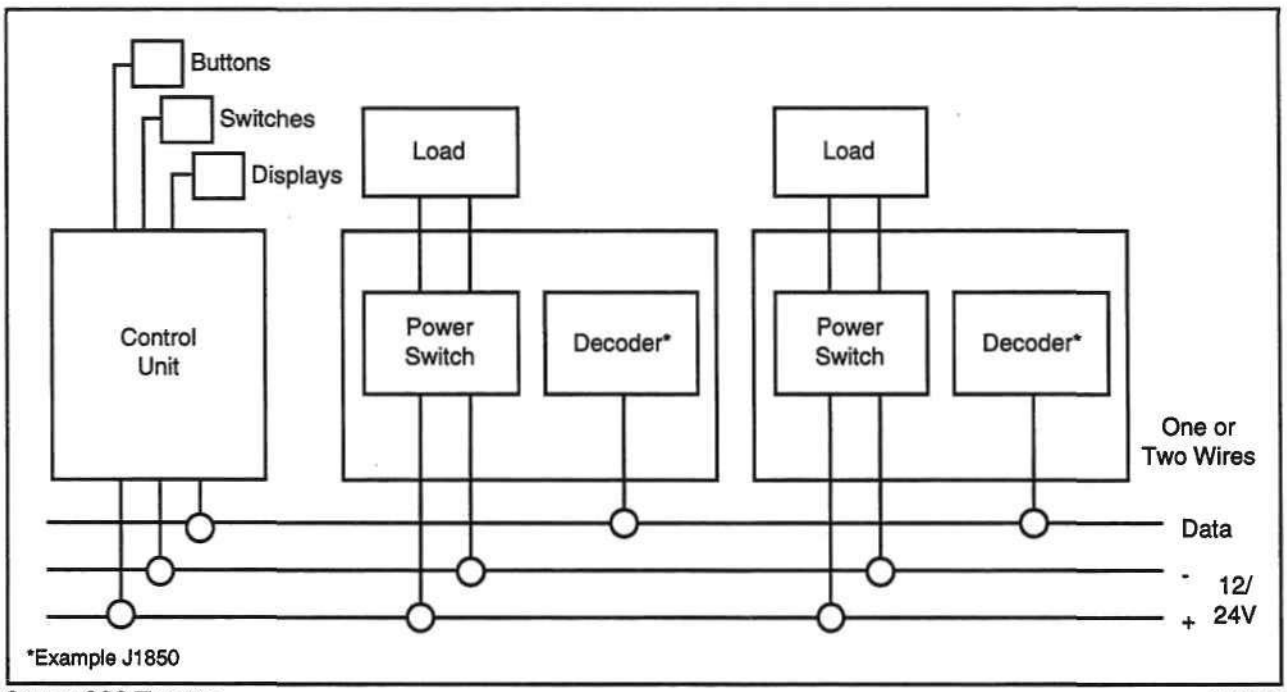
Figure 4-1
Average Semiconductor Dollar Content per Vehicle



Source: Dataquest (February 1995)

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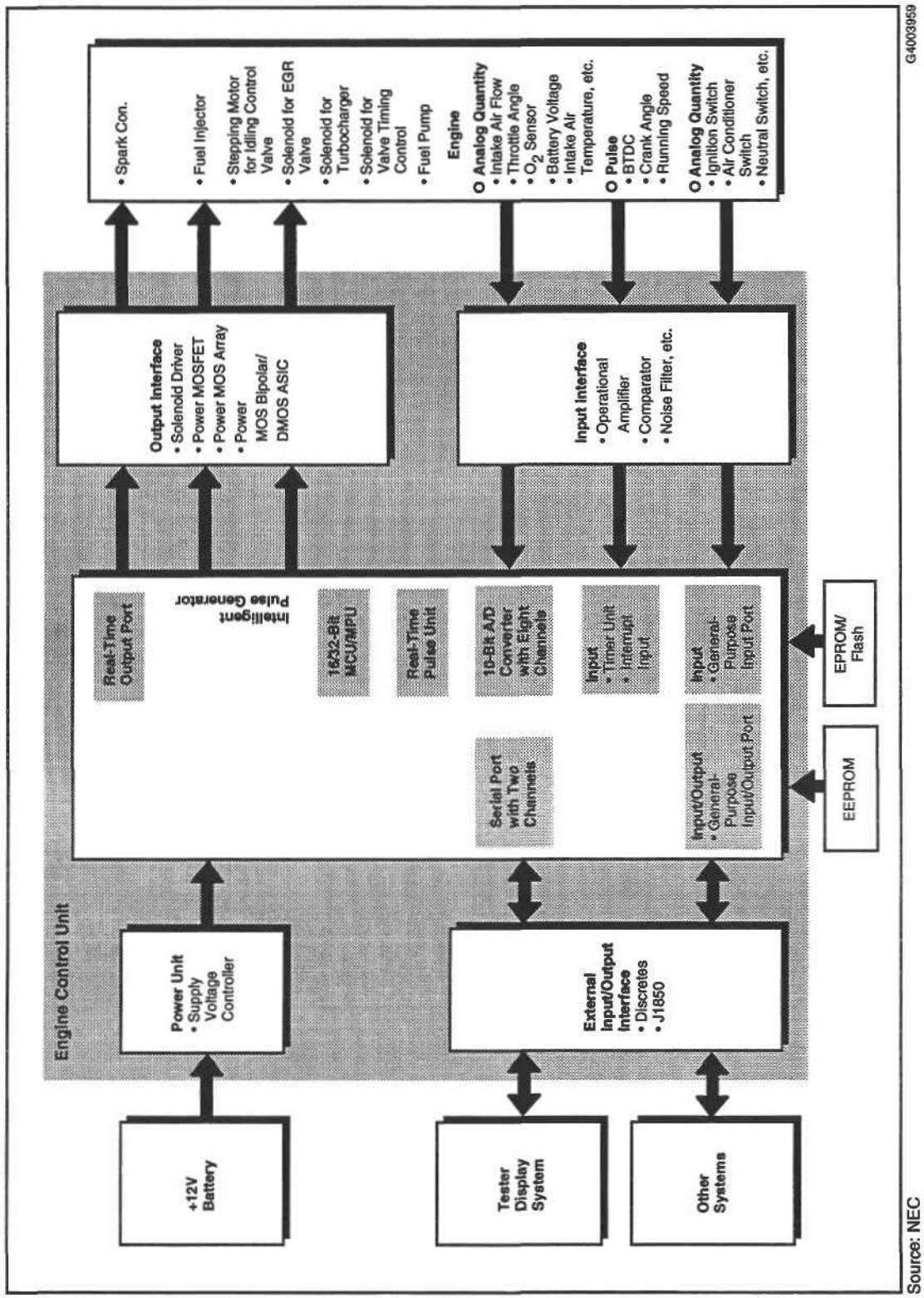
Figure 4-2
Multiplex Wiring Example



Source: SGS-Thomson

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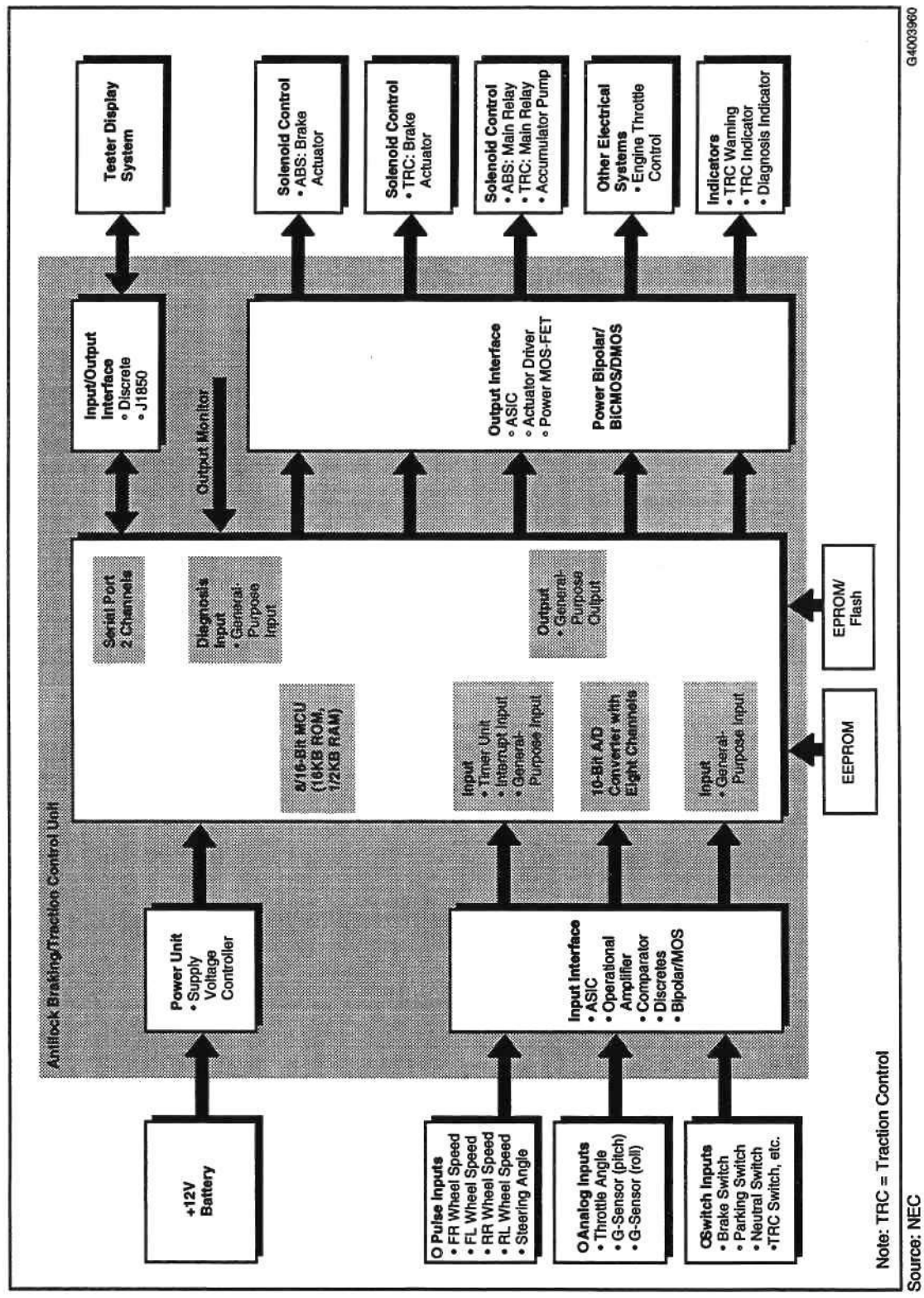


Source: NEC

Figure 4-3
Integrated Engine Control Unit

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Figure 4-4
Antilock Braking System (ABS) with Traction Control



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Hybrids/Bar Die

As much as 25 percent of a vehicle's chips are consumed in bare die or on hybrids. Most of these chips are power discretes, along with passives. Typically the OEM is the major manufacturer of these. Examples of hybrid applications include DC/DC converters, ignition modules, remote injector drivers, voltage regulators, air meters, and pressure sensors.

Multiplex Controllers

To facilitate intermodule, multiplexed communication and to bring out mandated emission diagnostic information, vehicle companies are starting to install bus transceivers and protocol ICs. Several standards are emerging, including the following:

- SAE J1850 (primarily for the United States to date)
- ISO 9141 (primarily for Europe)
- CAN (Bosch/Intel)
- VAN (Peugeot)
- C2D (Chrysler)
- HBCC (Ford)
- DLCS (GM)
- HSSD (high-speed standard considered in the United States)

Multiplexing generally is segmented into speed classes. One segmentation adopted by the U.S.-based Society of Automotive Engineers (SAE) defines a Class A (less than 10 Kbps), Class B (10 Kbps to 125 Kbps), and Class C (greater than 125 Mbps). Class C communication supports real-time control and tends to be more expensive. The CAN standard is an example of this; its 1-Mbps capability has been adopted by Mercedes. In the United States, the J1850, a Class B standard, recently was approved after years of deliberation. It incorporates many of the features that other U.S. auto manufacturers use in their proprietary standards. It appears, however, that vehicles made for the European market will be based on ISO 9141 with CAN and VAN, while the North American market will use J1850. The Japanese and Korean manufacturers will make all varieties to satisfy their overseas markets.

Harris Semiconductor has announced that it is making J1850 transceivers and protocol controllers. The one-wire version now is supported; a two-wire version is ready when market demand appears. Nodal cost is from $0.50 and $2.00.

Sensors

A new generation of sensor-technology-based solid-state micromachining is emerging. Pressure sensors and accelerometers for collision detection (for air bag deployment) are the main applications to date. Silicon sensors have the advantage of being recalibratable, directly connectable to communication lines, and more reliable. Their main drawback is price, but companies such as Analog Devices are moving along the learning curve quickly.

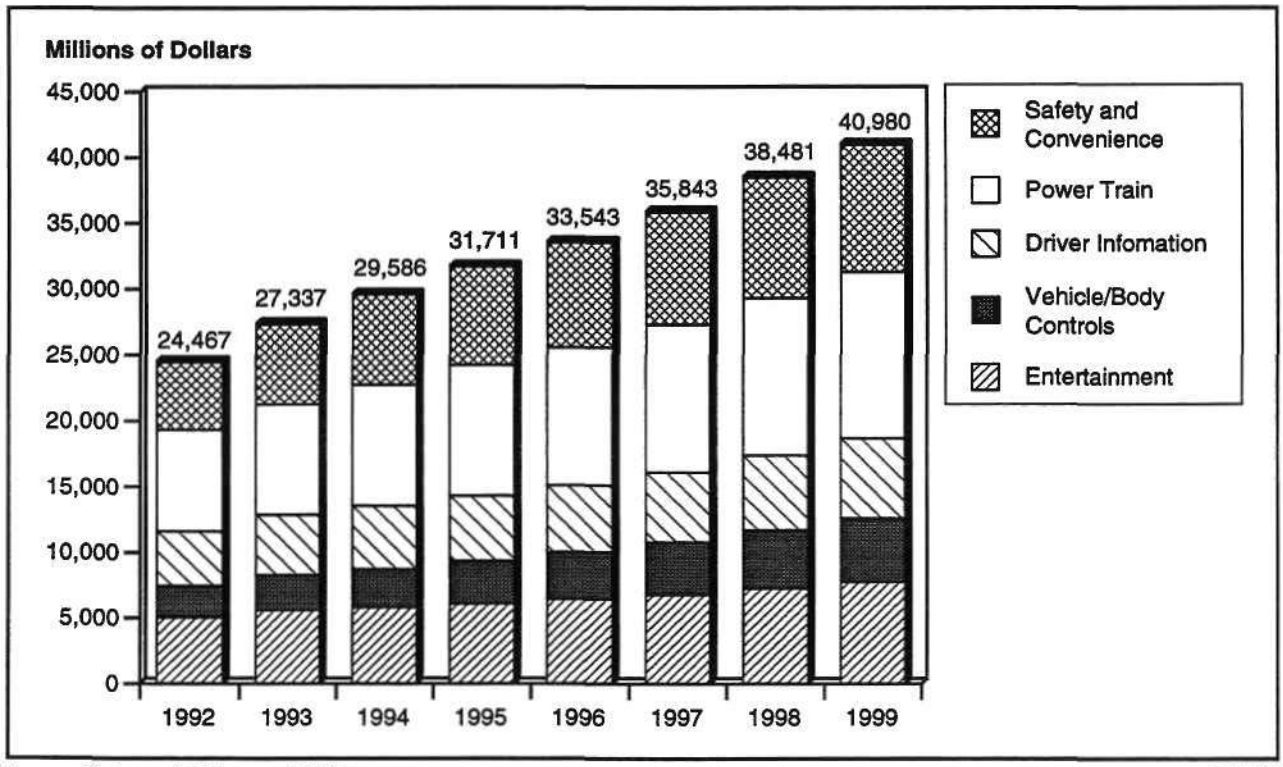
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Chapter 5
Automotive Electronics Production and Semiconductor Market

Figures 5-1 and 5-2 and Tables 5-1 through 5-4 show the worldwide and North American automotive electronics equipment production forecast and the accompanying semiconductor demand. The fastest-growing region of the world is expected be Asia/Pacific as production ramps for indigenous car sales and exports. The fastest-growing general category will be safety and convenience, driven by such killer applications as air bags and ABS.

Tables 5-5 through 5-9 show the North American module/system unit demand along with derived semiconductor demand for detail applications within each of major categories of entertainment, vehicle/body control, driver information, power train, and safety and convenience.

Figure 5-1
Worldwide Automotive Electronics Production by Product Area

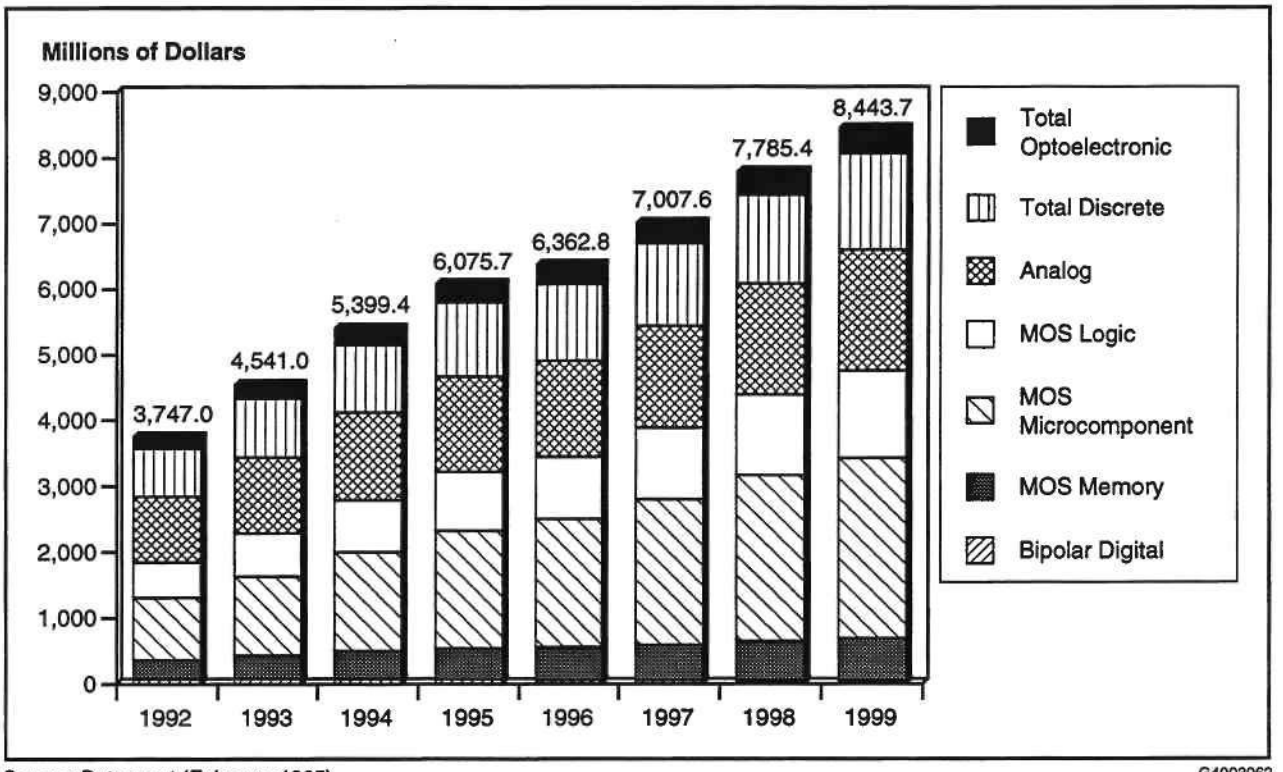


Source: Dataquest (February 1995)

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Figure 5-2
Worldwide Automotive Semiconductor Demand by Product Area



Source: Dataquest (February 1995)

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Table 5-1
Worldwide Automotive Electronics Production, by Product Area (Preliminary)
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Entertainment	5,039	5,611	5,799	6,105	6,434	6,798	7,286	7,785	6.1
Vehicle/Body controls	2,424	2,660	2,952	3,270	3,599	3,987	4,422	4,834	10.4
Driver Infomation	4,176	4,607	4,817	4,961	5,081	5,345	5,687	6,086	4.8
Power Train	7,691	8,411	9,183	9,921	10,484	11,184	11,922	12,578	6.5
Safety and Convenience	5,137	6,048	6,835	7,453	7,945	8,529	9,163	9,698	7.2
Total	24,467	27,337	29,586	31,711	33,543	35,843	38,481	40,980	6.7

Source: Dataquest (February 1995)

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Table 5-2
North American Automotive Electronics Production, by Product Area
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Entertainment	422	478	526	562	553	562	586	612	3.1
Vehicle/Body Controls	337	378	433	462	470	493	527	571	5.7
Driver infomation	681	771	881	952	972	1,030	1,129	1,226	6.8
Power Train	1,722	1,964	2,259	2,447	2,479	2,589	2,733	2,865	4.9
Safety and Convenience	749	1,050	1,438	1,722	1,883	2,119	2,346	2,484	11.6
Total	3,911	4,640	5,536	6,144	6,356	6,793	7,321	7,757	7.0

Source: Dataquest (February 1995)

Table 5-3
Worldwide Automotive Semiconductor Demand, by Product Area (Preliminary)
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	3,747.0	4,541.0	5,399.4	6,075.7	6,362.8	7,007.6	7,785.4	8,443.7	9.4
Bipolar Digital	77.0	82.0	75.6	69.8	62.3	59.4	55.3	51.0	-7.6
MOS Digital									
MOS Memory	290.0	360.0	436.8	472.9	499.6	536.6	594.3	645.2	8.1
MOS Micro-component	949.0	1,196.0	1,493.4	1,788.0	1,948.8	2,207.9	2,520.0	2,736.0	12.9
MOS Logic	533.0	656.0	784.2	888.1	938.3	1,082.6	1,220.1	1,324.7	11.1
Analog	999.0	1149.0	1,331.2	1,450.9	1,464.7	1,554.8	1,697.9	1,843.4	6.7
Total Discrete	723.0	888.0	1,030.6	1,126.7	1,161.8	1,253.2	1,349.3	1,464.9	7.3
Total Optoelec-tronic	176.0	210.0	247.5	279.3	287.4	313.0	348.6	378.5	8.9

Source: Dataquest (February 1995)

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Table 5-4
North American Automotive Semiconductor Demand, by Product Area (Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	1,068.2	1,299.3	1,596.5	1,827.9	1,934.9	2,108.6	2,308.3	2,477.6	9.2
Bipolar Digital	28.0	29.0	29.0	28.0	27.0	25.0	22.0	20.0	-7.2
MOS Digital									
MOS Memory	54.0	60.0	69.0	72.0	70.0	68.0	66.0	65.0	-1.2
MOS Microcomponent	255.0	295.8	355.0	397.6	417.4	450.8	500.4	545.5	9.0
MOS Logic	165.0	198.0	237.6	273.2	289.6	318.6	358.4	388.9	10.4
Analog	383.2	483.6	623.5	736.9	793.6	884.1	974.7	1052.4	11.0
Total Discrete	150.0	194.9	239.5	274.2	290.2	312.1	334.7	351.8	8.0
Total Optoelectronic	33.0	38.0	43.0	46.0	47.0	50.0	52.0	54.0	4.7
Recap (Based on the Above Table)									
MCU/MPU Units (Millions)	102.0	118.3	142.0	159.0	165.0	175.4	191.7	205.8	7.7
4 Bit	18.4	18.9	19.9	19.1	16.5	14.0	11.5	12.3	-9.1
8 Bit	76.5	88.7	106.5	117.7	120.4	126.3	134.2	144.1	6.2
16/32 Bit	7.1	10.6	15.6	19.1	24.7	29.8	34.5	39.1	20.2
ASIC ($M)									
Analog (All Technologies)	214.6	275.7	361.6	434.8	476.1	539.3	604.3	663.0	12.9
Digital and Mixed Signal (All Technologies)	133.7	162.4	197.2	229.5	246.2	270.8	304.7	330.6	10.9
Bare Die ICs (for Hybrids and MCMs)	199.9	256.5	336.1	404.2	445.9	508.6	574.5	634.9	13.6

Source: Dataquest (February 1995)

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Table 5-5
North America Automotive and Truck Entertainment System/Module Factory Installations (Selected) (Includes Imports)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
AM-FM Stereo/Cassette									
Units (M)	6.17	7.70	8.65	9.08	8.64	8.31	8.38	8.36	-0.7
Percentage Penetration	52.5	58.5	59.0	59.0	57.0	54.0	53.0	51.0	-2.9
Factory ASP ($)	87.0	84.0	83.0	83.0	82.5	82.5	82.0	82.0	-0.2
Revenue ($M)	537.0	647.0	718.0	753.7	712.6	685.3	686.8	685.6	-0.9
Semiconductor Market ($M)	107.4	132.6	150.8	158.3	149.7	143.9	144.2	144.0	-0.9
Semiconductor $/Unit	17.40	17.22	17.43	17.43	17.33	17.33	17.22	17.22	-0.2
AM-FM Stereo/Cassette (with Equalizer)									
Units (M)	1.53	1.71	1.91	2.15	2.27	2.46	2.69	2.95	9.1
Percentage Penetration	13.0	13.0	13.0	14.0	15.0	16.0	17.0	18.0	6.7
Factory ASP ($)	96.0	94.0	92.0	92.0	91.5	91.0	90.5	90.0	-0.4
Revenue ($M)	146.7	160.9	175.4	198.2	208.0	224.0	243.1	265.6	8.7
Semiconductor Market ($M)	30.8	34.3	37.7	43.6	45.8	49.3	53.5	58.4	9.2
Semiconductor $/Unit	20.16	20.02	19.78	20.24	20.13	20.02	19.91	19.80	0
AM-FM Stereo									
Units (M)	2.41	2.17	2.20	2.23	1.82	1.54	1.42	1.31	-9.8
Percentage Penetration	20.5	16.5	15.0	14.5	12.0	10.0	9.0	8.0	-11.8
Factory ASP ($)	56.0	53.0	50.0	48.0	47.0	47.0	47.0	47.0	-1.2
Revenue ($M)	135.0	115.1	110.0	107.1	85.5	72.3	66.8	61.6	-10.9
Semiconductor Market ($M)	27.0	23.0	23.1	22.5	17.9	15.2	14.0	12.9	-10.9
Semiconductor $/Unit	11.20	10.60	10.50	10.08	9.87	9.87	9.87	9.87	-1.2
AM-FM/CD									
Units (M)	0.26	0.34	0.53	0.69	1.06	1.54	1.90	2.30	34.2
Percentage Penetration	2.2	2.6	3.6	4.5	7.0	10.0	12.0	14.0	31.2
Factory ASP ($)	96.0	95.0	94.0	94.0	93.5	93.0	92.5	92.0	-0.4
Revenue ($M)	24.8	32.5	49.6	65.1	99.2	143.1	175.4	211.1	33.6

(Continued)

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Table 5-5 (Continued)
North America Automotive and Truck Entertainment System/Module Factory Installations (Selected) (Includes Imports)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Market ($M)	5.7	7.5	11.4	15.0	22.8	32.9	40.3	48.6	33.6
Semiconductor $/Unit	22.08	21.85	21.62	21.62	21.51	21.39	21.28	21.16	-0.4
Total Semiconductor Market ($M)	170.9	197.4	223.0	239.3	236.2	241.3	252.1	263.9	3.4
Total Equipment Revenue ($M)	843.6	955.5	1,052.9	1,124.1	1,105.3	1,124.6	1,172.2	1,223.9	3.1

Source: Dataquest (February 1995)

Table 5-6
North America Automotive and Truck Body/Vehicle Control System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Cruise Control									
Units (M)	8.23	9.35	10.56	11.23	11.21	11.54	12.01	12.62	3.6
Percentage Penetration	70.0	71.0	72.0	73.0	74.0	75.0	76.0	77.0	1.4
Factory ASP ($)	25.0	24.0	24.0	23.5	23.0	22.5	22.0	22.0	-1.7
Revenue ($M)	205.8	224.3	253.4	264.0	257.9	259.6	264.2	277.7	1.9
Semiconductor Market ($M)	82.3	89.7	101.3	105.6	103.2	103.8	105.7	111.1	1.9
Semiconductor $/Unit	10.00	9.60	9.60	9.40	9.20	9.00	8.80	8.80	-1.7
Electronic Power Steering									
Units (M)	0.39	0.46	0.59	0.77	0.91	1.15	1.42	1.80	25.2
Percentage Penetration	3.3	3.5	4.0	5.0	6.0	7.5	9.0	11.0	22.4
Factory ASP ($)	29.0	28.0	27.0	27.0	26.5	26.0	26.0	26.0	-0.8
Revenue ($M)	11.3	12.9	15.8	20.8	24.1	30.0	37.0	46.9	24.2
Semiconductor Market ($M)	4.2	4.8	5.9	7.7	8.9	11.1	13.7	17.3	24.2
Semiconductor $/Unit	10.73	10.36	9.99	9.99	9.81	9.62	9.62	9.62	-0.8

(Continued)

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Table 5-6 (Continued)
North America Automotive and Truck Body/Vehicle Control System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Ride/Suspension Control									
Units (M)	1.00	1.18	1.39	1.54	1.67	1.85	2.05	2.30	10.5
Percentage Penetration	8.5	9.0	9.5	10.0	11.0	12.0	13.0	14.0	8.1
Factory ASP ($)	40.0	40.0	39.0	37.0	37.0	36.5	36.0	36.0	-1.6
Revenue ($M)	40.0	47.4	54.3	56.9	61.7	67.4	74.0	82.6	8.7
Semiconductor Market ($M)	12.0	14.2	16.3	17.1	18.5	20.2	22.2	24.8	8.7
Semiconductor $/Unit	12.00	12.00	11.70	11.10	11.10	10.95	10.80	10.80	-1.6
Multiplex Systems (Door and Diagnostic, Among Others)									
Nodes (M)	2.12	4.61	7.48	10.77	14.55	19.38	26.86	32.79	34.4
Percentage Penetration	9.0	14.0	17.0	20.0	24.0	28.0	34.0	40.0	18.7
Factory ASP ($)	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9	-5.0
Revenue ($M)	5.7	11.9	18.3	25.0	32.1	40.6	53.5	62.0	27.7
Semiconductor Market ($M)	3.9	8.1	12.4	17.0	21.8	27.6	36.4	42.2	27.7
Semiconductor $/Unit	1.84	1.75	1.66	1.58	1.50	1.42	1.35	1.29	-5.0
Lighting Controls									
Units (M)	11.76	13.17	14.66	15.39	15.15	15.38	15.80	16.39	2.3
Percentage Penetration	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0
Factory ASP ($)	6.3	6.2	6.2	6.2	6.2	6.2	6.2	6.2	0
Revenue ($M)	74.1	81.6	90.9	95.4	94.0	95.4	98.0	101.6	2.3
Semiconductor Market ($M)	26.7	29.4	32.7	34.4	33.8	34.3	35.3	36.6	2.3
Semiconductor $/Unit	2.27	2.23	2.23	2.23	2.23	2.23	2.23	2.23	0
Total Semiconductor Market ($M)	129.0	146.2	168.6	181.7	186.2	197.1	213.2	232.0	6.6
Total Equipment Revenue ($M)	336.8	378.1	432.7	462.2	469.7	492.9	526.6	570.8	5.7

Source: Dataquest (February 1995)

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Table 5-7
North America Automotive and Truck Driver Information System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Electronic Instrument Cluster									
Units (M)	8.23	9.48	10.78	11.54	11.67	12.15	12.80	13.44	4.5
Percentage Penetration	70.0	72.0	73.5	75.0	77.0	79.0	81.0	82.0	2.2
Factory ASP ($)	49.0	48.0	47.0	46.5	46.0	45.5	45.0	44.5	-1.1
Revenue ($M)	403.3	455.0	506.5	536.7	536.8	552.9	576.0	598.2	3.4
Semiconductor Market ($M)	80.7	91.0	101.3	107.3	107.4	110.6	115.2	119.6	3.4
Semiconductor $/Unit	9.80	9.60	9.40	9.30	9.20	9.10	9.00	8.90	-1.1
Diagnostic Display									
Units (M)	2.00	2.30	2.64	2.92	3.03	3.23	3.48	3.77	7.4
Percentage Penetration	17.0	17.5	18.0	19.0	20.0	21.0	22.0	23.0	5.0
Factory ASP ($)	40.0	39.0	38.0	37.0	36.0	36.0	36.0	36.0	-1.1
Revenue ($M)	80.0	89.9	100.3	108.2	109.1	116.3	125.2	135.7	6.2
Semiconductor Market ($M)	32.8	35.9	43.1	46.5	46.9	50.0	53.8	58.4	6.2
Semiconductor $/Unit	16.40	15.60	16.34	15.91	15.48	15.48	15.48	15.48	-1.1
Trip Computer									
Units (M)	0.98	1.12	1.32	1.46	1.52	1.69	1.90	2.05	9.2
Percentage Penetration	8.3	8.5	9.0	9.5	10.0	11.0	12.0	12.5	6.8
Factory ASP ($)	46.0	45.0	44.0	43.0	43.0	43.0	43.0	43.0	-0.5
Revenue ($M)	44.9	50.4	58.1	62.9	65.2	72.8	81.5	88.1	8.7
Semiconductor Market ($M)	17.1	19.1	21.5	23.3	23.5	26.2	29.4	31.7	8.1
Semiconductor $/Unit	17.48	17.10	16.28	15.91	15.48	15.48	15.48	15.48	-1.0
Navigation System (Includes Nonfactory Sales)									
Units (M)	0.05	0.07	0.12	0.17	0.23	0.31	0.47	0.66	41.1
Percentage Penetration	0.4	0.5	0.8	1.1	1.5	2.0	3.0	4.0	38.0
Factory ASP ($)	630.0	570.0	525.0	485.0	445.0	410.0	380.0	353.0	-7.6

(Continued)

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Table 5-7
North America Automotive and Truck Driver Information System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Revenue ($M)	29.6	37.5	61.6	82.1	101.2	126.1	180.2	231.5	30.3
Semiconductor Market ($M)	6.2	8.3	13.5	18.1	22.8	29.0	41.4	53.2	31.5
Semiconductor $/Unit	132.30	125.40	115.50	106.70	100.13	94.30	87.40	81.19	-6.8
Electronic Clock									
System Revenue ($M)	123.62	138.42	154.15	161.81	159.33	161.72	166.15	172.36	2.3
Semiconductor Market ($M)	37.08	41.53	46.25	48.54	47.80	48.52	49.84	51.71	2.3
Total Semiconductor Market ($M)	136.7	154.3	179.5	195.2	200.5	215.8	239.8	263.0	7.9
Total Equipment Revenue ($M)	681.4	771.2	880.6	951.7	971.5	1,029.8	1,129.0	1,225.9	6.8

Source: Dataquest (February 1995)

Table 5-8
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Integrated Engine Control									
Units (M)	3.35	3.95	4.84	5.39	5.76	6.77	8.06	8.85	12.8
Percentage Penetration	28.5	30.0	33.0	35.0	38.0	44.0	51.0	54.0	10.4
Factory ASP ($)	80.0	77.0	76.5	76.0	76.0	75.5	75.5	74.0	-0.7
Revenue ($M)	268.1	304.1	370.1	409.4	437.7	511.0	608.5	655.1	12.1
Semiconductor Market ($M)	101.9	115.6	137.0	151.5	163.2	192.1	230.6	249.6	12.8
Semiconductor $/Unit	30.40	29.26	28.31	28.12	28.35	28.39	28.61	28.19	-0.1
Standalone Fuel Control									
Units (M)	8.41	9.22	9.82	10.00	9.40	8.61	7.74	7.54	-5.2
Percentage Penetration	71.5	70.0	67.0	65.0	62.0	56.0	49.0	46.0	-7.2

(Continued)

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Table 5-8 (Continued)
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Factory ASP ($)	72.0	70.0	70.0	69.5	69.0	68.5	68.0	67.5	-0.7
Revenue ($M)	605.3	645.1	687.6	695.3	648.3	590.1	526.5	509.0	-5.8
Semiconductor Market ($M)	175.5	187.1	199.4	201.6	188.0	171.1	152.7	147.6	-5.8
Semiconductor $/Unit	20.88	20.30	20.30	20.16	20.01	19.87	19.72	19.58	-0.7
Standalone Eng. Control (Ignition and Regulator, Among Others)									
Units (M)	21.16	23.70	26.39	27.70	27.28	27.69	28.44	29.51	2.3
Percentage Penetration	180.0	180.0	180.0	180.0	180.0	180.0	180.0	180.0	0
Factory ASP ($)	10.0	9.7	9.6	9.6	9.5	9.5	9.4	9.4	-0.4
Revenue ($M)	211.6	229.9	253.4	265.9	259.1	263.0	267.4	277.4	1.8
Semiconductor Market ($M)	99.5	108.0	116.5	122.3	119.2	121.0	123.0	127.6	1.8
Semiconductor $/Unit	4.70	4.56	4.42	4.42	4.37	4.37	4.32	4.32	-0.4
Transmission Control (Partially Included in Engine Controls)									
Units (M)	2.35	3.55	4.99	6.46	7.58	8.92	10.27	11.31	17.8
Percentage Penetration	20.0	27.0	34.0	42.0	50.0	58.0	65.0	69.0	15.2
Factory ASP ($)	63.0	61.0	59.0	57.0	55.0	53.0	52.0	51.0	-2.9
Revenue ($M)	148.1	216.8	294.1	368.4	416.8	472.8	534.1	576.9	14.4
Semiconductor Market ($M)	50.4	73.7	97.1	121.6	133.4	151.3	170.9	184.6	13.7
Semiconductor $/Unit	21.42	20.74	19.47	18.81	17.60	16.96	16.64	16.32	-3.5
Distributorless Ignition									
Units (M)	2.12	3.16	4.40	5.54	6.36	7.38	8.69	9.84	17.5
Percentage Penetration	18.0	24.0	30.0	36.0	42.0	48.0	55.0	60.0	14.9
Factory ASP ($)	27.5	27.0	26.5	26.0	25.5	25.5	25.0	25.0	-1.2
Revenue ($M)	58.2	85.3	116.6	144.1	162.3	188.3	217.3	245.9	16.1

(Continued)

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Table 5-8 (Continued)
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Market ($M)	20.4	29.0	39.6	49.0	55.2	64.0	73.9	83.6	16.1
Semiconductor $/Unit	9.63	9.18	9.01	8.84	8.67	8.67	8.50	8.50	-1.2
Sensors									
Revenue ($M)	430.66	482.25	537.05	563.73	555.10	563.42	578.84	600.46	2.3
Semiconductor TAM ($M)	12.92	24.11	48.33	84.56	111.02	129.59	150.50	180.14	30.1
Total Semiconductor Market ($M)	460.5	537.5	637.9	730.6	770.0	829.2	901.6	973.1	8.8
Total Equipment Revenue ($M)	1,722.0	1,963.6	2,258.9	2,446.8	2,479.3	2,588.6	2,732.7	2,864.7	4.9

Source: Dataquest (February 1995)

Table 5-9
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
ABS (2W/4W)									
Units (M)	6.11	8.56	10.70	12.47	13.03	13.84	14.54	15.25	7.3
Percentage Penetration	52.0	65.0	73.0	81.0	86.0	90.0	92.0	93.0	5.0
Factory ASP ($)	42.0	45.0	55.0	58.0	59.0	59.0	58.0	57.0	0.7
Revenue ($M)	256.8	385.1	588.7	723.0	768.9	816.8	843.2	869.0	8.1
Semiconductor Market ($M)	91.2	138.6	211.9	262.5	281.4	301.4	313.7	325.9	9.0
Semiconductor $/Unit	14.91	16.20	19.80	21.05	21.59	21.77	21.58	21.38	1.5
Air Bag Control (Driver/Passenger)									
Units (M)	5.17	8.56	12.46	16.16	19.70	24.61	30.03	31.97	20.7
Percentage Penetration	44.0	65.0	85.0	105.0	130.0	160.0	190.0	195.0	18.1

(Continued)

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Table 5-9 (Continued)
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Factory ASP ($)	39.0	37.0	36.0	35.5	35.0	35.0	34.5	34.5	-0.8
Revenue ($M)	201.8	316.6	448.7	573.7	689.5	861.4	1,035.9	1,102.9	19.7
Semiconductor Market ($M)	70.6	110.8	157.0	200.8	241.3	301.5	362.6	386.0	19.7
Semiconductor $/Unit	13.65	12.95	12.60	12.43	12.25	12.25	12.08	12.08	-0.8
Seat Belt Control									
Units (M)	1.88	2.11	2.05	1.54	1.21	0.92	0.79	0.66	-20.4
Percentage Penetration	16.0	16.0	14.0	10.0	8.0	6.0	5.0	4.0	-22.2
Factory ASP ($)	23.0	22.0	21.0	20.0	19.0	18.0	18.0	18.0	-3.0
Revenue ($M)	43.3	46.3	43.1	30.8	23.0	16.6	14.2	11.8	-22.8
Semiconductor Market ($M)	12.1	13.0	12.1	8.6	6.4	4.7	4.0	3.3	-22.8
Semiconductor $/Unit	6.44	6.16	5.88	5.60	5.32	5.04	5.04	5.04	-3.0
Automatic Climate Control									
Units (M)	1.70	2.17	2.79	3.23	3.49	3.85	4.35	4.92	12.0
Percentage Penetration	14.5	16.5	19.0	21.0	23.0	25.0	27.5	30.0	9.6
Factory ASP ($)	30.0	30.0	29.0	28.0	28.0	28.0	28.0	28.0	-0.7
Revenue ($M)	51.1	65.2	80.8	90.5	97.6	107.7	121.7	137.7	11.3
Semiconductor Market ($M)	17.4	22.2	27.5	29.9	32.2	35.5	40.2	45.4	10.6
Semiconductor $/Unit	10.20	10.20	9.86	9.24	9.24	9.24	9.24	9.24	-1.3
Interval Wipers									
Units (M)	10.52	11.98	13.56	14.31	14.09	14.31	14.70	15.25	2.4
Percentage Penetration	89.5	91.0	92.5	93.0	93.0	93.0	93.0	93.0	0.1
Factory ASP ($)	14.0	14.0	13.5	13.5	13.0	13.0	12.5	12.5	-1.5
Revenue ($M)	147.3	167.7	183.1	193.2	183.2	186.0	183.7	190.6	0.8
Semiconductor Market ($M)	51.6	58.7	64.1	67.6	64.1	65.1	64.3	66.7	0.8
Semiconductor $/Unit	4.90	4.90	4.73	4.73	4.55	4.55	4.38	4.38	-1.5

(Continued)

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Table 5-9 (Continued)
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Keyless Entry Control									
Units (M)	0.33	0.55	0.66	0.68	0.68	0.65	0.63	0.62	-1.1
Percentage Penetration	2.8	4.2	4.5	4.5	4.5	4.2	4.0	3.8	-3.3
Factory ASP ($)	38.0	37.0	36.0	35.0	34.0	33.0	32.0	31.0	-2.9
Revenue ($M)	12.5	20.5	23.8	24.0	23.2	21.3	20.2	19.3	-4.1
Semiconductor Market ($M)	2.9	4.7	5.5	5.5	5.4	4.9	4.7	4.5	-3.8
Semiconductor $/Unit	8.74	8.51	8.28	8.05	7.85	7.66	7.46	7.22	-2.7
Security Controls (Includes Nonfactory Sales)									
Units (M)	1.00	1.38	2.05	2.62	3.03	3.54	4.11	4.92	19.1
Percentage Penetration	8.5	10.5	14.0	17.0	20.0	23.0	26.0	30.0	16.5
Factory ASP ($)	36.0	35.0	34.0	33.0	32.0	31.0	31.0	31.0	-1.8
Revenue ($M)	36.0	48.4	69.8	86.3	97.0	109.7	127.4	152.5	16.9
Semiconductor Market ($M)	10.8	14.5	20.9	25.9	29.1	32.9	38.2	45.7	16.9
Semiconductor $/Unit	10.80	10.50	10.20	9.90	9.60	9.30	9.30	9.30	-1.8
Total Semiconductor Market ($M)	256.5	362.5	499.0	600.8	660.0	746.0	827.6	877.6	12.0
Total Equipment Revenue ($M)	748.8	1,049.8	1,437.9	1,721.5	1,882.5	2,119.4	2,346.3	2,483.7	11.6

Source: Dataquest (February 1995)

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Chapter 6
Automotive Electronics OEMs

Table 6-1 lists the leading worldwide OEMs in automotive electronics. Nippondenso and Delco primarily are suppliers to Toyota and General Motors, respectively. Although Robert Bosch is a top supplier to the German auto companies, it has a broad base of customers. Pioneer's size is attributable to its large position in the auto sound aftermarket. Ford ELD primarily is a captive organization. Nippondenso, Delco, and Bosch all have captive semiconductor operations that make items not available from the open market.

In-house electronics operations such as Delco and Ford increasingly are looking outside their companies for merchant business. They have the challenge of competing with independents such as Bosch, which gain favor because of their flexibility and neutrality. Table 6-2 lists some of the OEMs that serve the North American market and notes what they produce.

Table 6-1
Top Worldwide Automotive Electronics OEMs, Automotive Electronics Revenue* Estimates for 1993 (Billions of Dollars)

Company	Revenue
Nippondenso	5.2
GM Hughes/Delco	4.5
Robert Bosch	4.1
Pioneer	1.7
Ford ELD	1.6
Mitsubishi Electric	1.5
Clarion	1.3
ITT	1.0
Matsushita	0.9
Alpine	0.9
Siemens	0.9
Valeo	0.9
Mannesmann	0.8
Motorola	0.8
Chrysler/Acustar	0.8
Japan Electric Control Systems	0.8
Hitachi	0.7
Magneti-Marelli	0.7
Lucas	0.7
TEMIC	0.6

*A broad measure that includes more than just modules and systems
Source: Dataquest (July 1994)

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Table 6-2
OEMs Serving the North American Market

Company	Principal Electronic System(s)
Allied-Signal	Aftermarket, ABS
Audiovox	Aftermarket audio, security, cruise control
Chrysler/Acustar	Audio, engine control, displays, body control
Eaton	Engine and body control, climate control
Ford-ELD	Engine and body control
General Motors/Delco	Audio, ABS, engine and body control, suspension, displays
Hitachi Automotive	Audio, engine control, ignition modules
ITT	Audio, ABS
Kelsey/Hayes	ABS
Motorola/AIEG	ABS, engine control, sensors, instruments
Nippondenso	Engine control
Oki	Engine control
Robert Bosch	Audio, ABS, engine control, ignition modules
Rockwell International	Body control, suspension, motor control
Siemens	Fuel injection, ABS, ignition modules
TRW	Steering, engine and body control
United Technologies	Switches, ignition systems
Wagner	Lighting control

Source: Dataquest (July 1994)

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Appendix A
Definitions

Factory Installation

These are systems or modules that are installed by the primary assembler of the vehicle (such as G.M., Toyota, Fiat).

Modules

These are assembled circuit boards that perform various control functions. They can be made of various substrates including laminent and ceramic.

Multiplex Systems

These are modules that concentrate automotive control signals on the one or two wires thus reducing wiring costs and reliability problems. These can be localized in the door or dash board or they can also be vehicle wide.

Navigation Systems

These are systems that provide the driver navigation on a display. Included are versions that receive Global Positioning System (GPS), inertial, and road communications input. Most versions work with ROM or CD-ROM map data bases. Some are capable of "you are here" information and some can plot out an entire route to a desired destination.

Percentage of Penetration

Refers to the proportion of all vehicles manufactured that are shipped with this feature.

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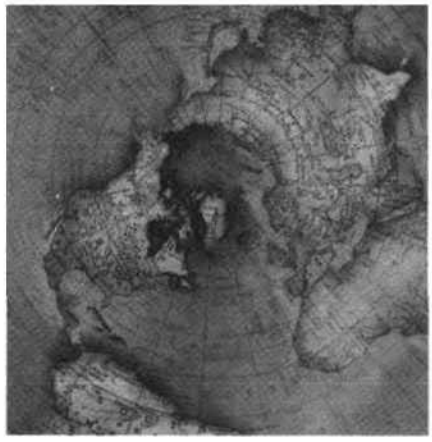
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Automotive Application Markets

Market Trends Report

Program: Semiconductor Application Markets Worldwide
Product Code: SAMM-WW-MT-9501
Publication Date: February 20, 1995
Filing: Market Analysis

Automotive Application Markets



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Chapter 1
Introduction and Methodology

This document is the first in a series of six that provide reference information and analysis about the principal system application markets for semiconductors. The six areas are data processing, communications (two), consumer electronics, automotive electronics, and a combined document on industrial and military and civil aerospace electronics. Each document brings forth basic information about the opportunity offered by particular systems:

- System market size (in production terms) in revenue, units, and average selling price
- System market and product feature trends
- Hardware architecture trends and semiconductor device opportunities
- Semiconductor content and market forecast
- Key OEMs

The information in this report is gathered from both primary and secondary sources. Primary sources include surveys and interviews of industry vendors and customers, as well as analyst knowledge and opinion. Some of the primary sources include Dataquest's own industry services. Secondary sources include various governmental and trade sources on sales, production, trade, and public spending. Semiconductor content assumptions are based on both surveys of producing OEMs and physical teardown evaluations by Dataquest analysts of representative systems.

The forecast methodology is based on various methods and assumptions, depending upon the area. To form a solid basis for projecting system demand, capital, government, and consumer spending assumptions are made for various regions of the world. For specific markets, saturation and displacement dynamics are considered as well. Key exogenous factors such as new software introductions, exchange rates changes, and government policies also are considered. Semiconductor content forecasts are based upon interviews of system marketers and designers (including makers of enabling semiconductor technology) along with an analysis of historical trends.

Project Analyst: Greg Sheppard

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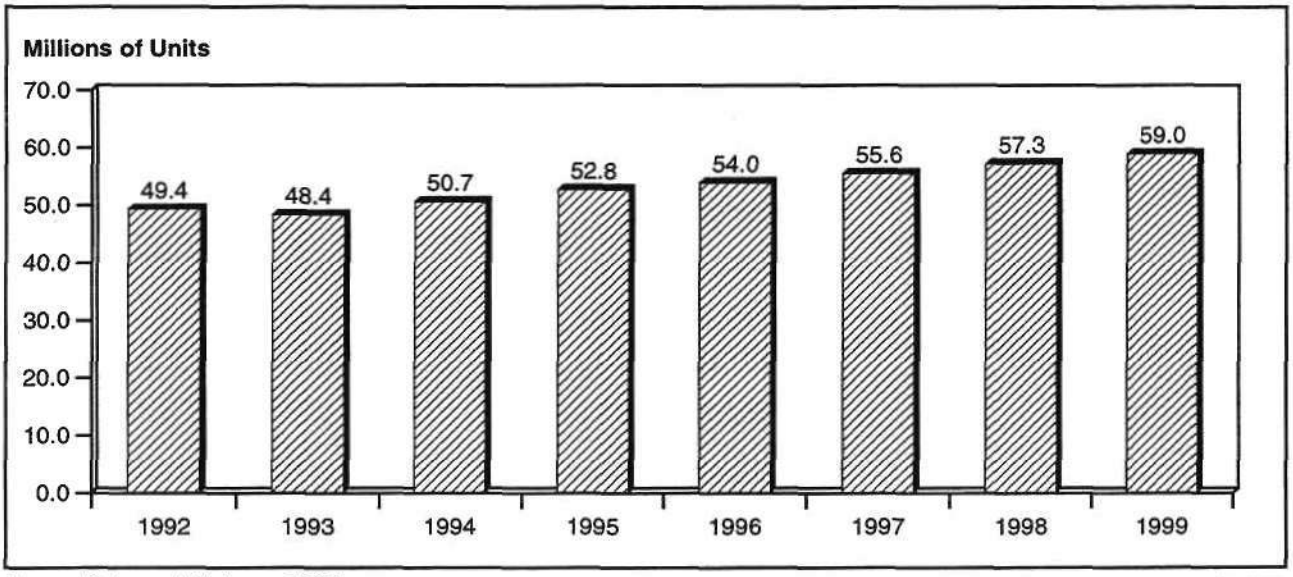
Chapter 2
Automotive Market Trends

Highlights of the automotive market are as follows:

- The hot U.S. market should slow down in 1995 and throughout 1996 as higher interest rates dissuade some buyers. The slowdown should not be as pronounced as those previously because of the replacement of older vehicles. The average age of vehicles on U.S. highways remains at an all-time high. The Canadian and German markets are expected to show some recovery this year as those economies bounce back. European auto production is expected to show a modest recovery overall throughout 1995 and 1996. Strong exports and a slowly recovering economy are expected to boost Japanese production. Figure 2-1 provides an outlook on global production; Table 2-1 shows actual production by region, and Table 2-2 provides an outlook for North American production.
- Japanese manufacturers and suppliers are continuing to move production out of Japan into the United States, Europe, and Asia as the high yen value and market demand for local manufacturing shape capital spending. Mercedes-Benz and BMW have announced movement of production to North America for that market as costs become prohibitive in Germany.
- The emerging countries of Asia are expected be the fastest-growing automotive producers in the coming decade. Companies such as Nissan and Volkswagen have been very aggressive in seeking joint ventures in such countries as China. The electronic module designs typically are licensed to Asian partners in such ventures.
- Government-mandated fuel economy (corporate average fuel economy, or CAFE, in the United States), emission requirements, and safety requirements will continue to become more restrictive in the developed countries and applied for the first time in developing countries. For applications in developed countries, this means that more electronics will be used that include integrating transmission control functions. For developing regions, it means employment of electronic engine controls for the first time.
- General Motors remained the top global producer in 1993 (and believed to be in 1994, too), followed by Ford and Toyota, buoyed by the strength of the U.S. market. The three major American producers were the only companies to grow last year (see Table 2-3).

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Figure 2-1
Worldwide Vehicle Production Forecast



Source: Dataquest (February 1995)

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Table 2-1
Worldwide Vehicle Production Forecast by Region

	1984	1992	1993	1993 Percentage Worldwide	Growth (%) 1992/1993
United States	10,924	9,778	10,890	22.6	11.4
Canada	1,878	1,983	2,239	3.9	12.9
Mexico	343	1,080	1,080	0.7	0
North America	13,145	12,841	14,209	27.1	10.7
Belgium	249	314	417	0.5	32.8
France	3,062	3,733	3,131	6.3	-16.1
Germany	4,045	5,194	3,991	8.4	-23.2
Italy	1,602	1,686	1,267	3.3	-24.9
Spain	1,308	1,782	1,542	2.7	-13.5
Sweden	432	357	337	0.9	-5.6
United Kingdom	1,134	1,540	1,496	2.3	-2.9
Europe	11,832	14,606	12,181	24.4	-16.6
Japan	11,393	12,449	11,228	23.5	-9.8
Australia	399	260	294	0.8	13.1
Brazil	865	1,095	1,422	1.8	29.9
Russia/CIS	2,209	1,598	1,589	4.6	-0.6
Korea	265	1,730	2,050	0.5	18.5
Others*	2,050	4,861	5,454	4.2	12.2
Total Worldwide	42,158	49,440	48,427	-	-2.0

*Includes China and at least 30 other producing countries
Source: Automotive News/Dataquest (July 1994)

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Table 2-2
U.S. and Canadian Auto and Truck Production (Millions of Units)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Automobiles	6,692	7,337	7,818	8,170	8,006	8,127	8,330	8,621	2.0
Trucks/Vans	5,065	5,829	6,844	7,220	7,148	7,255	7,473	7,772	2.6
Total	11,757	13,166	14,662	15,390	15,155	15,382	15,803	16,393	2.3

Source: Dataquest (February 1995)

Table 2-3
Top Worldwide Vehicle Producers (Thousands of Units)

	1992	1993	1993 Percentage Worldwide	Growth (%) 1992/1993
General Motors	7,097	7,299	15.1	2.8
Ford	5,500	5,700	11.8	3.6
Toyota	4,696	4,450	9.2	-5.2
Volkswagen	3,466	3,000	6.2	-13.4
Nissan	2,981	2,818	5.8	-5.5
Chrysler	2,033	2,348	4.8	15.5
Mitsubishi	1,832	1,875	3.9	2.3
Honda	1,883	1,827	3.8	-3.0
Renault	2,095	1,761	3.6	-15.9
Peugeot-Citroen	2,050	1,751	3.6	-14.6
Fiat	1,900	1,600	3.3	-15.8
Mazda	1,459	1,241	2.6	-14.9
Total	36,992	35,670	73.7	-3.6

Source: Automotive News/Dataquest (July 1994)

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Chapter 3
Automotive Electronics Market Trends

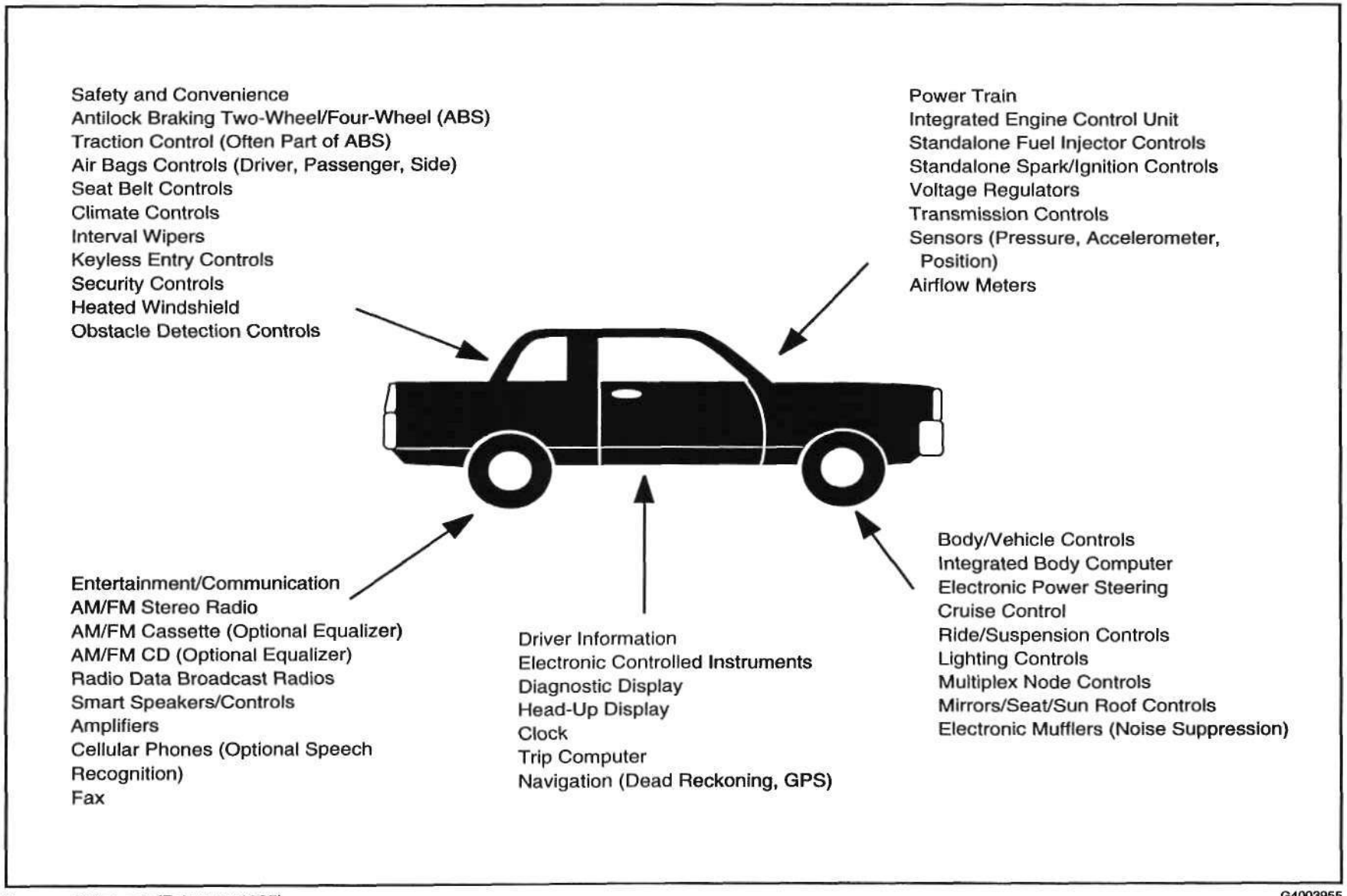
There is a continuing penetration of various electronic subsystems and controls into cars and trucks. Figure 3-1 shows the proliferation of electronic systems. Key factors driving the wave of electronic penetration continue to be public initiatives such as better fuel economy, lower emission, air bag safety, and a new one that standardizes the diagnostics/communications system. Consumer demand and product differentiation, as in most markets, contribute to the proliferation on options. Figure 3-2 shows that we estimate the average vehicle today to have about $565 of modules and systems; the figure will be $678 per vehicle by 1999. The average car can have a dozen modules (circuit boards), typically located in the passenger or engine compartment.

Highlights are as follows:

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming 6 modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the drive train area. A trend toward 32-bit MPU-based integrated modules is being stimulated by efficiencies needed for even higher corporate fuel economy requirements.
- Electronic-intensive antilock brakes and air bags controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (two wheels) to be used on high-end cars (four wheels). Driver-side air bags are becoming standard equipment on almost every vehicle. Passenger-side air bag versions now are entering the market. Side air bags are emerging as an option.
- Electronic suspension and steering are beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information, and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry, and light timers are proving to be popular options in an ever-security-conscious world.
- Personalization features such as memory seats, mirror, and radio settings now are popular on high-end modules.
- Entertainment systems are dominantly cassette-based today, with CD-based systems emerging at a modest rate. New digital compact cassette (DCC) and Mini Disc systems are beginning to find their way into 1994 vehicles. Intelligent/distributed speaker systems are becoming more common.

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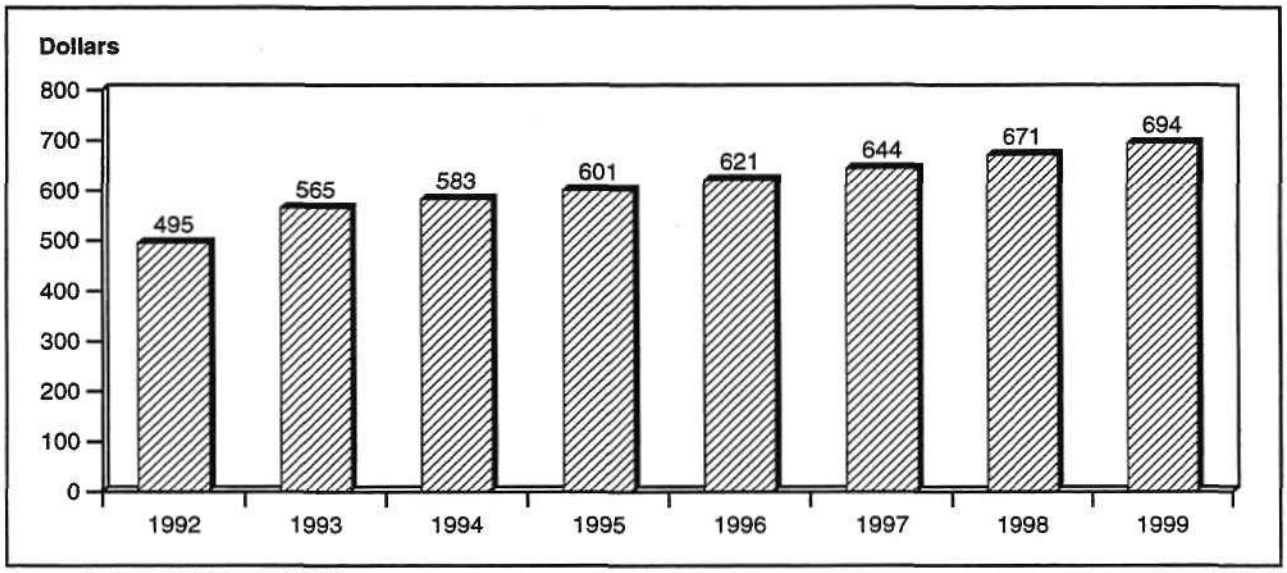
Figure 3-1
Automotive Electronics: Standard Features and Options Proliferate



Source: Dataquest (February 1995)

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Figure 3-2
Electronic Module and System Content



Source: Dataquest (February 1995) G4003956

- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 has been adopted in the United States. This interface is heading toward serving as the communications link between modules. Europe is rolling out a standard called ISO 9141 and two proprietary standards known as CAN and VAN.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement for a 2 percent requirement on all vehicles sold in that state by 1998 (10 percent by 2003). Several manufacturers have chosen the a minivan test platform. The most critical challenge is creating cost-effective battery technology. Nickel metal hydride seems to be the leader at the moment. Electric vehicles currently cost about 50 percent more than do gas engine versions. Battery life averages about three years; it costs the consumer $3,000 to replace them. Hybrid approaches are being considered, including advanced flywheel technology.

Navigation, Communication, and Smart Highways

Highlights in the navigation, communication, and smart highways areas are as follows:

- Navigation systems based on dead reckoning and the Global Positioning System (GPS) are becoming very popular in Japan and are appearing in the United States and Europe. General Motors has introduced a $2,000 system that uses a PCMCIA card for the map database and a Motorola-based 68EC020 processor for GPS and dead reckoning processing (made by Zexel and Rockwell).

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- The Radio Data Broadcast System (RDBS) has been available in Europe for some time and now is rolling out in the United States. The system will alert the driver to traffic reports and will display radio station format and call letters.
- Intelligent vehicles that employ infrastructure-integrated navigation aids and collision avoidance systems, and that communicate with the highway system to optimize traffic flow, remain at least a decade off from broad-scale use. Japan has embarked on its Vehicle Identification and Communication System (VICS), which combines government and industry on devising ways to route vehicles efficiently over Japan's crowded highways. Japan has spent more than $1 billion in the past decade researching intelligent traffic management methods. To date Japan is the furthest along in the availability of navigational aides such as GPS receivers.

The $800 million Prometheus Program in Europe is an effort to devise a common way for smart cars and smart infrastructure to communicate with each other. Drive I and Drive II are other pan-Europe programs. Drive II, which started this year, also covers other modes of transportation, such as trains. Other European efforts include one in Manchester, England, that involves the use of 500,000 wireless smart cards for automatic toll collection on roads.

The major program in the United States is coined the Intelligent Vehicle Highway System (IVHS) and is underwritten by $659 million in Federal Highway Administration funding for several R&D contracts. Tests were just completed in Orlando, Florida, with a GM system known as TravTek that informed the driver of area attractions, weather, and road conditions. It could give voice-synthesized instructions on where to turn. The goal of IVHS program is to develop a standard technology for car-road navigation as well as vehicle control such intercar spacing and movement. A trade association known as IVHS America estimates that $200 billion could be spent on IVHS in the next 20 years in the United States alone.

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Chapter 4
Architecture and Semiconductor Opportunities

Figure 4-1 shows average worldwide and North American vehicle semiconductor content. Now at $103 of content in 1994, $135 is possible by 1999, given the expected pervasion of systems. Figures 4-2 through 4-4 show block diagrams of a typical integrated engine control unit, antilock braking controller, and a multiplex wiring system. In general all automotive opportunities can be characterized as cost-sensitive and quality-demanding. Almost all components will not get design-in consideration if they do not meet the parts-per-billion defect rate. Likewise, every chip must be cost-justified on an engineering trade-off basis, and the tremendous volumes involved allow the OEMs plenty of negotiating leverage. As design opportunities move into the engine compartment, it is not unusual to find temperature requirements approaching 150°C.

Controllers and Cores

4-, 8-, 16-, and 32-bit MCUs and MPUs in standalone configuration and ASIC cores are staples on most vehicles. These serve as the nerve center of the various modules, whose numbers can vary from 2 to 3 on low-end vehicles to 35 to 50 on high-end luxury cars. Companies such as Texas Instruments and Motorola have been successful at creating reconfigurable core libraries that place the MCU core, data conversion, ROM, RAM, and even power circuitry on the same chip. 8-bit is the most common variety for engine management and body functions, whereas the stereo system typically have been satisfied with 4-bit MCUs for tuning, among others. Future power train applications will use 32-bit controllers as 683xx and PowerPC have garnered design wins at many of the major OEMs.

ASICs

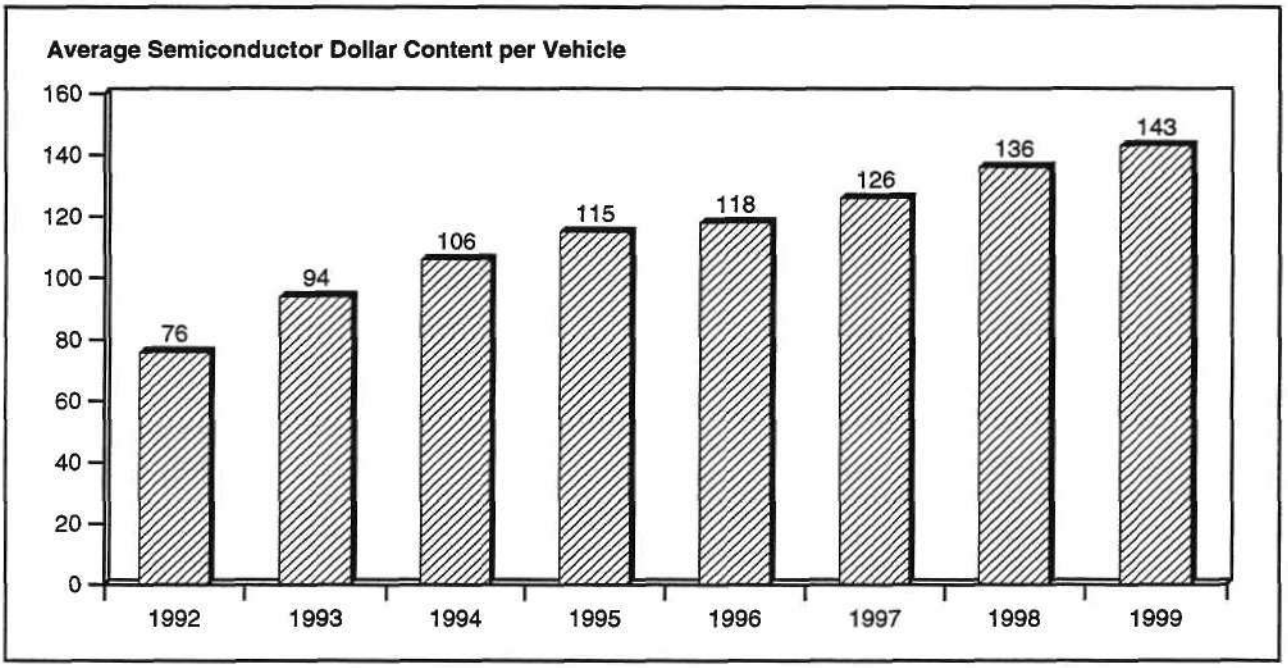
A substantial part of the circuitry surrounding the module-based MCU are CMOS, bipolar, or BiCMOS functions that multiplex and condition signal inputs and outputs. This principally is handled by ASICs and various standard analog functions such as op amps and comparators. The trend is toward integrating these functions on to the same ASIC chip as the processor core. In some cases the power driver circuitry also is being included.

Power

There is no lack of a need to switch and regulate 12/5V and control loads such as motors (windows, seats, antennas, and wipers), fuel injectors, actuators, and lights. Bipolar and MOSFET power transistors and power protection circuits are used by the dozens in each vehicle. Each module also generally has a voltage regulating device on it. The main voltage regulator (often a hybrid) and alternator diode are on every vehicle. Most power devices generally have to be able to accept 80V of "load dumping" energy. New outsourcing practices for items such as wiper motors are forcing the power circuits into the controlled items themselves. Electric vehicles of course will require a new genre of power chips that can handle 300V.

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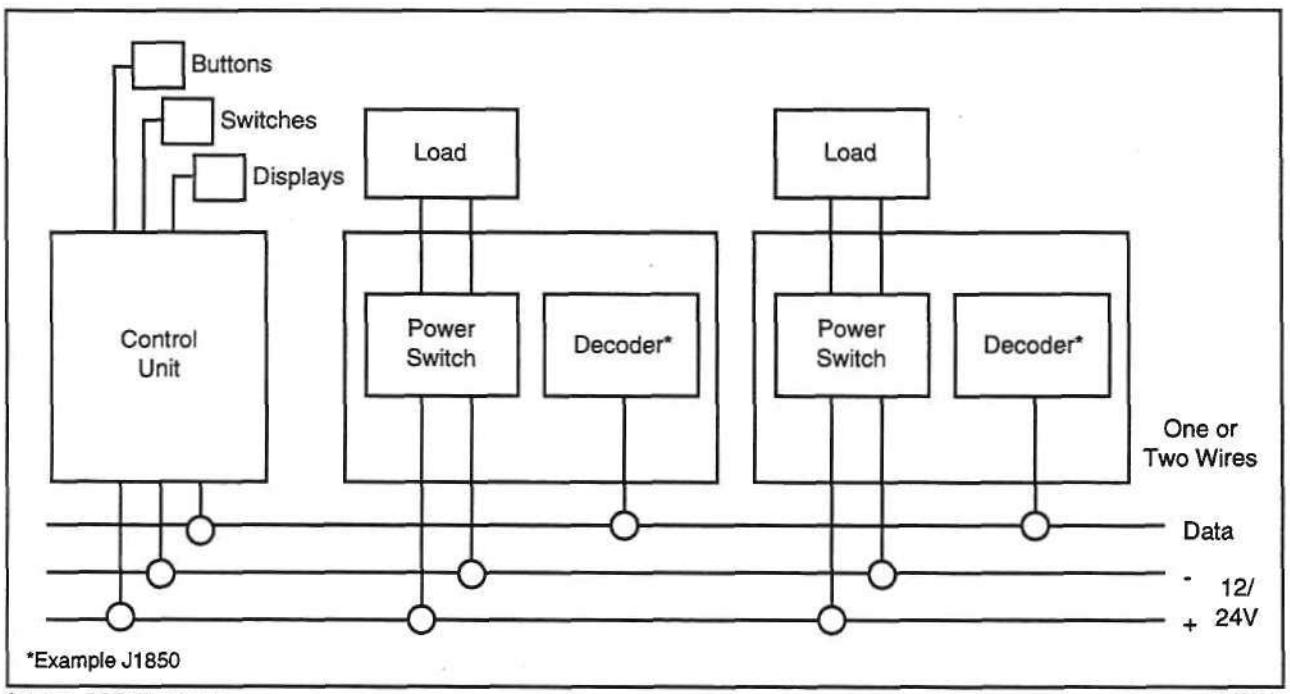
Figure 4-1
Average Semiconductor Dollar Content per Vehicle



Source: Dataquest (February 1995)

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Figure 4-2
Multiplex Wiring Example

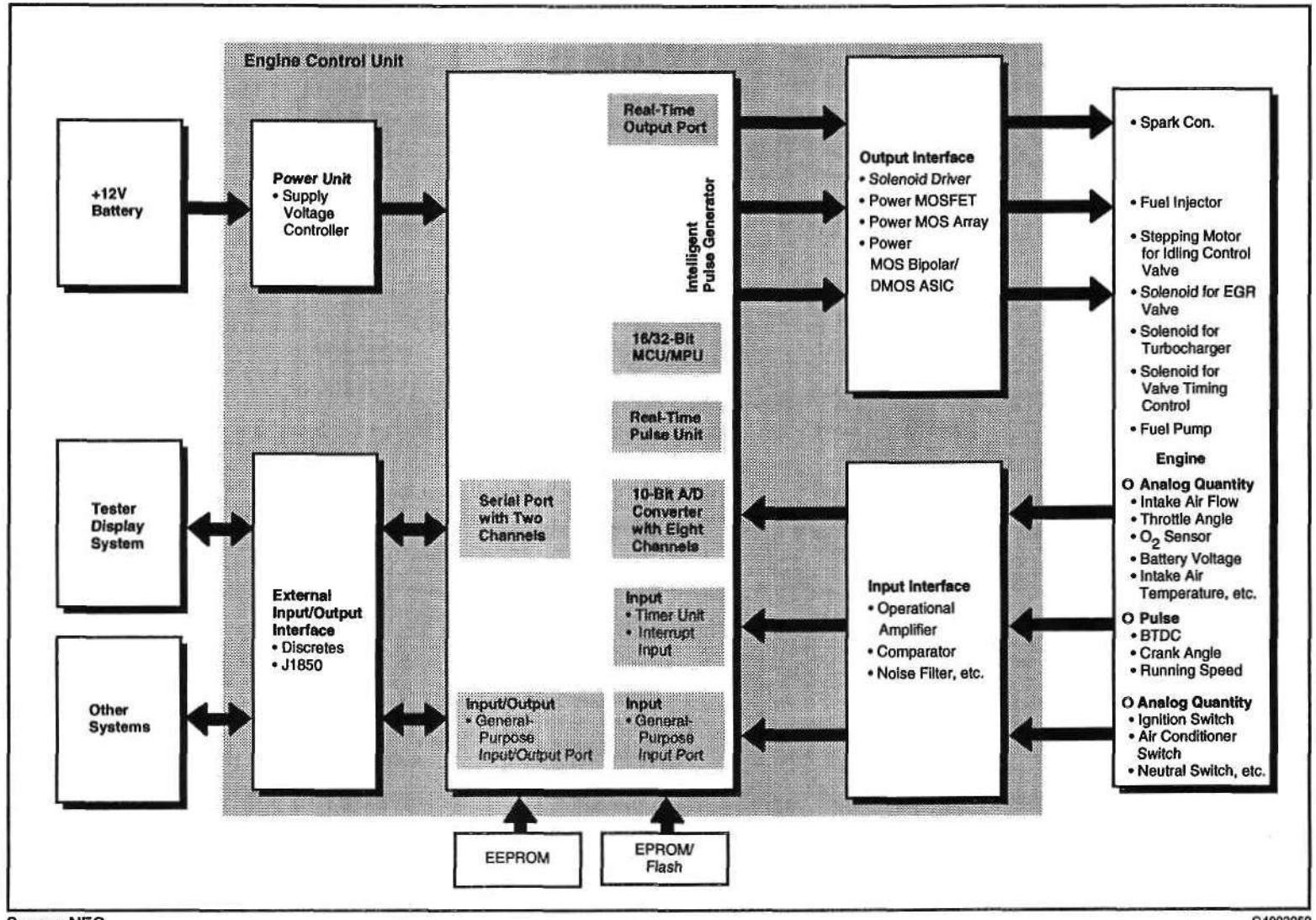


Source: SGS-Thomson

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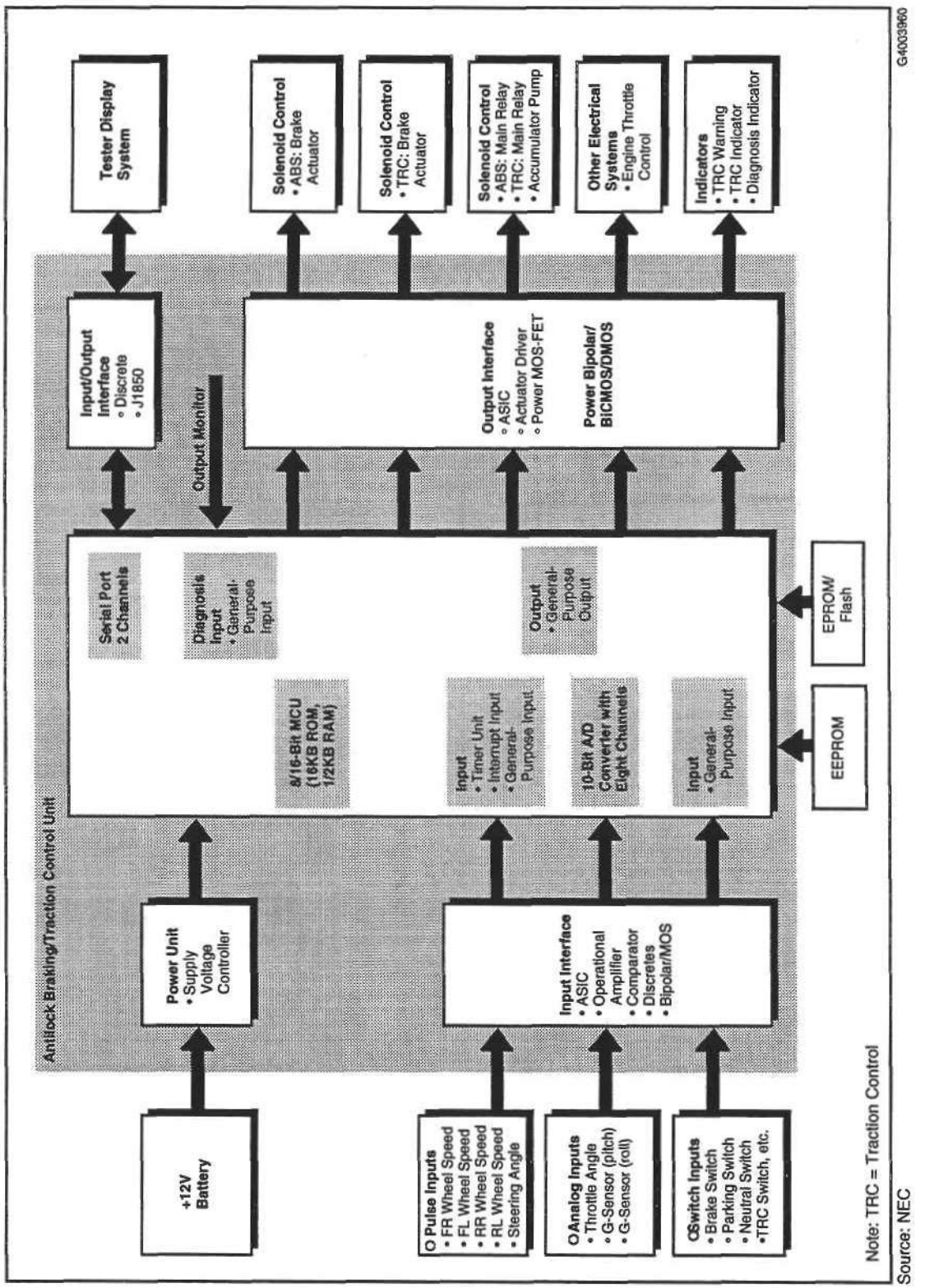
Figure 4-3
Integrated Engine Control Unit



Source: NEC

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Figure 4-4
Antilock Braking System (ABS) with Traction Control



Source: NEC

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Hybrids/Bar Die

As much as 25 percent of a vehicle's chips are consumed in bare die or on hybrids. Most of these chips are power discretes, along with passives. Typically the OEM is the major manufacturer of these. Examples of hybrid applications include DC/DC converters, ignition modules, remote injector drivers, voltage regulators, air meters, and pressure sensors.

Multiplex Controllers

To facilitate intermodule, multiplexed communication and to bring out mandated emission diagnostic information, vehicle companies are starting to install bus transceivers and protocol ICs. Several standards are emerging, including the following:

- SAE J1850 (primarily for the United States to date)
- ISO 9141 (primarily for Europe)
- CAN (Bosch/Intel)
- VAN (Peugeot)
- C2D (Chrysler)
- HBCC (Ford)
- DLCS (GM)
- HSSD (high-speed standard considered in the United States)

Multiplexing generally is segmented into speed classes. One segmentation adopted by the U.S.-based Society of Automotive Engineers (SAE) defines a Class A (less than 10 Kbps), Class B (10 Kbps to 125 Kbps), and Class C (greater than 125 Mbps). Class C communication supports real-time control and tends to be more expensive. The CAN standard is an example of this; its 1-Mbps capability has been adopted by Mercedes. In the United States, the J1850, a Class B standard, recently was approved after years of deliberation. It incorporates many of the features that other U.S. auto manufacturers use in their proprietary standards. It appears, however, that vehicles made for the European market will be based on ISO 9141 with CAN and VAN, while the North American market will use J1850. The Japanese and Korean manufacturers will make all varieties to satisfy their overseas markets.

Harris Semiconductor has announced that it is making J1850 transceivers and protocol controllers. The one-wire version now is supported; a two-wire version is ready when market demand appears. Nodal cost is from $0.50 and $2.00.

Sensors

A new generation of sensor-technology-based solid-state micromachining is emerging. Pressure sensors and accelerometers for collision detection (for air bag deployment) are the main applications to date. Silicon sensors have the advantage of being recalibratable, directly connectable to communication lines, and more reliable. Their main drawback is price, but companies such as Analog Devices are moving along the learning curve quickly.

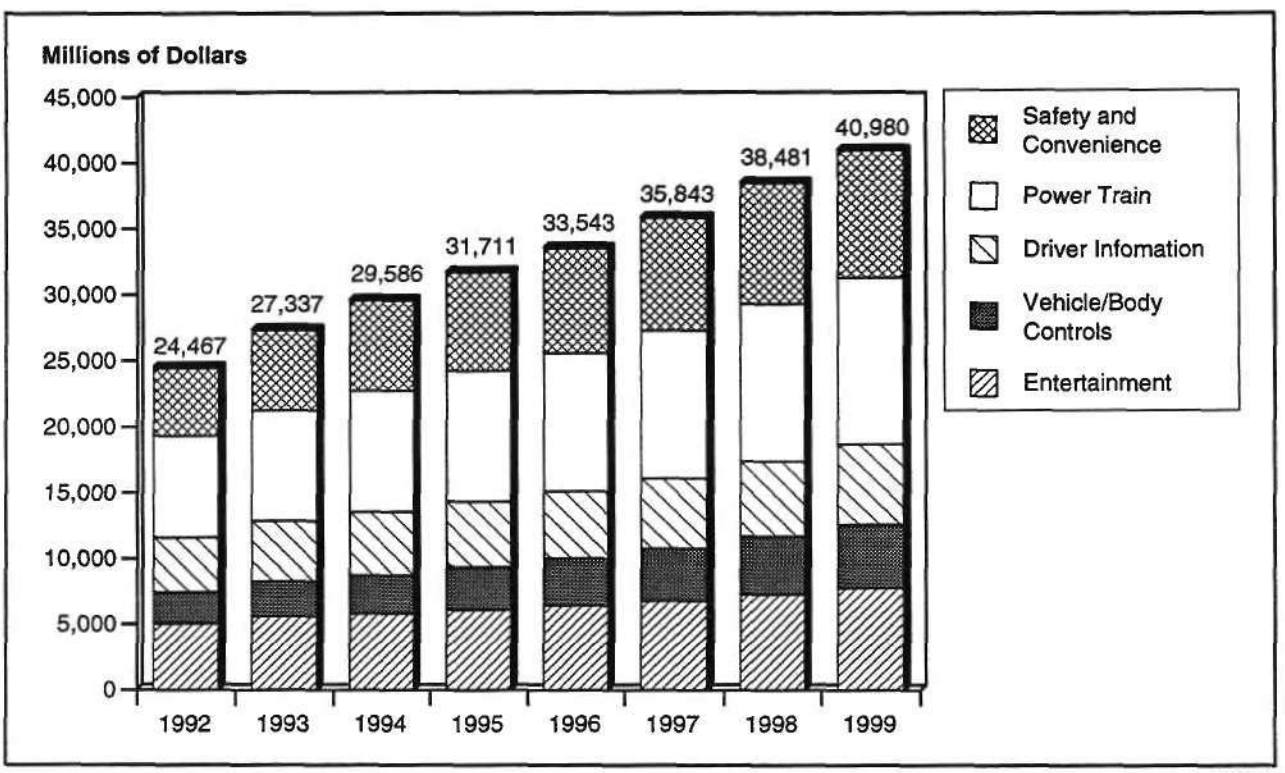
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Chapter 5
Automotive Electronics Production and Semiconductor Market

Figures 5-1 and 5-2 and Tables 5-1 through 5-4 show the worldwide and North American automotive electronics equipment production forecast and the accompanying semiconductor demand. The fastest-growing region of the world is expected be Asia/Pacific as production ramps for indigenous car sales and exports. The fastest-growing general category will be safety and convenience, driven by such killer applications as air bags and ABS.

Tables 5-5 through 5-9 show the North American module/system unit demand along with derived semiconductor demand for detail applications within each of major categories of entertainment, vehicle/body control, driver information, power train, and safety and convenience.

Figure 5-1
Worldwide Automotive Electronics Production by Product Area

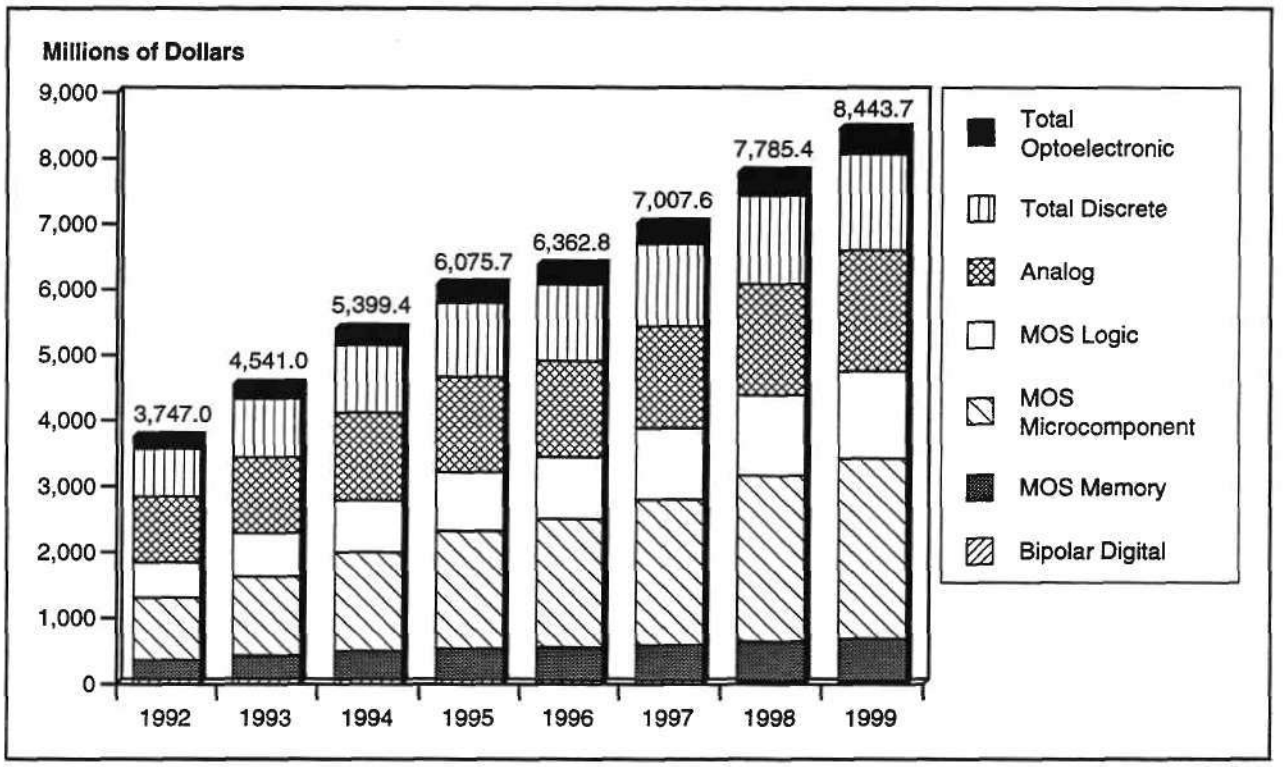


Source: Dataquest (February 1995)

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Figure 5-2
Worldwide Automotive Semiconductor Demand by Product Area



Source: Dataquest (February 1995)

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Table 5-1
Worldwide Automotive Electronics Production, by Product Area (Preliminary)
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Entertainment	5,039	5,611	5,799	6,105	6,434	6,798	7,286	7,785	6.1
Vehicle/Body controls	2,424	2,660	2,952	3,270	3,599	3,987	4,422	4,834	10.4
Driver Infomation	4,176	4,607	4,817	4,961	5,081	5,345	5,687	6,086	4.8
Power Train	7,691	8,411	9,183	9,921	10,484	11,184	11,922	12,578	6.5
Safety and Convenience	5,137	6,048	6,835	7,453	7,945	8,529	9,163	9,698	7.2
Total	24,467	27,337	29,586	31,711	33,543	35,843	38,481	40,980	6.7

Source: Dataquest (February 1995)

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Table 5-2
North American Automotive Electronics Production, by Product Area
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Entertainment	422	478	526	562	553	562	586	612	3.1
Vehicle/Body Controls	337	378	433	462	470	493	527	571	5.7
Driver infomation	681	771	881	952	972	1,030	1,129	1,226	6.8
Power Train	1,722	1,964	2,259	2,447	2,479	2,589	2,733	2,865	4.9
Safety and Convenience	749	1,050	1,438	1,722	1,883	2,119	2,346	2,484	11.6
Total	3,911	4,640	5,536	6,144	6,356	6,793	7,321	7,757	7.0

Source: Dataquest (February 1995)

Table 5-3
Worldwide Automotive Semiconductor Demand, by Product Area (Preliminary)
(Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	3,747.0	4,541.0	5,399.4	6,075.7	6,362.8	7,007.6	7,785.4	8,443.7	9.4
Bipolar Digital	77.0	82.0	75.6	69.8	62.3	59.4	55.3	51.0	-7.6
MOS Digital									
MOS Memory	290.0	360.0	436.8	472.9	499.6	536.6	594.3	645.2	8.1
MOS Micro-component	949.0	1,196.0	1,493.4	1,788.0	1,948.8	2,207.9	2,520.0	2,736.0	12.9
MOS Logic	533.0	656.0	784.2	888.1	938.3	1,082.6	1,220.1	1,324.7	11.1
Analog	999.0	1149.0	1,331.2	1,450.9	1,464.7	1,554.8	1,697.9	1,843.4	6.7
Total Discrete	723.0	888.0	1,030.6	1,126.7	1,161.8	1,253.2	1,349.3	1,464.9	7.3
Total Optoelec-tronic	176.0	210.0	247.5	279.3	287.4	313.0	348.6	378.5	8.9

Source: Dataquest (February 1995)

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Table 5-4
North American Automotive Semiconductor Demand, by Product Area (Millions of Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Total Semiconductor	1,068.2	1,299.3	1,596.5	1,827.9	1,934.9	2,108.6	2,308.3	2,477.6	9.2
Bipolar Digital	28.0	29.0	29.0	28.0	27.0	25.0	22.0	20.0	-7.2
MOS Digital									
MOS Memory	54.0	60.0	69.0	72.0	70.0	68.0	66.0	65.0	-1.2
MOS Microcomponent	255.0	295.8	355.0	397.6	417.4	450.8	500.4	545.5	9.0
MOS Logic	165.0	198.0	237.6	273.2	289.6	318.6	358.4	388.9	10.4
Analog	383.2	483.6	623.5	736.9	793.6	884.1	974.7	1052.4	11.0
Total Discrete	150.0	194.9	239.5	274.2	290.2	312.1	334.7	351.8	8.0
Total Optoelectronic	33.0	38.0	43.0	46.0	47.0	50.0	52.0	54.0	4.7
Recap (Based on the Above Table)									
MCU/MPU Units (Millions)	102.0	118.3	142.0	159.0	165.0	175.4	191.7	205.8	7.7
4 Bit	18.4	18.9	19.9	19.1	16.5	14.0	11.5	12.3	-9.1
8 Bit	76.5	88.7	106.5	117.7	120.4	126.3	134.2	144.1	6.2
16/32 Bit	7.1	10.6	15.6	19.1	24.7	29.8	34.5	39.1	20.2
ASIC ($M)									
Analog (All Technologies)	214.6	275.7	361.6	434.8	476.1	539.3	604.3	663.0	12.9
Digital and Mixed Signal (All Technologies)	133.7	162.4	197.2	229.5	246.2	270.8	304.7	330.6	10.9
Bare Die ICs (for Hybrids and MCMs)	199.9	256.5	336.1	404.2	445.9	508.6	574.5	634.9	13.6

Source: Dataquest (February 1995)

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Table 5-5
North America Automotive and Truck Entertainment System/Module Factory Installations (Selected) (Includes Imports)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
AM-FM Stereo/Cassette									
Units (M)	6.17	7.70	8.65	9.08	8.64	8.31	8.38	8.36	-0.7
Percentage Penetration	52.5	58.5	59.0	59.0	57.0	54.0	53.0	51.0	-2.9
Factory ASP ($)	87.0	84.0	83.0	83.0	82.5	82.5	82.0	82.0	-0.2
Revenue ($M)	537.0	647.0	718.0	753.7	712.6	685.3	686.8	685.6	-0.9
Semiconductor Market ($M)	107.4	132.6	150.8	158.3	149.7	143.9	144.2	144.0	-0.9
Semiconductor $/Unit	17.40	17.22	17.43	17.43	17.33	17.33	17.22	17.22	-0.2
AM-FM Stereo/Cassette (with Equalizer)									
Units (M)	1.53	1.71	1.91	2.15	2.27	2.46	2.69	2.95	9.1
Percentage Penetration	13.0	13.0	13.0	14.0	15.0	16.0	17.0	18.0	6.7
Factory ASP ($)	96.0	94.0	92.0	92.0	91.5	91.0	90.5	90.0	-0.4
Revenue ($M)	146.7	160.9	175.4	198.2	208.0	224.0	243.1	265.6	8.7
Semiconductor Market ($M)	30.8	34.3	37.7	43.6	45.8	49.3	53.5	58.4	9.2
Semiconductor $/Unit	20.16	20.02	19.78	20.24	20.13	20.02	19.91	19.80	0
AM-FM Stereo									
Units (M)	2.41	2.17	2.20	2.23	1.82	1.54	1.42	1.31	-9.8
Percentage Penetration	20.5	16.5	15.0	14.5	12.0	10.0	9.0	8.0	-11.8
Factory ASP ($)	56.0	53.0	50.0	48.0	47.0	47.0	47.0	47.0	-1.2
Revenue ($M)	135.0	115.1	110.0	107.1	85.5	72.3	66.8	61.6	-10.9
Semiconductor Market ($M)	27.0	23.0	23.1	22.5	17.9	15.2	14.0	12.9	-10.9
Semiconductor $/Unit	11.20	10.60	10.50	10.08	9.87	9.87	9.87	9.87	-1.2
AM-FM/CD									
Units (M)	0.26	0.34	0.53	0.69	1.06	1.54	1.90	2.30	34.2
Percentage Penetration	2.2	2.6	3.6	4.5	7.0	10.0	12.0	14.0	31.2
Factory ASP ($)	96.0	95.0	94.0	94.0	93.5	93.0	92.5	92.0	-0.4
Revenue ($M)	24.8	32.5	49.6	65.1	99.2	143.1	175.4	211.1	33.6

(Continued)

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Table 5-5 (Continued)
North America Automotive and Truck Entertainment System/Module Factory Installations (Selected) (Includes Imports)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Market ($M)	5.7	7.5	11.4	15.0	22.8	32.9	40.3	48.6	33.6
Semiconductor $/Unit	22.08	21.85	21.62	21.62	21.51	21.39	21.28	21.16	-0.4
Total Semiconductor Market ($M)	170.9	197.4	223.0	239.3	236.2	241.3	252.1	263.9	3.4
Total Equipment Revenue ($M)	843.6	955.5	1,052.9	1,124.1	1,105.3	1,124.6	1,172.2	1,223.9	3.1

Source: Dataquest (February 1995)

Table 5-6
North America Automotive and Truck Body/Vehicle Control System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Cruise Control									
Units (M)	8.23	9.35	10.56	11.23	11.21	11.54	12.01	12.62	3.6
Percentage Penetration	70.0	71.0	72.0	73.0	74.0	75.0	76.0	77.0	1.4
Factory ASP ($)	25.0	24.0	24.0	23.5	23.0	22.5	22.0	22.0	-1.7
Revenue ($M)	205.8	224.3	253.4	264.0	257.9	259.6	264.2	277.7	1.9
Semiconductor Market ($M)	82.3	89.7	101.3	105.6	103.2	103.8	105.7	111.1	1.9
Semiconductor $/Unit	10.00	9.60	9.60	9.40	9.20	9.00	8.80	8.80	-1.7
Electronic Power Steering									
Units (M)	0.39	0.46	0.59	0.77	0.91	1.15	1.42	1.80	25.2
Percentage Penetration	3.3	3.5	4.0	5.0	6.0	7.5	9.0	11.0	22.4
Factory ASP ($)	29.0	28.0	27.0	27.0	26.5	26.0	26.0	26.0	-0.8
Revenue ($M)	11.3	12.9	15.8	20.8	24.1	30.0	37.0	46.9	24.2
Semiconductor Market ($M)	4.2	4.8	5.9	7.7	8.9	11.1	13.7	17.3	24.2
Semiconductor $/Unit	10.73	10.36	9.99	9.99	9.81	9.62	9.62	9.62	-0.8

(Continued)

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Table 5-6 (Continued)
North America Automotive and Truck Body/Vehicle Control System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Ride/Suspension Control									
Units (M)	1.00	1.18	1.39	1.54	1.67	1.85	2.05	2.30	10.5
Percentage Penetration	8.5	9.0	9.5	10.0	11.0	12.0	13.0	14.0	8.1
Factory ASP ($)	40.0	40.0	39.0	37.0	37.0	36.5	36.0	36.0	-1.6
Revenue ($M)	40.0	47.4	54.3	56.9	61.7	67.4	74.0	82.6	8.7
Semiconductor Market ($M)	12.0	14.2	16.3	17.1	18.5	20.2	22.2	24.8	8.7
Semiconductor $/Unit	12.00	12.00	11.70	11.10	11.10	10.95	10.80	10.80	-1.6
Multiplex Systems (Door and Diagnostic, Among Others)									
Nodes (M)	2.12	4.61	7.48	10.77	14.55	19.38	26.86	32.79	34.4
Percentage Penetration	9.0	14.0	17.0	20.0	24.0	28.0	34.0	40.0	18.7
Factory ASP ($)	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9	-5.0
Revenue ($M)	5.7	11.9	18.3	25.0	32.1	40.6	53.5	62.0	27.7
Semiconductor Market ($M)	3.9	8.1	12.4	17.0	21.8	27.6	36.4	42.2	27.7
Semiconductor $/Unit	1.84	1.75	1.66	1.58	1.50	1.42	1.35	1.29	-5.0
Lighting Controls									
Units (M)	11.76	13.17	14.66	15.39	15.15	15.38	15.80	16.39	2.3
Percentage Penetration	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0
Factory ASP ($)	6.3	6.2	6.2	6.2	6.2	6.2	6.2	6.2	0
Revenue ($M)	74.1	81.6	90.9	95.4	94.0	95.4	98.0	101.6	2.3
Semiconductor Market ($M)	26.7	29.4	32.7	34.4	33.8	34.3	35.3	36.6	2.3
Semiconductor $/Unit	2.27	2.23	2.23	2.23	2.23	2.23	2.23	2.23	0
Total Semiconductor Market ($M)	129.0	146.2	168.6	181.7	186.2	197.1	213.2	232.0	6.6
Total Equipment Revenue ($M)	336.8	378.1	432.7	462.2	469.7	492.9	526.6	570.8	5.7

Source: Dataquest (February 1995)

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Table 5-7
North America Automotive and Truck Driver Information System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Electronic Instrument Cluster									
Units (M)	8.23	9.48	10.78	11.54	11.67	12.15	12.80	13.44	4.5
Percentage Penetration	70.0	72.0	73.5	75.0	77.0	79.0	81.0	82.0	2.2
Factory ASP ($)	49.0	48.0	47.0	46.5	46.0	45.5	45.0	44.5	-1.1
Revenue ($M)	403.3	455.0	506.5	536.7	536.8	552.9	576.0	598.2	3.4
Semiconductor Market ($M)	80.7	91.0	101.3	107.3	107.4	110.6	115.2	119.6	3.4
Semiconductor $/Unit	9.80	9.60	9.40	9.30	9.20	9.10	9.00	8.90	-1.1
Diagnostic Display									
Units (M)	2.00	2.30	2.64	2.92	3.03	3.23	3.48	3.77	7.4
Percentage Penetration	17.0	17.5	18.0	19.0	20.0	21.0	22.0	23.0	5.0
Factory ASP ($)	40.0	39.0	38.0	37.0	36.0	36.0	36.0	36.0	-1.1
Revenue ($M)	80.0	89.9	100.3	108.2	109.1	116.3	125.2	135.7	6.2
Semiconductor Market ($M)	32.8	35.9	43.1	46.5	46.9	50.0	53.8	58.4	6.2
Semiconductor $/Unit	16.40	15.60	16.34	15.91	15.48	15.48	15.48	15.48	-1.1
Trip Computer									
Units (M)	0.98	1.12	1.32	1.46	1.52	1.69	1.90	2.05	9.2
Percentage Penetration	8.3	8.5	9.0	9.5	10.0	11.0	12.0	12.5	6.8
Factory ASP ($)	46.0	45.0	44.0	43.0	43.0	43.0	43.0	43.0	-0.5
Revenue ($M)	44.9	50.4	58.1	62.9	65.2	72.8	81.5	88.1	8.7
Semiconductor Market ($M)	17.1	19.1	21.5	23.3	23.5	26.2	29.4	31.7	8.1
Semiconductor $/Unit	17.48	17.10	16.28	15.91	15.48	15.48	15.48	15.48	-1.0
Navigation System (Includes Nonfactory Sales)									
Units (M)	0.05	0.07	0.12	0.17	0.23	0.31	0.47	0.66	41.1
Percentage Penetration	0.4	0.5	0.8	1.1	1.5	2.0	3.0	4.0	38.0
Factory ASP ($)	630.0	570.0	525.0	485.0	445.0	410.0	380.0	353.0	-7.6

(Continued)

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Table 5-7
North America Automotive and Truck Driver Information System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Revenue ($M)	29.6	37.5	61.6	82.1	101.2	126.1	180.2	231.5	30.3
Semiconductor Market ($M)	6.2	8.3	13.5	18.1	22.8	29.0	41.4	53.2	31.5
Semiconductor $/Unit	132.30	125.40	115.50	106.70	100.13	94.30	87.40	81.19	-6.8
Electronic Clock									
System Revenue ($M)	123.62	138.42	154.15	161.81	159.33	161.72	166.15	172.36	2.3
Semiconductor Market ($M)	37.08	41.53	46.25	48.54	47.80	48.52	49.84	51.71	2.3
Total Semiconductor Market ($M)	136.7	154.3	179.5	195.2	200.5	215.8	239.8	263.0	7.9
Total Equipment Revenue ($M)	681.4	771.2	880.6	951.7	971.5	1,029.8	1,129.0	1,225.9	6.8

Source: Dataquest (February 1995)

Table 5-8
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Integrated Engine Control									
Units (M)	3.35	3.95	4.84	5.39	5.76	6.77	8.06	8.85	12.8
Percentage Penetration	28.5	30.0	33.0	35.0	38.0	44.0	51.0	54.0	10.4
Factory ASP ($)	80.0	77.0	76.5	76.0	76.0	75.5	75.5	74.0	-0.7
Revenue ($M)	268.1	304.1	370.1	409.4	437.7	511.0	608.5	655.1	12.1
Semiconductor Market ($M)	101.9	115.6	137.0	151.5	163.2	192.1	230.6	249.6	12.8
Semiconductor $/Unit	30.40	29.26	28.31	28.12	28.35	28.39	28.61	28.19	-0.1
Standalone Fuel Control									
Units (M)	8.41	9.22	9.82	10.00	9.40	8.61	7.74	7.54	-5.2
Percentage Penetration	71.5	70.0	67.0	65.0	62.0	56.0	49.0	46.0	-7.2

(Continued)

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Table 5-8 (Continued)
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Factory ASP ($)	72.0	70.0	70.0	69.5	69.0	68.5	68.0	67.5	-0.7
Revenue ($M)	605.3	645.1	687.6	695.3	648.3	590.1	526.5	509.0	-5.8
Semiconductor Market ($M)	175.5	187.1	199.4	201.6	188.0	171.1	152.7	147.6	-5.8
Semiconductor $/Unit	20.88	20.30	20.30	20.16	20.01	19.87	19.72	19.58	-0.7
Standalone Eng. Control (Ignition and Regulator, Among Others)									
Units (M)	21.16	23.70	26.39	27.70	27.28	27.69	28.44	29.51	2.3
Percentage Penetration	180.0	180.0	180.0	180.0	180.0	180.0	180.0	180.0	0
Factory ASP ($)	10.0	9.7	9.6	9.6	9.5	9.5	9.4	9.4	-0.4
Revenue ($M)	211.6	229.9	253.4	265.9	259.1	263.0	267.4	277.4	1.8
Semiconductor Market ($M)	99.5	108.0	116.5	122.3	119.2	121.0	123.0	127.6	1.8
Semiconductor $/Unit	4.70	4.56	4.42	4.42	4.37	4.37	4.32	4.32	-0.4
Transmission Control (Partially Included in Engine Controls)									
Units (M)	2.35	3.55	4.99	6.46	7.58	8.92	10.27	11.31	17.8
Percentage Penetration	20.0	27.0	34.0	42.0	50.0	58.0	65.0	69.0	15.2
Factory ASP ($)	63.0	61.0	59.0	57.0	55.0	53.0	52.0	51.0	-2.9
Revenue ($M)	148.1	216.8	294.1	368.4	416.8	472.8	534.1	576.9	14.4
Semiconductor Market ($M)	50.4	73.7	97.1	121.6	133.4	151.3	170.9	184.6	13.7
Semiconductor $/Unit	21.42	20.74	19.47	18.81	17.60	16.96	16.64	16.32	-3.5
Distributorless Ignition									
Units (M)	2.12	3.16	4.40	5.54	6.36	7.38	8.69	9.84	17.5
Percentage Penetration	18.0	24.0	30.0	36.0	42.0	48.0	55.0	60.0	14.9
Factory ASP ($)	27.5	27.0	26.5	26.0	25.5	25.5	25.0	25.0	-1.2
Revenue ($M)	58.2	85.3	116.6	144.1	162.3	188.3	217.3	245.9	16.1

(Continued)

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Table 5-8 (Continued)
North America Automotive and Truck Power Train System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Market ($M)	20.4	29.0	39.6	49.0	55.2	64.0	73.9	83.6	16.1
Semiconductor $/Unit	9.63	9.18	9.01	8.84	8.67	8.67	8.50	8.50	-1.2
Sensors									
Revenue ($M)	430.66	482.25	537.05	563.73	555.10	563.42	578.84	600.46	2.3
Semiconductor TAM ($M)	12.92	24.11	48.33	84.56	111.02	129.59	150.50	180.14	30.1
Total Semiconductor Market ($M)	460.5	537.5	637.9	730.6	770.0	829.2	901.6	973.1	8.8
Total Equipment Revenue ($M)	1,722.0	1,963.6	2,258.9	2,446.8	2,479.3	2,588.6	2,732.7	2,864.7	4.9

Source: Dataquest (February 1995)

Table 5-9
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
ABS (2W/4W)									
Units (M)	6.11	8.56	10.70	12.47	13.03	13.84	14.54	15.25	7.3
Percentage Penetration	52.0	65.0	73.0	81.0	86.0	90.0	92.0	93.0	5.0
Factory ASP ($)	42.0	45.0	55.0	58.0	59.0	59.0	58.0	57.0	0.7
Revenue ($M)	256.8	385.1	588.7	723.0	768.9	816.8	843.2	869.0	8.1
Semiconductor Market ($M)	91.2	138.6	211.9	262.5	281.4	301.4	313.7	325.9	9.0
Semiconductor $/Unit	14.91	16.20	19.80	21.05	21.59	21.77	21.58	21.38	1.5
Air Bag Control (Driver/Passenger)									
Units (M)	5.17	8.56	12.46	16.16	19.70	24.61	30.03	31.97	20.7
Percentage Penetration	44.0	65.0	85.0	105.0	130.0	160.0	190.0	195.0	18.1

(Continued)

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Table 5-9 (Continued)
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Factory ASP ($)	39.0	37.0	36.0	35.5	35.0	35.0	34.5	34.5	-0.8
Revenue ($M)	201.8	316.6	448.7	573.7	689.5	861.4	1,035.9	1,102.9	19.7
Semiconductor Market ($M)	70.6	110.8	157.0	200.8	241.3	301.5	362.6	386.0	19.7
Semiconductor $/Unit	13.65	12.95	12.60	12.43	12.25	12.25	12.08	12.08	-0.8
Seat Belt Control									
Units (M)	1.88	2.11	2.05	1.54	1.21	0.92	0.79	0.66	-20.4
Percentage Penetration	16.0	16.0	14.0	10.0	8.0	6.0	5.0	4.0	-22.2
Factory ASP ($)	23.0	22.0	21.0	20.0	19.0	18.0	18.0	18.0	-3.0
Revenue ($M)	43.3	46.3	43.1	30.8	23.0	16.6	14.2	11.8	-22.8
Semiconductor Market ($M)	12.1	13.0	12.1	8.6	6.4	4.7	4.0	3.3	-22.8
Semiconductor $/Unit	6.44	6.16	5.88	5.60	5.32	5.04	5.04	5.04	-3.0
Automatic Climate Control									
Units (M)	1.70	2.17	2.79	3.23	3.49	3.85	4.35	4.92	12.0
Percentage Penetration	14.5	16.5	19.0	21.0	23.0	25.0	27.5	30.0	9.6
Factory ASP ($)	30.0	30.0	29.0	28.0	28.0	28.0	28.0	28.0	-0.7
Revenue ($M)	51.1	65.2	80.8	90.5	97.6	107.7	121.7	137.7	11.3
Semiconductor Market ($M)	17.4	22.2	27.5	29.9	32.2	35.5	40.2	45.4	10.6
Semiconductor $/Unit	10.20	10.20	9.86	9.24	9.24	9.24	9.24	9.24	-1.3
Interval Wipers									
Units (M)	10.52	11.98	13.56	14.31	14.09	14.31	14.70	15.25	2.4
Percentage Penetration	89.5	91.0	92.5	93.0	93.0	93.0	93.0	93.0	0.1
Factory ASP ($)	14.0	14.0	13.5	13.5	13.0	13.0	12.5	12.5	-1.5
Revenue ($M)	147.3	167.7	183.1	193.2	183.2	186.0	183.7	190.6	0.8
Semiconductor Market ($M)	51.6	58.7	64.1	67.6	64.1	65.1	64.3	66.7	0.8
Semiconductor $/Unit	4.90	4.90	4.73	4.73	4.55	4.55	4.38	4.38	-1.5

(Continued)

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Table 5-9 (Continued)
North America Automotive and Truck Safety and Convenience System/Module Factory Installations (Selected)

	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Keyless Entry Control									
Units (M)	0.33	0.55	0.66	0.68	0.68	0.65	0.63	0.62	-1.1
Percentage Penetration	2.8	4.2	4.5	4.5	4.5	4.2	4.0	3.8	-3.3
Factory ASP ($)	38.0	37.0	36.0	35.0	34.0	33.0	32.0	31.0	-2.9
Revenue ($M)	12.5	20.5	23.8	24.0	23.2	21.3	20.2	19.3	-4.1
Semiconductor Market ($M)	2.9	4.7	5.5	5.5	5.4	4.9	4.7	4.5	-3.8
Semiconductor $/Unit	8.74	8.51	8.28	8.05	7.85	7.66	7.46	7.22	-2.7
Security Controls (Includes Nonfactory Sales)									
Units (M)	1.00	1.38	2.05	2.62	3.03	3.54	4.11	4.92	19.1
Percentage Penetration	8.5	10.5	14.0	17.0	20.0	23.0	26.0	30.0	16.5
Factory ASP ($)	36.0	35.0	34.0	33.0	32.0	31.0	31.0	31.0	-1.8
Revenue ($M)	36.0	48.4	69.8	86.3	97.0	109.7	127.4	152.5	16.9
Semiconductor Market ($M)	10.8	14.5	20.9	25.9	29.1	32.9	38.2	45.7	16.9
Semiconductor $/Unit	10.80	10.50	10.20	9.90	9.60	9.30	9.30	9.30	-1.8
Total Semiconductor Market ($M)	256.5	362.5	499.0	600.8	660.0	746.0	827.6	877.6	12.0
Total Equipment Revenue ($M)	748.8	1,049.8	1,437.9	1,721.5	1,882.5	2,119.4	2,346.3	2,483.7	11.6

Source: Dataquest (February 1995)

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Chapter 6
Automotive Electronics OEMs

Table 6-1 lists the leading worldwide OEMs in automotive electronics. Nippondenso and Delco primarily are suppliers to Toyota and General Motors, respectively. Although Robert Bosch is a top supplier to the German auto companies, it has a broad base of customers. Pioneer's size is attributable to its large position in the auto sound aftermarket. Ford ELD primarily is a captive organization. Nippondenso, Delco, and Bosch all have captive semiconductor operations that make items not available from the open market.

In-house electronics operations such as Delco and Ford increasingly are looking outside their companies for merchant business. They have the challenge of competing with independents such as Bosch, which gain favor because of their flexibility and neutrality. Table 6-2 lists some of the OEMs that serve the North American market and notes what they produce.

Table 6-1
Top Worldwide Automotive Electronics OEMs, Automotive Electronics Revenue* Estimates for 1993 (Billions of Dollars)

Company	Revenue
Nippondenso	5.2
GM Hughes/Delco	4.5
Robert Bosch	4.1
Pioneer	1.7
Ford ELD	1.6
Mitsubishi Electric	1.5
Clarion	1.3
ITT	1.0
Matsushita	0.9
Alpine	0.9
Siemens	0.9
Valeo	0.9
Mannesmann	0.8
Motorola	0.8
Chrysler/Acustar	0.8
Japan Electric Control Systems	0.8
Hitachi	0.7
Magneti-Marelli	0.7
Lucas	0.7
TEMIC	0.6

*A broad measure that includes more than just modules and systems
Source: Dataquest (July 1994)

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Table 6-2
OEMs Serving the North American Market

Company	Principal Electronic System(s)
Allied-Signal	Aftermarket, ABS
Audiovox	Aftermarket audio, security, cruise control
Chrysler/Acustar	Audio, engine control, displays, body control
Eaton	Engine and body control, climate control
Ford-ELD	Engine and body control
General Motors/Delco	Audio, ABS, engine and body control, suspension, displays
Hitachi Automotive	Audio, engine control, ignition modules
ITT	Audio, ABS
Kelsey/Hayes	ABS
Motorola/AIEG	ABS, engine control, sensors, instruments
Nippondenso	Engine control
Oki	Engine control
Robert Bosch	Audio, ABS, engine control, ignition modules
Rockwell International	Body control, suspension, motor control
Siemens	Fuel injection, ABS, ignition modules
TRW	Steering, engine and body control
United Technologies	Switches, ignition systems
Wagner	Lighting control

Source: Dataquest (July 1994)

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Appendix A
Definitions

Factory Installation

These are systems or modules that are installed by the primary assembler of the vehicle (such as G.M., Toyota, Fiat).

Modules

These are assembled circuit boards that perform various control functions. They can be made of various substrates including laminent and ceramic.

Multiplex Systems

These are modules that concentrate automotive control signals on the one or two wires thus reducing wiring costs and reliability problems. These can be localized in the door or dash board or they can also be vehicle wide.

Navigation Systems

These are systems that provide the driver navigation on a display. Included are versions that receive Global Positioning System (GPS), inertial, and road communications input. Most versions work with ROM or CD-ROM map data bases. Some are capable of "you are here" information and some can plot out an entire route to a desired destination.

Percentage of Penetration

Refers to the proportion of all vehicles manufactured that are shipped with this feature.

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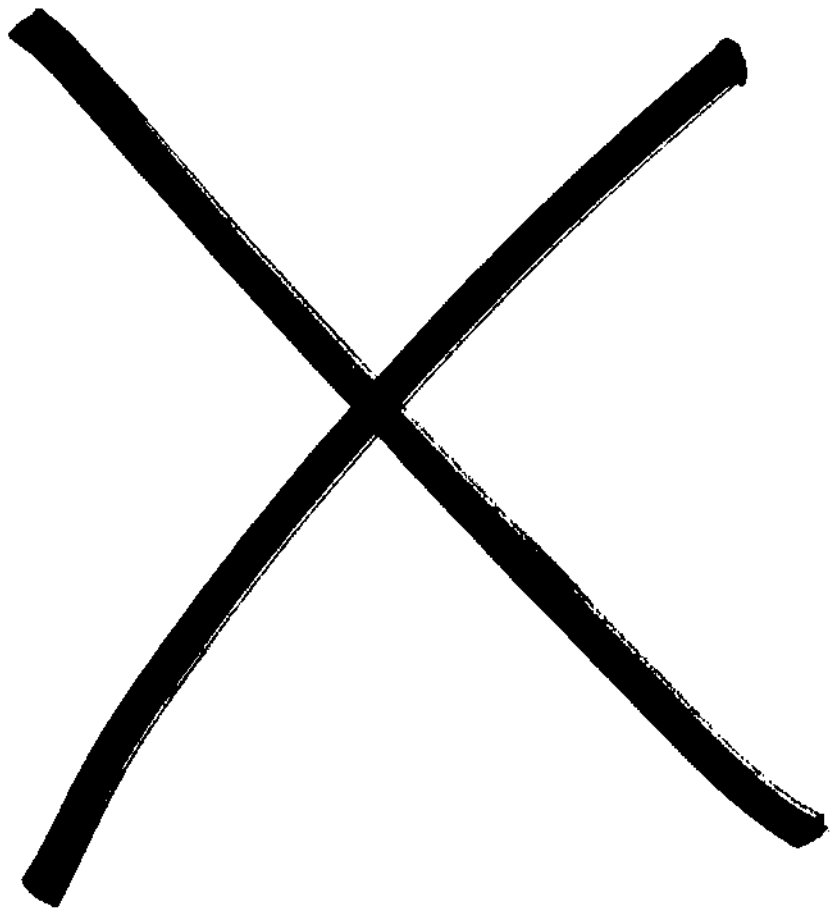
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SEMICONDUCTOR APPLICATION MARKETS
EUROPE 1995

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February 7, 1995

Dear Client

NEW BINDERS FOR 1995

Dataquest is pleased to enclose your new European binders for 1995; this year European publications are in A4 format, as are the binders. The two binders are arranged to accommodate documents during the year as follows, indicating the tabs behind which documents should be filed:

In the first binder:

- **Perspectives** - Please file here the document that has already been mailed to you "European PC Production 1994: The Year in Review," SAMM-EU-PD-9501
- **Focus Studies**
- **Competitive Dynamics**

In the second binder:

- **Market Analysis**

Publications in 1995 have filing instructions with the document details to assist you in filing as you receive them during the year.

Dataquest's new service, **PC Watch**, has its own binder for filing the regular documents.

There is also a new binder for filing monthly issues of **I.C. EUROPE.**

An additional **Semiconductors Core** binder will be sent to you separately. This will accommodate documents that Dataquest publishes on a worldwide basis, along with indexes of both worldwide and European documents, published cumulatively during the course of the year.

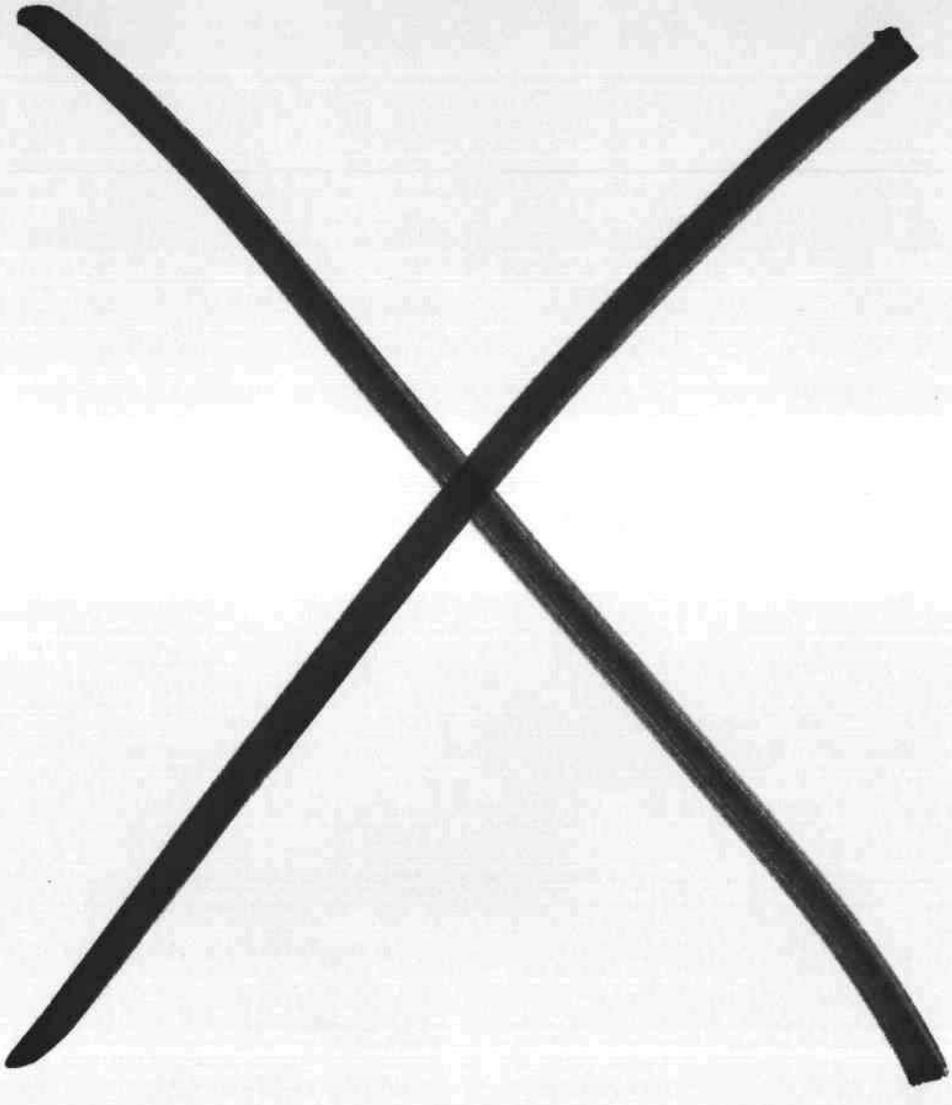
If you have any questions about your binders or the publications, please contact me at the address below.

Yours sincerely

David Moorhouse

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Dataquest

Market Analysis

Market Analysis



Semiconductor Application Markets Europe

Market Forecast

Abstract: *The European semiconductor market continues to grow; following two years of outstanding growth, this is set to continue in 1995, with a forecast minimum growth rate of 39 percent for the year. The PC continues to provide the core growth to the semiconductor market, but high-growth applications in most other segments will contribute to pushing the total semiconductor market to $51.86 billion by 1999. As an update to documents published earlier this year, this report forecasts the European semiconductor market, including total semiconductor market forecast by applications subsegment and a semiconductor product forecast by each of the six application segments.*

European Semiconductor Applications Market Forecast by Product—Second Half 1995

Executive Summary

- The PC continues its relentless growth, driving the overall semiconductor market and in particular contributing to the growth in both MOS memory and MOS microcomponent products.
- The communications segment is the star performer in terms of growth, overtaking the electronic data processing (EDP) and automotive segments. The main contributor to this growth is the mobile/radio communications subsegment. This has provided a useful contribution to both MOS memory and microcomponent.
- Industrial will lose its third place ranking to consumer by the end of the forecast period and will also be seriously challenged by automotive.

Introduction

Dataquest published its 1995 *European Electronic Equipment Production Forecast* in April 1995 (SAMM-EU-MS-9501). The initial production forecast has been revised in line with new research findings and new information. This report forecasts the resulting European semiconductor market, including total semiconductor market forecast by applications subsegment and a semiconductor product forecast by each of the six application segments. The European semiconductor market grew from $15,486 million in 1993 to $20,819 million in 1994, a growth of 34 percent; and we forecast the market

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Filing: Market Analysis

will grow to $51,859 million by 1999. We examine the underlying applications that are driving this growth.

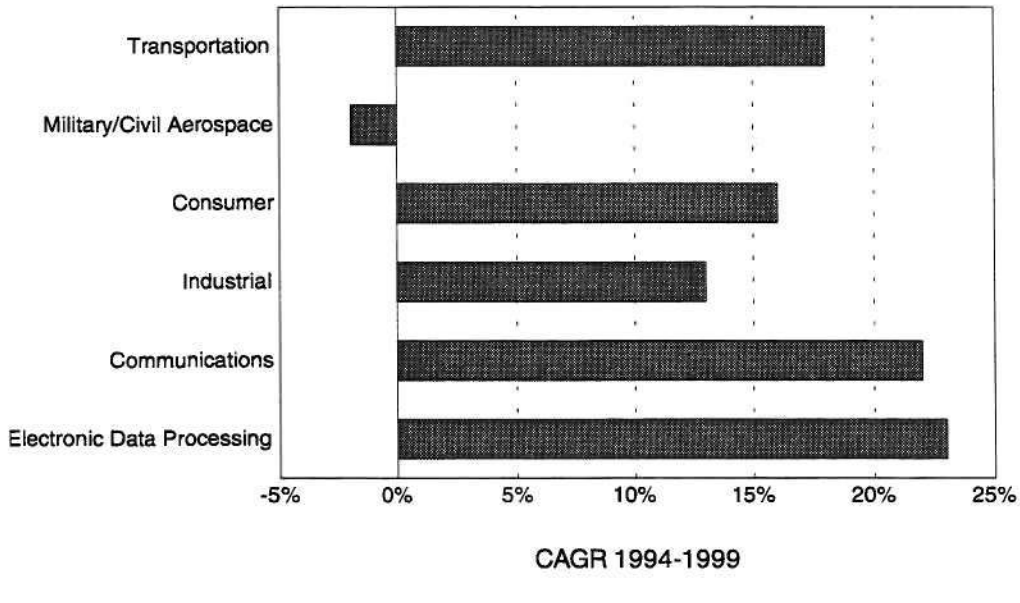
Applications Growth Trends

Figure 1 shows Dataquest's forecast of growth rate by application between 1994 and 1999. We now expect the communications segment to grow the fastest over the next five years. The automotive (transportation) and electronic data processing segments rank second and third respectively by growth rate.

The EDP segment continues to dominate the European semiconductor market, with the PC as the main driver. The computer semiconductor market is dominated by the PC, and is expected to grow from $7.5 billion in 1994 to $16.8 billion in 1999. The growth in the EDP segment is also given a significant boost from the dedicated systems subsegment. This subsegment is dominated by chip and smart cards

Historically (1989 to 1994), the data storage subsegment had a growth rate higher than the overall EDP segment as shown in Table 1. This was due to the phenomenal rise in demand from PCs for small rigid disk drives (RDDs). Major disk drive producers in Europe were Conner, IKB and IBM. However, in the forecast period we expect this growth to be reversed, with Conner closing down one of its facilities and the underlying demand for large disk drives (5.25-inch and 8-inch) for mainframe and midrange computers reducing. Recent announcements from Seagate, though, about locating a major production operation in Ireland may change our long-term view for the positive. Also, the announcement of the merger of Seagate and Conner has further confused the situation.

Figure 1
European Semiconductor Growth Rate by Application, 1994-1999



Source: Dataquest (December 1995 Estimates)

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There had also been tremendous growth in the computer segment from 1989 to 1994, with a compound annual growth rate (CAGR) of 28 percent. This growth is all attributable to the PC, which we now expect to grow faster than our previous estimate, with PC production expected to reach 35 million units by the year 2000. This growth in PC production will also affect the demand for memory because the Pentium processor will become mainstream sooner than expected. The average memory content is growing quickly to 16MB in 1996 and moving to 35MB by 1999.

Communications shows the most impressive growth of all segments, growing at a CAGR of 21.8 percent between 1994 and 1999. The driver for this growth is the continued spectacular growth in the mobile/radio communications equipment segment shown in Table 2.

Also historically, the mobile subsegment showed spectacular growth at 50 percent CAGR. This was due mainly to the tremendous growth in European production of cellular handsets and base stations. Most of this growth was from 1992 to 1994; we do not expect this growth rate to be sustained during the forecast period, reverting to a more modest 25.9 percent CAGR.

The industrial segment is now starting to show signs of growth, although still well below the market average of 20 percent CAGR from 1994 to 1999. Industrial has been ranked as the third-largest segment after EDP and communications, but will be overtaken by consumer electronics by the end of the forecast period. The security and energy management systems subsegment is growing ahead of the overall segment growth. Robot systems applications are also showing strong growth, but this is less important as it is the smallest of all the subsegments at $60 million in 1994.

Consumer electronics is entering a period of growth with a forecast CAGR of 15.7 percent. The main subsegments driving this growth are video and domestic appliances. The introduction of more and more digital technology, and the major developments in cable and satellite set-top boxes will push growth in the video subsegment to 16.9 percent over the forecast period. Recent research in this area has revealed that digital set-top boxes will be built in much greater volumes and earlier than we expected, with digital set-top box production hitting 500,000 units in 1995 and rising to 1.7 million in 1996.

Military and civil aerospace applications still show no change from our last forecast, with an overall decline of 1.5 percent.

The automotive (transportation) segment has shown above-average growth for a number of years, but it is acknowledged that high growth is more easily achieved from a segment which is small in value. We expect this growth to continue with a 18 percent CAGR over the forecast period. Although the forecast growth is below the market average, the automotive semiconductor market is still more than doubling in size over the forecast period.

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Table 1
European Semiconductor Market by Application—Total Market, History
(Millions of Dollars, Ex-Factory Revenues)

Segment	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Total Semiconductor	**$9,498**	**$10,415**	**$11,014**	**$12,217**	**$15,450**	**$20,819**	**17.0%**
Electronic Data Processing	$2,965	$2,963	$3,136	$3,572	$5,915	$9,010	24.9%
Computers	2,181	2,256	2,425	2,760	4,658	7,501	28.0%
Data Storage	73	99	115	159	222	269	29.7%
Input/Ouput Devices	464	395	379	397	541	551	3.5%
Dedicated Systems	246	213	217	256	494	689	22.9%
Communications	$1,915	$2,362	$2,567	$2,823	$3,559	$5,000	21.2%
Premise Telecoms Equipment	603	683	746	780	845	1,015	11.0%
Public Telecoms Equipment	664	826	883	832	860	1,005	8.6%
Mobile/Radio Communications Equipment	326	418	510	818	1,492	2,545	50.9%
Other Communications	266	346	350	319	264	325	4.1%
Broadcast and Studio	56	89	79	74	98	109	14.4%
Industrial	$1,685	$1,917	$1,979	$2,152	$2,278	$2,350	6.9%
Security/Energy Management Systems	182	182	197	228	249	278	8.7%
Manufacturing & Instrumentation Systems	981	1,182	1,232	1,319	1,414	1,429	7.8%
Robot Systems	45	45	48	53	56	61	6.3%
Medical Equipment	246	298	297	336	345	365	8.2%
Other Industrial	231	211	206	216	214	218	-1.1%
Consumer	$1,795	$1,883	$1,951	$2,137	$1,938	$2,300	5.1%
Audio	328	359	381	445	326	372	2.6%
Video	1,209	1,215	1,249	1,283	1,257	1,532	4.8%
Personal Electronics	140	171	166	217	184	209	8.4%
Appliances	118	138	155	193	171	187	9.6%
Other Consumer Equipment	-	-	-	-	-	-	-
Military and Civil Aerospace	$498	$478	$488	$515	$504	$504	0.2%
Transportation	$640	$812	$893	$1,018	$1,256	$1,655	20.9%

Source: Dataquest (December 1995 Estimates)

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Table 2
European Semiconductor Market by Application—Total Market, Forecast
(Millions of Dollars, Ex-Factory Revenues)

Segment	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Total Semiconductor	**$20,819**	**$28,995**	**$35,517**	**$39,674**	**$44,895**	**$51,859**	**20.0%**
Electronic Data Processing	$9,010	$13,381	$16,586	$18,250	$21,101	$25,152	22.8%
Computers	7,501	11,566	14,253	15,906	18,051	21,772	23.8%
Data Storage	269	279	304	216	201	194	-6.4%
Input/Ouput Devices	551	691	779	743	793	931	11.1%
Dedicated Systems	689	845	1,249	1,385	2,057	2,255	26.7%
Communications	$5,000	$7,060	$9,000	$10,395	$11,771	$13,390	21.8%
Premise Telecoms Equipment	1,015	1,399	1,737	1,954	2,155	2,383	18.6%
Public Telecoms Equipment	1,005	1,346	1,620	1,762	1,872	1,988	14.6%
Mobile/Radio Communications Equipment	2,545	3,722	4,913	5,863	6,853	8,044	25.9%
Other Communications	325	148	182	202	220	239	-6.0%
Broadcast and Studio	109	445	549	613	671	736	46.5%
Industrial	$2,350	$2,871	$3,289	$3,610	$3,906	$4,304	12.9%
Security/Energy Management Systems	278	362	439	510	581	662	19.0%
Manufacturing & Instrumentation Systems	1,429	1,730	1,978	2,167	2,348	2,605	12.8%
Robot Systems	61	69	73	82	92	100	10.6%
Medical Equipment	365	449	505	531	543	563	9.1%
Other Industrial	218	262	294	319	343	374	11.4%
Consumer	$2,300	$2,900	$3,410	$3,809	$4,220	$4,760	15.7%
Audio	372	456	508	575	656	677	12.7%
Video	1,532	1,966	2,363	2,626	2,901	3,345	16.9%
Personal Electronics	209	248	273	300	319	338	10.1%
Appliances	187	230	267	307	343	400	16.5%
Other Consumer Equipment	-	-	-	-	-	-	-
Military and Civil Aerospace	$504	$492	$462	$476	$449	$467	-1.5%
Transportation	$1,655	$2,291	$2,770	$3,134	$3,448	$3,786	18.0%

Source: Dataquest (December 1995 Estimates)

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Semiconductor Product Growth Trends

EDP

The PC's insatiable demands for memory and microcomponents continue to drive these product markets, with the memory market alone growing by more than 40 percent over the last forecast. The EDP memory market is now set to grow at a CAGR from 1994 to 1999 of 26.3 percent. The growth in the memory market is compounded by three factors: the unit production growth, the increase in system memory per PC, and the current high prices for memory caused by shortages. Nevertheless, there were some very early signs in November 1995 that the change in demand from fast page mode to EDO DRAM will provide a temporary softening of the market. The growth in multimedia, especially to the home market, will continue to drive demand for analog and mixed signal products, shown in Tables 3 and 4 (see page 8).

Communications

Dataquest has increased its forecast of European unit production of digital cellular handsets to more than 50 million units by 1999. The increasing use of memory—in particular SRAM and flash memory in the mobile subsegment—contributes to a forecast 27.6 percent CAGR from 1994 to 1999 in MOS memory (see Tables 5 and 6). The use of SRAM is expected to increase in digital cellular. The norm in 1995 was to use two or three pieces of 32K×8 SRAM; we expect this to move quickly to 1Mb devices in a ×16 configuration as early as 1996. The flash memory market has been given a substantial boost by digital cellular, both increasing unit production and increasing size of flash memory. In 1995 the amount of flash memory per handset was increasing from 4Mb to 8Mb, we expect 8Mb to be the norm in 1996.

The cellular communications market for both handsets and base stations is driving demand for digital signal processors (DSPs) and high-performance microcontrollers, contributing to a 20.2 percent CAGR from 1994 to 1999 in MOS microcomponents.

Industrial

The sustained period of GDP growth in Europe that is expected to continue throughout the forecast period will drive the industrial market now with a CAGR from 1994 to 1999 of 12.9 percent, as shown in Table 7 and 8. Although the industrial segment is the historical major market for analog products, this market is now becoming important for MOS memory and microcomponents.

Consumer

The consumer segment, a major market for discretes and analog, may soon become a significant market for memory, microcomponent and logic products because of the growing importance of the digital set-top box. Recent Dataquest research estimates that some 500,000 digital set-top boxes will be produced in Europe in 1995, rising to 1.8 million in 1996. This single product alone has probably added $40 million to the consumer memory total available market (TAM). The memory market in the consumer segment is set to grow faster than any other at 31.6 percent CAGR from 1994 to 1999 (Tables 9 and 10.) This new product is helping to drive an overall consumer semiconductor market growth of 15.7 percent CAGR.

Military and Civil Aerospace

The last forecast had this segment in overall decline; as shown in Tables 11 and 12, this will remain the case for the rest of the forecast period. Towards the end of the forecast period there will be a slight upturn in civil aerospace electronics.

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Automotive

The automotive (transportation) semiconductor market is now expected to grow at 18 percent CAGR from 1994 to 1999 (see Tables 13 and 14). Although this is below the total semiconductor market growth of 20 percent CAGR, it still means that this market is more than doubling in value over the forecast period. The continued introduction of electronic systems into cars, especially digital systems, will help drive a healthy growth in memory and logic products. We expect products from the safety and convenience subsegment, such as antilock braking systems and airbag systems, to grow in acceptance and be included in most cars. This provides further impetus to growth in MOS digital. Towards the end of the forecast period we expect to see the introduction of emerging technologies such as multiplex wiring, navigation systems and electronic stability control.

Dataquest Perspective

The European semiconductor market continues to grow strongly. There have been two years of outstanding growth, 26.4 percent in 1993/1992 and 34.8 percent in 1994/1993. This is set to continue in 1995, with a forecast minimum growth rate of 39 percent for 1995/1994. The PC continues to provide the core growth to the semiconductor market.

The further exceptional growth both in cellular handsets and base stations is providing a significant boost to the communications segment. Set-top boxes in the consumer segment are to be produced in high volume sooner than expected, providing an early boost to the consumer semiconductor market. The automotive segment continues its relentless growth with new applications and pervasion of sophisticated electronic systems into all ranges of cars.

These high-growth applications on top of a solid core of growth in most other segments will push the total semiconductor market to $51.86 billion by 1999.

By David Moorhouse

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Table 3
European Semiconductor Market by Application—Electronic Data Processing Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Electronic Data Processing Equipment	31,776	37,469	36,860	34,899	37,160	41,482	5.5%
Total Semiconductor	2,965	2,963	3,136	3,572	5,915	9,009	24.9%
Total IC	2,827	2,791	2,963	3,412	5,696	8,731	25.3%
Bipolar Digital	333	299	257	219	262	251	-5.5%
MOS Digital	2,304	2,214	2,420	2,919	5,077	7,979	28.2%
MOS Memory	1,538	1,308	1,359	1,659	2,587	4,428	23.6%
MOS Microcomponent	503	642	745	939	2,136	3,075	43.6%
MOS Logic	264	264	317	321	354	476	12.6%
Analog (mono + hybrid)	190	279	285	274	357	501	21.4%
Total Discrete	114	144	140	132	159	174	8.8%
Total Optoelectronic	23	28	33	28	60	104	34.7%

Source: Dataquest (December 1995 Estimates)

Table 4
European Semiconductor Market by Application—Electronic Data Processing Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Electronic Data Processing Equipment	41,482	46,595	52,102	56,925	63,940	69,035	10.7%
Total Semiconductor	9,009	13,381	16,586	18,250	21,101	25,152	22.8%
Total IC	8,731	12,931	16,064	17,724	20,535	24,489	22.9%
Bipolar Digital	251	240	211	172	151	132	-12.0%
MOS Digital	7,979	11,994	14,963	16,620	19,290	23,029	23.6%
MOS Memory	4,428	7,217	9,078	10,233	11,924	14,230	26.3%
MOS Microcomponent	3,075	4,144	5,144	5,609	6,462	7,711	20.2%
MOS Logic	476	633	741	779	904	1,088	18.0%
Analog (mono + hybrid)	501	697	890	931	1,094	1,327	21.5%
Total Discrete	174	321	376	378	413	487	22.8%
Total Optoelectronic	104	128	146	148	153	177	11.2%

Source: Dataquest (December 1995 Estimates)

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Table 5
European Semiconductor Market by Application—Communications Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Communications Equipment	25,030	28,698	31,087	32,899	34,886	37,983	8.7%
Total Semiconductor	1,915	2,362	2,567	2,823	3,559	5,001	21.2%
Total IC	1,486	1,780	1,960	2,230	3,102	4,307	23.7%
Bipolar Digital	140	138	121	110	43	37	-23.3%
MOS Digital	1,003	1,093	1,266	1,535	2,270	3,211	26.2%
MOS Memory	389	362	383	498	735	1,224	25.8%
MOS Microcomponent	192	268	318	426	637	817	33.6%
MOS Logic	422	463	566	611	897	1,169	22.6%
Analog (mono + hybrid)	343	549	573	585	789	1,059	25.3%
Total Discrete	329	453	449	451	371	541	10.5%
Total Optoelectronic	100	129	158	142	86	153	8.8%

Source: Dataquest (December 1995 Estimates)

Table 6
European Semiconductor Market by Application—Communications Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Communications Equipment	37,983	42,417	47,369	51,499	56,283	58,939	9.2%
Total Semiconductor	5,001	7,060	9,000	10,395	11,771	13,390	21.8%
Total IC	4,307	6,084	7,800	9,062	10,263	11,675	22.1%
Bipolar Digital	37	32	26	22	17	16	-16.0%
MOS Digital	3,211	4,609	5,894	6,950	7,863	8,906	22.6%
MOS Memory	1,224	1,989	2,620	3,195	3,654	4,141	27.6%
MOS Microcomponent	817	1,060	1,369	1,628	1,836	2,054	20.2%
MOS Logic	1,169	1,559	1,905	2,127	2,373	2,711	18.3%
Analog (mono + hybrid)	1,059	1,443	1,880	2,091	2,383	2,753	21.1%
Total Discrete	541	767	942	1,042	1,183	1,355	20.1%
Total Optoelectronic	153	209	258	291	325	360	18.7%

Source: Dataquest (December 1995 Estimates)

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Table 7
European Semiconductor Market by Application—Industrial Equipment, History
(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Industrial Equipment	21,244	26,078	26,196	27,491	26,295	27,217	5.1%
Total Semiconductor	1,685	1,917	1,979	2,152	2,278	2,350	6.9%
Total IC	1,046	1,152	1,214	1,402	1,502	1,535	8.0%
Bipolar Digital	106	92	78	70	31	21	-27.7%
MOS Digital	649	651	724	911	1,073	1,112	11.4%
MOS Memory	247	203	207	269	343	390	9.5%
MOS Microcomponent	226	277	317	425	431	432	13.9%
MOS Logic	177	171	201	217	298	290	10.4%
Analog (mono + hybrid)	290	409	412	420	398	402	6.7%
Total Discrete	510	619	592	595	709	731	7.4%
Total Optoelectronic	129	146	173	156	67	84	-8.2%

Source: Dataquest (December 1995 Estimates)

Table 8
European Semiconductor Market by Application—Industrial Equipment, Forecast
(Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Industrial Equipment	27,217	28,525	30,196	32,202	34,539	37,359	6.5%
Total Semiconductor	2,350	2,871	3,289	3,610	3,906	4,304	12.9%
Total IC	1,535	1,882	2,197	2,467	2,657	2,929	13.8%
Bipolar Digital	21	17	12	10	7	5	-25.1%
MOS Digital	1,112	1,381	1,587	1,815	1,959	2,144	14.0%
MOS Memory	390	545	596	714	792	857	17.1%
MOS Microcomponent	432	491	604	692	741	814	13.5%
MOS Logic	290	345	387	409	426	473	10.3%
Analog (mono + hybrid)	402	484	598	642	691	781	14.2%
Total Discrete	731	887	980	1,023	1,118	1,233	11.0%
Total Optoelectronic	84	102	112	121	132	142	11.0%

Source: Dataquest (December 1995 Estimates)

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Table 9
European Semiconductor Market by Application—Consumer Equipment, History
(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Comsumer Equipment	18,964	19,606	20,410	19,450	20,036	20,845	1.9%
Total Semiconductor	1,795	1,883	1,951	2,137	1,938	2,300	5.1%
Total IC	1,353	1,421	1,499	1,682	1,545	1,805	5.9%
Bipolar Digital	14	11	9	8	8	6	-15.6%
MOS Digital	659	579	656	807	438	519	-4.7%
MOS Memory	146	104	105	139	81	113	-4.9%
MOS Microcomponent	197	211	240	327	242	280	7.2%
MOS Logic	316	265	311	341	115	125	-16.9%
Analog (mono + hybrid)	680	832	834	866	1,099	1,280	13.5%
Total Discrete	389	409	390	398	274	321	-3.8%
Total Optoelectronic	54	53	62	57	119	175	26.7%

Source: Dataquest (December 1995 Estimates)

Table 10
European Semiconductor Market by Application—Consumer Equipment, Forecast
(Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Consumer Equipment	20,845	22,124	23,880	25,219	26,910	28,799	6.7%
Total Semiconductor	2,300	2,900	3,410	3,809	4,220	4,760	15.7%
Total IC	1,805	2,283	2,729	3,070	3,416	3,869	16.5%
Bipolar Digital	6	5	4	3	3	2	-19.6%
MOS Digital	519	681	852	1,009	1,144	1,267	19.6%
MOS Memory	113	193	293	352	403	448	31.6%
MOS Microcomponent	280	336	386	450	493	540	14.0%
MOS Logic	125	151	172	207	247	279	17.4%
Analog (mono + hybrid)	1,280	1,597	1,873	2,059	2,269	2,600	15.2%
Total Discrete	321	402	440	473	522	584	12.7%
Total Optoelectronic	175	215	241	266	283	307	11.9%

Source: Dataquest (December 1995 Estimates)

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Table 11
European Semiconductor Market by Application—Military/Civil Aerospace Equipment, History(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Military/Civil Aerospace Equipment	21,749	20,976	21,171	21,055	21,447	20,851	-0.8%
Total Semiconductor	498	478	488	515	504	504	0.2%
Total IC	346	326	339	377	454	449	5.3%
Bipolar Digital	29	21	17	15	35	21	-6.2%
MOS Digital	225	195	214	257	309	319	7.2%
MOS Memory	64	44	44	54	133	161	20.3%
MOS Microcomponent	95	98	109	140	81	72	-5.3%
MOS Logic	66	54	62	63	96	86	5.4%
Analog (mono + hybrid)	93	110	108	105	110	109	3.4%
Total Discrete	119	121	113	108	35	36	-21.2%
Total Optoelectronic	32	31	36	30	15	19	-10.5%

Source: Dataquest (December 1995 Estimates)

Table 12
European Semiconductor Market by Application—Military/Civil Aerospace Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Military/Civil Aerospace Equipment	20,851	20,628	20,489	20,275	20,075	19,719	-1.1%
Total Semiconductor	504	493	462	476	449	467	-1.5%
Total IC	449	440	413	427	403	421	-1.3%
Bipolar Digital	21	14	10	8	6	4	-26.6%
MOS Digital	319	323	310	330	314	326	0.5%
MOS Memory	161	181	178	198	190	194	3.9%
MOS Microcomponent	72	66	64	69	66	67	-1.4%
MOS Logic	86	76	68	63	58	64	-5.6%
Analog (mono + hybrid)	109	104	93	89	83	90	-3.9%
Total Discrete	36	35	32	32	31	30	-3.4%
Total Optoelectronic	19	18	16	17	15	16	-2.9%

Source: Dataquest (December 1995 Estimates)

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Table 13
European Semiconductor Market by Application—Transportation (Automotive) Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Automotive Equipment	5,191	6,262	6,818	7,809	8,558	9,953	13.9%
Total Semiconductor	640	812	893	1,018	1,256	1,655	20.9%
Total IC	512	645	726	856	1,009	1,309	20.6%
Bipolar Digital	5	5	4	4	12	10	14.1%
MOS Digital	411	492	571	702	818	1,075	21.2%
MOS Memory	34	30	31	40	162	256	49.7%
MOS Microcomponent	229	306	354	466	504	631	22.5%
MOS Logic	148	155	186	196	153	188	5.0%
Analog (mono + hybrid)	96	148	151	151	179	223	18.3%
Total Discrete	112	148	144	141	221	304	22.1%
Total Optoelectronic	16	19	23	20	26	43	22.1%

Source: Dataquest (December 1995 Estimates)

Table 14
European Semiconductor Market by Application—Transportation (Automotive) Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Automotive Equipment	9,953	11,231	12,606	14,075	15,763	17,538	12.0%
Total Semiconductor	1,655	2,290	2,770	3,134	3,448	3,786	18.0%
Total IC	1,309	1,785	2,153	2,458	2,699	2,954	17.7%
Bipolar Digital	10	10	5	4	3	3	-22.8%
MOS Digital	1,075	1,476	1,773	2,041	2,255	2,450	17.9%
MOS Memory	256	420	521	564	601	624	19.5%
MOS Microcomponent	631	805	961	1,111	1,238	1,365	16.7%
MOS Logic	188	252	291	365	415	462	19.6%
Analog (mono + hybrid)	223	299	374	413	441	501	17.5%
Total Discrete	304	438	539	590	657	732	19.2%
Total Optoelectronic	43	67	78	86	92	100	18.6%

Source: Dataquest (December 1995 Estimates)

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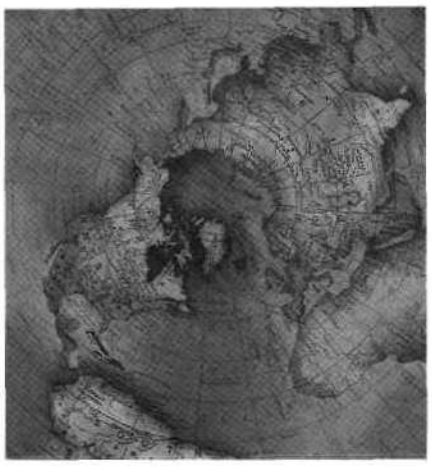
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European Regional Semiconductor Consumption by Application



Market Statistics

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European Regional Semiconductor Consumption by Application



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Chapter 1
Introduction

This Market Statistics document presents Dataquest's midyear forecast for European country semiconductor consumption by application market segment. The data are presented in two different ways for additional clarity of the market demographics for the reader. We have therefore divided the tables into two main sections. The first section shows country semiconductor consumption by end-application markets, and the second section gives end-application markets by country data. In the following paragraphs we explain our definitions, research forecast assumptions, and how to use the tables.

Definitions

This report analyses the market sizes and outlooks for major European regions from 1988 to 2000. Dataquest's forecast details the following regions.

Europe

Dataquest defines seven regions in total: Benelux, France, Italy, Nordic, UK and Ireland, Germany, and Rest of Europe. These regions encompass the following nations:

- **Benelux:** Belgium, Netherlands and Luxembourg
- **France:** France
- **Italy:** Italy
- **Nordic:** Denmark, Norway, Sweden and Finland
- **UK and Ireland:** United Kingdom and Ireland
- **Germany:** Germany
- **Rest of Europe:** Austria, Switzerland, Spain, Portugal, Greece, Cyprus, Gibraltar, Liechtenstein, Malta, San Marino, Iceland, Turkey, Andorra, Vatican City, Eastern Europe
  - *Eastern Europe:* Includes Albania, Bulgaria, Czech Republic, Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Republics of the former Yugoslavia, Ukraine, Belarus, Georgia, Russian Federation, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, Turkmenistan

Semiconductor Market Definition

Dataquest defines the semiconductor market as representing all merchant market business together with in-house business that exists for those semiconductor manufacturers that also participate in the merchant market. This element of in-house business between a manufacturer and its equipment divisions or subsidiaries is valued at merchant market prices. This gives a true reflection of the total available market (TAM) to merchant semiconductor suppliers.

Assumptions

The following are some key assumptions that were used in the forecast model. Significant changes in these assumptions will therefore affect the forecast outlook.

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Exchange Rates

Actual exchange rates for the European regions covered in this report are contained in Table 1-1. Dataquest does not forecast currency fluctuations. The rate used from 1995 onwards is the average of 1995 year to date combined with the last month's rates (June) used for the rest of the year.

In Europe, the dollar's importance was extremely noticeable. Its rise in strength against many European currencies and the yen affected market growth levels. In markets where the dollar is used for many transactions, this effect was profound. In the United Kingdom where dollar-based transactions may be almost half the total, dollar appreciation may have knocked 2 to 3 percent off the growth from 1993 to 1994.

Table 1-1
European Exchange Rates Against the US Dollar

Region	Currency	1988	1989	1990	1991	1992	1993	1994
Benelux	Gulden	1.98	2.12	1.82	1.868	1.751	1.858	1.817
France	Franc	5.96	6.39	5.44	5.638	5.271	5.672	5.537
Germany	Deutsche Mark	1.76	1.88	1.62	1.658	1.555	1.656	1.620
Italy	Lira	1,301	1,374	1,197	1,239	1,228	1,578	1,609
Nordic	Swedish Krona	6.13	6.45	5.92	6.045	5.811	7.822	7.696
UK/Ireland	UK Pound	0.56	0.61	0.56	0.568	0.569	0.667	0.654
Rest of Europe	Peseta	116.96	118.55	102.03	103.81	101.90	127.87	133.48
Total Europe	ECU	0.846	0.908	0.788	0.811	0.770	0.858	0.844

Source: Dataquest (October 1995 Estimates)

Economic Conditions

The gross domestic product (GDP) outlook for the major European regions is contained in Table 1-2. In 1994, all regions showed an increase in their GDP growth over 1993, a sign of returning health after the economic problems of the early 1990s. Another good year is predicted for 1995, though the situation will begin to slow again in 1996. The general outlook is that there should be good economic conditions for the duration of the forecast.

Table 1-2
GDP Growth Rates, Percent Change

Country	1993	1994	1995	1996
Belgium	-1.3	2.3	2.7	2.6
France	-0.9	2.7	3.0	3.2
Germany	-1.3	2.9	2.9	2.7
Netherlands	0.2	2.5	3.1	2.7
Italy	-0.7	2.2	3.0	2.9
Spain	-1.0	2.0	3.0	3.2
Sweden	-2.1	2.2	2.5	2.4
Switzerland	-0.6	2.1	1.7	2.3
United Kingdom	1.9	3.8	3.4	3.0

Source: OECD, June 1995

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Semiconductor Production Capacity

Investment in production equipment and new wafer fabrication plants is booming. Dataquest expects a 20 percent increase in worldwide spending this year following a 30 percent increase in 1994. Much investment is going into DRAM production, as demand levels continue to outstrip production quantities. It is also in 1995 that submicron production (in square inches) is larger than 1 µm and above for the first time.

Dataquest is following the great success that foundries are having during this period of shortage of production space. Many larger companies are using foundry alongside smaller fab-less companies, keeping overall utilization levels up at close to 95 percent across the world.

Forecast Summary

Dataquest published, in April 1995, two market statistics documents which show electronic equipment production (reference, SAMM-EU-MS-9501) and semiconductor consumption forecast as at that time (reference, SAMM-EU-MF-9501). Our further research into application markets this year has resulted in this new forecast by country and application. The European semiconductor market in 1994 continued a rapid growth acceleration into 1995 from the fourth quarter of 1994. We have revised our forecasts to reflect this. The four major semiconductor markets are Germany, UK and Ireland, France, and Italy. Our forecast assumptions are mostly influenced by trends in these major markets highlighted here.

Germany

Germany's telecommunications network is still being converted to digital exchanges, so there is considerable business for Siemens and other non-German producers. Siemens is also looking outside Europe at developing markets. Production is still centered in Europe for markets such as Asia/Pacific and Latin America, although some screwdriver plants are already operating there. There is also a substantial amount of cellular production for Nokia and Motorola in Germany.

Although the largest segment for Germany is electronic data processing (EDP), its industrial market is still the largest in Europe. Many large conglomerates center production in Germany, and with the absorption of eastern Germany many more formerly state-owned companies are now included in the industrial segment.

PC manufacturing and sales, together with other EDP equipment production, are growing in importance. Several major PC producers such as Vobis and Escom are now dramatically expanding their sales regions, with production quantities increasing to support this strategy. Escom has recently taken over 200 stores in the United Kingdom to develop its sales infrastructure.

Dataquest expects the German region to become the largest semiconductor market in Europe again. By 1996, Germany, with its varied production, will overtake the UK and Ireland region, which has been the largest region since 1994. Tables 2-12 and 2-15 show the region's development, and Dataquest expects a long-term compound annual growth rate (CAGR) of 17 percent for the region.

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United Kingdom and Ireland

The UK and Ireland region accounts for more than half of the PCs produced in Europe. In fact, Scotland alone represents close to 30 percent of all production. Dataquest expects the region to remain the largest PC production region in Europe, though its lead may be eroded over the forecast period. The main issue in the United Kingdom for PCs is that there is little actual design. Most production sites rely on other world regions, especially the United States, to transfer machine specifications for local production.

In the telecommunications sector, key customers are increasing their production levels. This is especially true in the mobile sector where Motorola is evident. Large exchange business is also showing some strength, although some production is being moved off-shore to lower-cost production regions. The United Kingdom also enjoys a reasonable share of European mobile handset and base station production, with the market leader, Motorola, and a number of other companies designing and building equipment.

Japanese transplants in the automotive segment make the UK and Ireland the fastest-growing region for car production in Europe. At this stage the market is probably the fourth largest in Europe, but Dataquest expects this to change within the forecast period.

The UK and Ireland region will grow in line with the average European outlook as shown in the detailed product forecast in Tables 2-24 and 2-27.

France

Despite the difficult economic situation in France, semiconductor demand is still buoyant. This demand is being seen from a number of end-equipment segments, thanks to France's diverse production base. Historically, France has been well known for its consumer and automotive strength, but other equipment producers are now beginning to flourish.

In the EDP sector, both Hewlett-Packard (via SCI) and Packard Bell (via Bull) are increasing their production levels of PCs. End demand is high for PCs, and attractive pricing and innovative machines have made these two producers particularly successful. Hewlett-Packard is particularly important as its facility in Grenoble is the company's center for worldwide PC research and development. France is a center of excellence for smart card production, and large producers such as Gemplus and Schlumberger are growing their market shares.

The military and aerospace segment is still important, with companies such as Dassault and Thomson still producing guidance and navigation equipment. Continued work on the European Airbus is also producing some semiconductor demand.

Telecommunications companies such as Alcatel are benefiting from the large increase in demand for mobile telephones. France has also attracted some investment from Japanese suppliers such as Sony and Mitsubishi, which are producing cellular telephones and answering machines.

France enjoys significant consumer equipment production, with production of color TVs among the highest in Europe.

The history and forecast for the France semiconductor market are shown in Tables 2-8 and 2-11. The long-term outlook for France is a CAGR of 15 percent, a significant rise over the past five years' average growth of 11 percent.

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Italy

Italy's largest telecommunications company, Italtel, has recently been acquired by Siemens. Italtel's local production is large, and semiconductor procurement takes place in Italy. It enjoys good export business to the Far East and South America as many countries develop digital telecommunications infrastructures.

Italy's semiconductor demand is largely linked to the EDP segment. Both Olivetti and IBM demand significant levels of most semiconductor devices. Olivetti's production levels are growing, although business is difficult due to the stiff competition from other European producers.

Italy's car producers make the country's automotive market the fourth largest in Europe. Developments in safety, navigation and engine control mean that the car is becoming a home for sophisticated subsystems. At this time many of these subsystems are being imported. However, Dataquest expects this to change over the forecast period as smaller suppliers develop to support the large vehicle producers.

Dataquest is expecting the Italian market to grow below the European average at 11 percent as shown in Tables 2-16 and 2-19.

Nordic

The Nordic region's semiconductor demand is largely for its huge telecommunications production. In the past the industry had been dominated by central exchange and switching projects, but in the last few years, much of this has moved off-shore. This semiconductor demand has been replaced by the current surge in demand for mobile communications, and the Nordic region has two of the top three producers—Nokia and Ericsson. Over the past few years these companies have both more than doubled their production capacities, and their semiconductor purchases have grown almost exponentially.

PC production in the region has also grown, with Nokia-ICL producing many different types of PC and server. Numerous PC assemblers also exist in the region, and contribute to the overall EDP TAM.

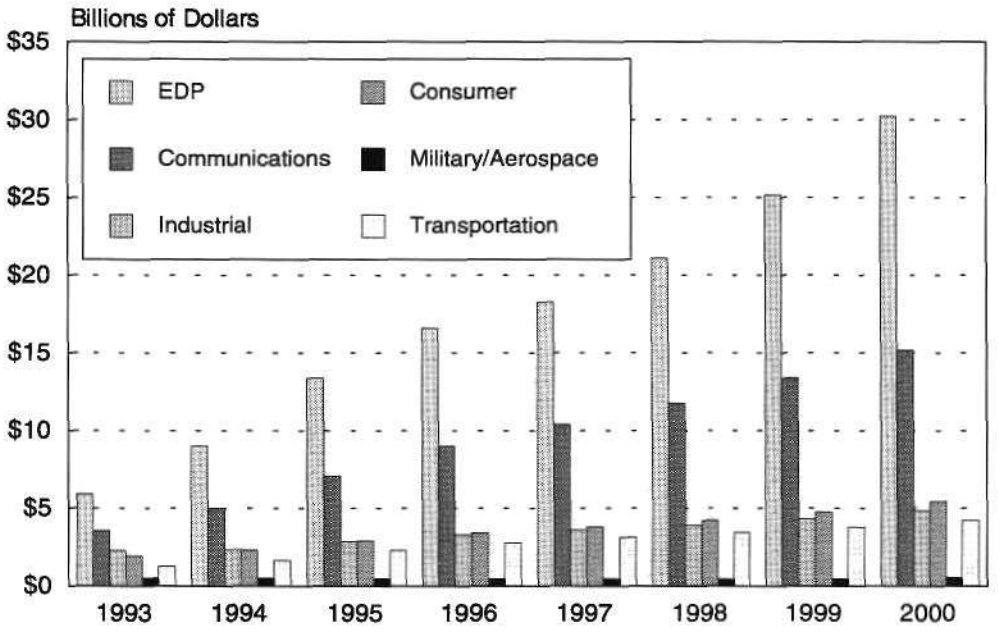
Automotive producers such as Volvo are leading the design-in of more semiconductors into cars. The European Commission is now realizing the importance of navigation systems in the longer term. As well as cutting down congestion, emissions will be reduced—a key issue in environmental management.

The Nordic region will grow fastest of all European regions for the forecast period. It will grow with a CAGR of 17 percent to reach more than $5.5 billion by 2000. The detailed forecast is contained in Tables 2-20 and 2-23.

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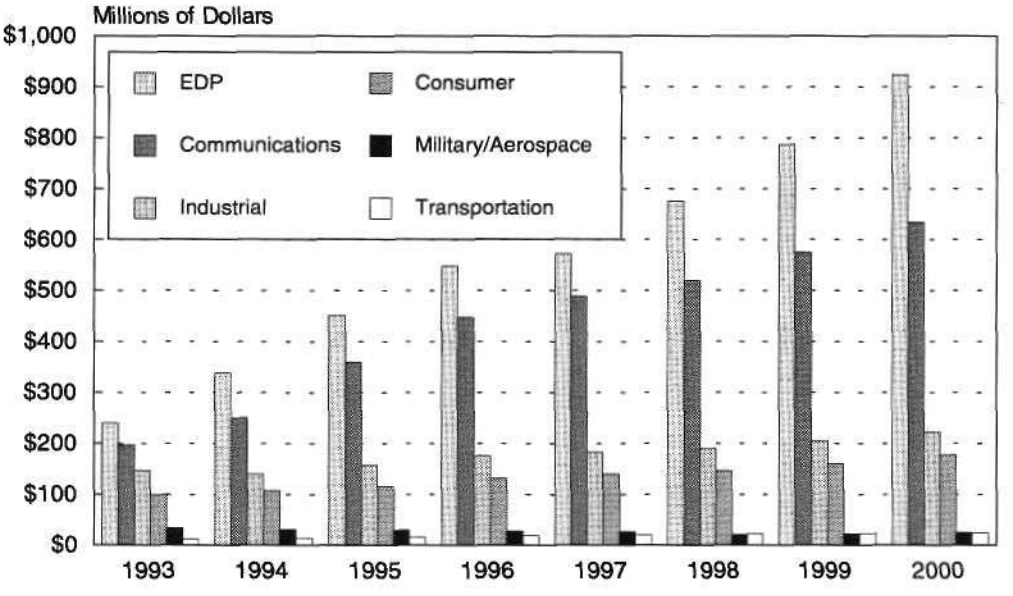
Chapter 2
Consumption by Region

Figure 2-1
European Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

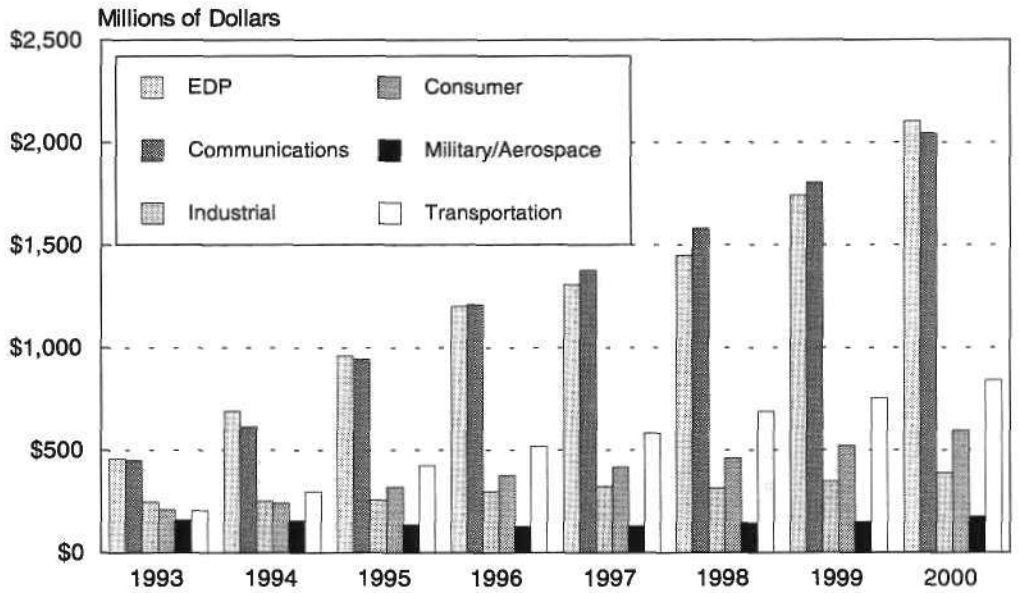
Figure 2-2
Benelux Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

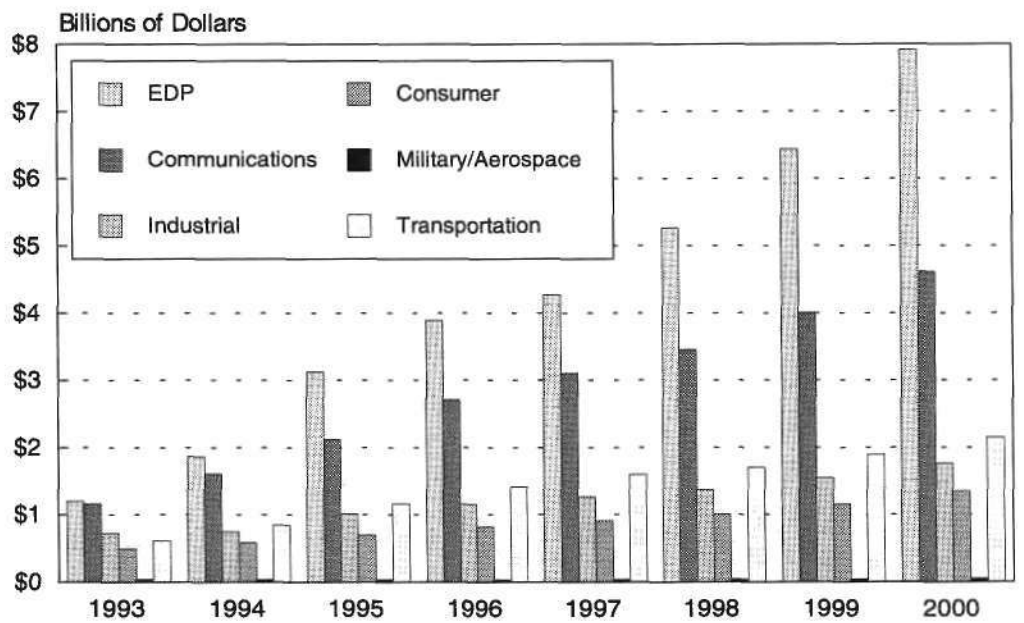
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Figure 2-3
French Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

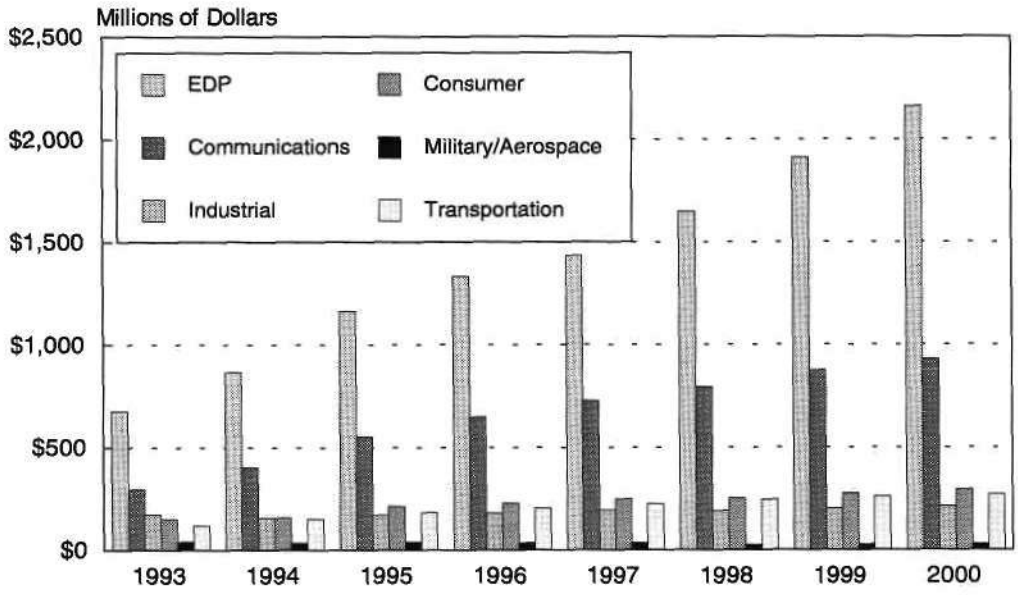
Figure 2-4
German Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

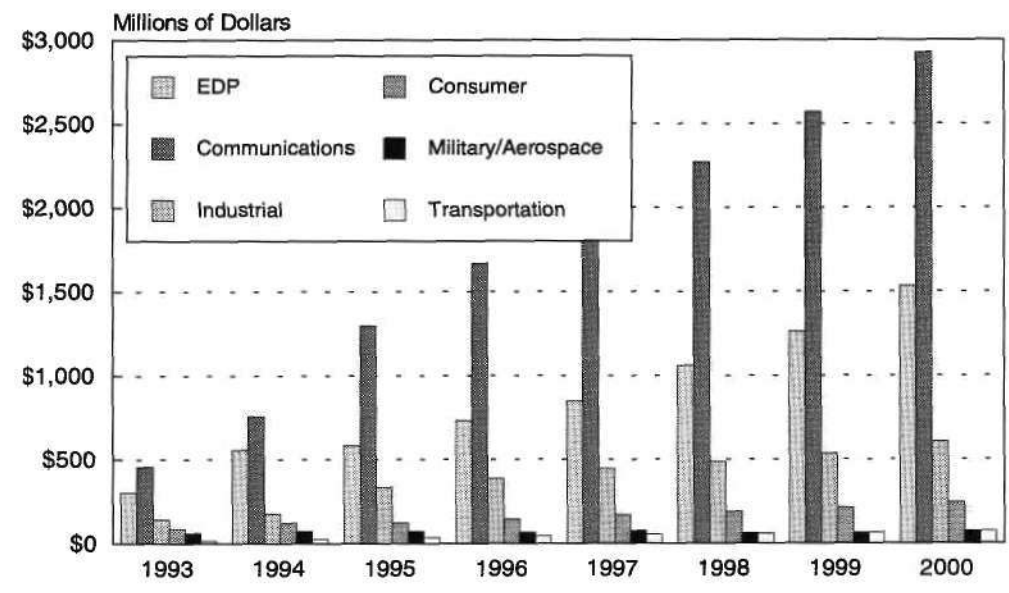
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Figure 2-5
Italian Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

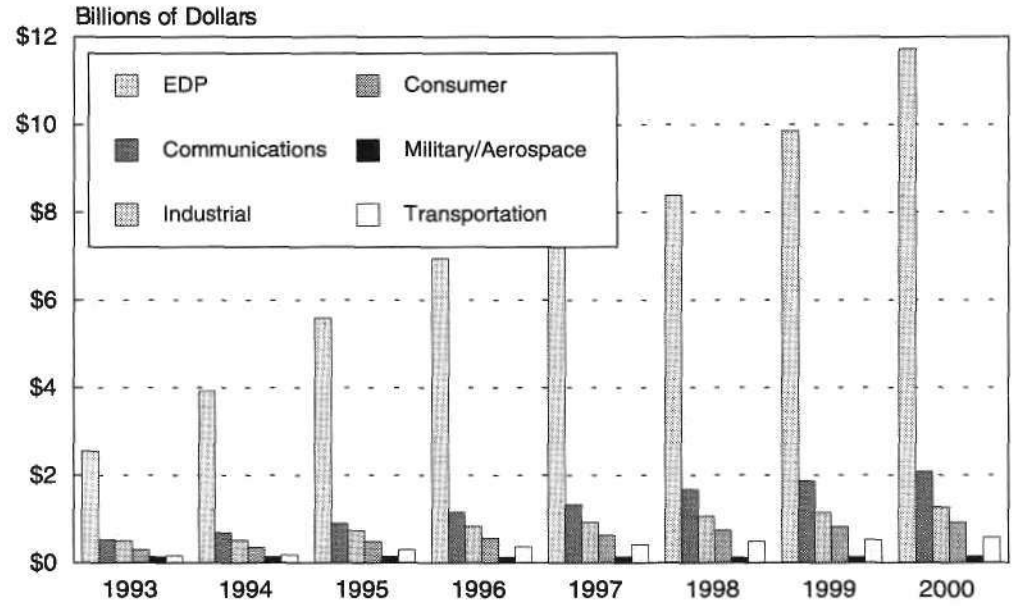
Figure 2-6
Nordic Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

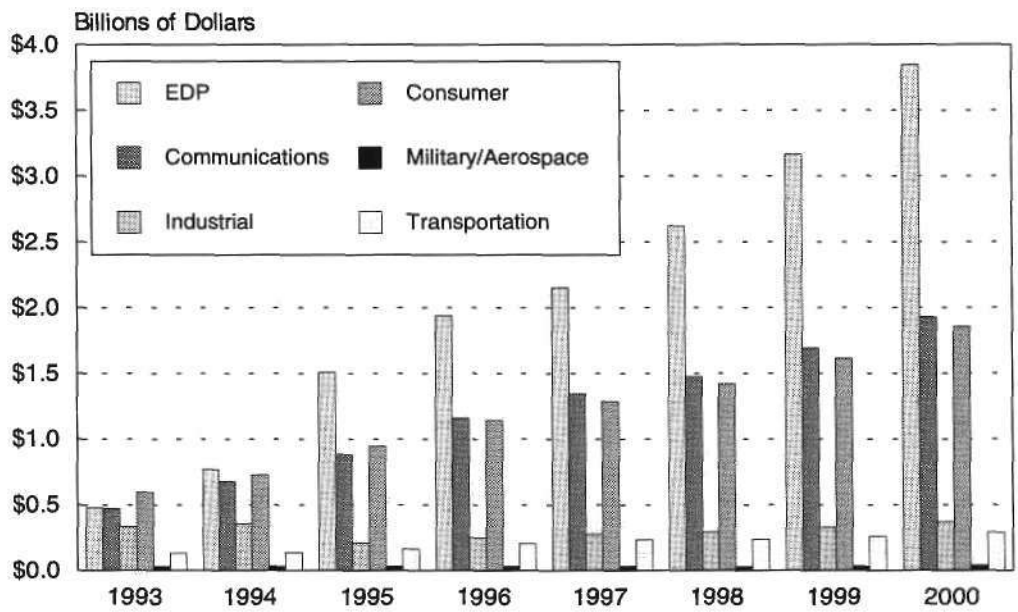
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Figure 2-7
UK and Ireland Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

Figure 2-8
Rest of Europe Semiconductor Consumption by End-Use Application Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

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Table 2-1
European Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	2,540	2,965	2,963	3,136	3,946	5,915	9,010	13,380	16,586	18,250	21,101	25,152	30,210	35.2%	17.7%	48.5%
Communications	1,736	1,915	2,362	2,567	2,854	3,559	5,000	7,060	9,000	10,395	11,771	13,390	15,166	24.5%	16.5%	41.2%
Industrial	1,625	1,685	1,917	1,979	2,112	2,278	2,350	2,871	3,289	3,610	3,906	4,304	4,834	8.4%	11.0%	22.2%
Consumer	1,526	1,795	1,883	1,951	1,718	1,938	2,300	2,900	3,410	3,809	4,220	4,760	5,438	9.0%	13.4%	26.1%
Military & Civil Aerospace	505	498	478	488	488	504	504	493	462	476	449	467	544	0.6%	2.0%	-2.2%
Transportation	559	640	812	893	1,100	1,256	1,655	2,291	2,770	3,134	3,448	3,786	4,230	23.1%	13.0%	38.4%
Total	$8,491	$9,498	$10,415	$11,014	$12,218	$15,450	$20,819	$28,995	$35,517	$39,674	$44,895	$51,859	$60,422	22.7%	15.8%	39.3%

Source: Dataquest (October 1995 Estimates)

Table 2-2
European Semiconductor Consumption by Application
As a Percentage of Total Europe

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	29.9%	31.2%	28.4%	28.5%	32.3%	38.3%	43.3%	46.1%	46.7%	46.0%	47.0%	48.5%	50.0%
Communications	20.4%	20.2%	22.7%	23.3%	23.4%	23.0%	24.0%	24.3%	25.3%	26.2%	26.2%	25.8%	25.1%
Industrial	19.1%	17.7%	18.4%	18.0%	17.3%	14.7%	11.3%	9.9%	9.3%	9.1%	8.7%	8.3%	8.0%
Consumer	18.0%	18.9%	18.1%	17.7%	14.1%	12.5%	11.0%	10.0%	9.6%	9.6%	9.4%	9.2%	9.0%
Military & Civil Aerospace	5.9%	5.2%	4.6%	4.4%	4.0%	3.3%	2.4%	1.7%	1.3%	1.2%	1.0%	0.9%	0.9%
Transportation	6.6%	6.7%	7.8%	8.1%	9.0%	8.1%	7.9%	7.9%	7.8%	7.9%	7.7%	7.3%	7.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-3
European Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	16.7%	-0.1%	5.8%	25.8%	49.9%	52.3%	48.5%	24.0%	10.0%	15.6%	19.2%	20.1%
Communications	10.3%	23.3%	8.7%	11.2%	24.7%	40.5%	41.2%	27.5%	15.5%	13.2%	13.8%	13.3%
Industrial	3.7%	13.8%	3.2%	6.7%	7.9%	3.2%	22.2%	14.6%	9.8%	8.2%	10.2%	12.3%
Consumer	17.6%	4.9%	3.6%	-11.9%	12.8%	18.7%	26.1%	17.6%	11.7%	10.8%	12.8%	14.2%
Military & Civil Aerospace	-1.4%	-4.0%	2.1%	0.0%	3.3%	0.0%	-2.2%	-6.3%	3.0%	-5.7%	4.0%	16.5%
Transportation	14.5%	26.9%	10.0%	23.2%	14.2%	31.8%	38.4%	20.9%	13.1%	10.0%	9.8%	11.7%
Total	11.9%	9.7%	5.8%	10.9%	26.5%	34.8%	39.3%	22.5%	11.7%	13.2%	15.5%	16.5%

Source: Dataquest (October 1995 Estimates)

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Table 2-4
Benelux Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	CAGR 94>95
Electronic Data Processing	120	136	166	170	159	240	339	451	548	572	676	787	924	22.1%	15.4%	33.2%
Communications	121	120	178	188	169	197	250	360	448	489	520	575	634	15.1%	12.0%	44.2%
Industrial	140	116	160	160	143	147	140	157	176	183	190	204	222	-0.4%	7.2%	12.6%
Consumer	76	82	100	96	96	100	107	116	132	140	146	160	178	3.0%	9.0%	8.3%
Military & Civil Aerospace	41	33	37	38	33	34	31	30	28	27	21	22	25	-4.2%	-4.0%	-2.1%
Transportation	7	6	9	9	10	12	14	16	19	20	22	23	25	12.0%	9.5%	11.2%
Total	$504	$493	$651	$661	$610	$730	$880	$1,130	$1,351	$1,431	$1,575	$1,771	$2,008	11.7%	12.2%	28.4%

Source: Dataquest (October 1995 Estimates)

Table 2-5
Benelux Semiconductor Consumption by Application
As a Percentage of Total Benelux Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	23.9%	27.6%	25.5%	25.7%	26.1%	32.9%	38.5%	39.9%	40.5%	40.0%	42.9%	44.5%	46.0%
Communications	24.0%	24.3%	27.4%	28.4%	27.7%	27.0%	28.4%	31.9%	33.2%	34.2%	33.0%	32.5%	31.6%
Industrial	27.7%	23.6%	24.6%	24.2%	23.4%	20.2%	15.9%	13.9%	13.0%	12.8%	12.1%	11.5%	11.1%
Consumer	15.0%	16.6%	15.4%	14.5%	15.7%	13.7%	12.2%	10.2%	9.8%	9.8%	9.3%	9.0%	8.9%
Military & Civil Aerospace	8.1%	6.6%	5.7%	5.8%	5.4%	4.6%	3.5%	2.7%	2.0%	1.9%	1.3%	1.2%	1.2%
Transportation	1.3%	1.2%	1.4%	1.4%	1.6%	1.6%	1.6%	1.4%	1.4%	1.4%	1.4%	1.3%	1.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-6
Benelux Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	4.7%	4.6%	5.6%	5.4%	4.0%	4.1%	3.8%	3.4%	3.3%	3.1%	3.2%	3.1%	3.1%
Communications	7.0%	6.3%	7.5%	7.3%	5.9%	5.5%	5.0%	5.1%	5.0%	4.7%	4.4%	4.3%	4.2%
Industrial	8.6%	6.9%	8.4%	8.1%	6.8%	6.5%	5.9%	5.5%	5.4%	5.1%	4.9%	4.7%	4.6%
Consumer	5.0%	4.6%	5.3%	4.9%	5.6%	5.2%	4.7%	4.0%	3.9%	3.7%	3.5%	3.4%	3.3%
Military & Civil Aerospace	8.1%	6.5%	7.8%	7.9%	6.8%	6.7%	6.1%	6.1%	6.0%	5.7%	4.7%	4.6%	4.5%
Transportation	1.2%	0.9%	1.1%	1.0%	0.9%	0.9%	0.9%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%
Total	5.9%	5.2%	6.3%	6.0%	5.0%	4.7%	4.2%	3.9%	3.8%	3.6%	3.5%	3.4%	3.3%

Source: Dataquest (October 1995 Estimates)

Table 2-7
Benelux Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	13.1%	21.9%	2.2%	-6.3%	50.9%	41.2%	33.2%	21.4%	4.4%	18.2%	16.5%	17.4%
Communications	-0.8%	48.4%	5.5%	-10.1%	16.6%	26.8%	44.2%	24.6%	9.0%	6.4%	10.6%	10.1%
Industrial	-16.6%	37.8%	-0.3%	-10.6%	3.1%	-5.3%	12.6%	12.1%	3.9%	3.7%	7.2%	9.3%
Consumer	8.1%	22.3%	-4.1%	0.2%	4.4%	6.7%	8.3%	14.2%	5.9%	4.5%	9.5%	11.1%
Military & Civil Aerospace	-20.4%	15.1%	2.6%	-14.0%	2.7%	-9.2%	-2.1%	-8.2%	-2.4%	-21.6%	1.7%	13.9%
Transportation	-8.4%	50.0%	1.8%	9.1%	15.7%	23.2%	11.2%	18.4%	7.7%	7.4%	6.2%	8.3%
Total	-2.2%	32.0%	1.5%	-7.7%	19.7%	20.5%	28.4%	19.6%	5.9%	10.1%	12.4%	13.4%

Source: Dataquest (October 1995 Estimates)

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Table 2-8
French Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	327	360	371	348	350	458	690	960	1,201	1,308	1,450	1,741	2,103	21.0%	17.0%	39.3%
Communications	271	283	354	343	372	450	613	944	1,211	1,377	1,582	1,804	2,043	21.6%	16.7%	54.0%
Industrial	225	237	276	253	243	249	251	258	298	323	314	347	390	-1.3%	8.6%	2.8%
Consumer	177	205	212	186	205	210	242	321	378	417	462	522	596	8.7%	13.2%	32.7%
Military & Civil Aerospace	150	182	177	166	155	159	156	136	128	130	143	150	175	-5.1%	5.3%	-13.2%
Transportation	61	83	105	98	128	204	299	426	520	584	689	754	840	32.4%	14.5%	42.7%
Total	$1,210	$1,349	$1,494	$1,395	$1,453	$1,730	$2,250	$3,045	$3,736	$4,140	$4,639	$5,318	$6,147	15.3%	**15.1%**	35.3%

Source: Dataquest (October 1995 Estimates)

Table 2-9
French Semiconductor Consumption by Application
As a Percentage of Total French Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	27.0%	26.7%	24.8%	25.0%	24.1%	26.5%	30.6%	31.5%	32.2%	31.6%	31.3%	32.7%	34.2%
Communications	22.4%	20.9%	23.7%	24.6%	25.6%	26.0%	27.2%	31.0%	32.4%	33.3%	34.1%	33.9%	33.2%
Industrial	18.6%	17.6%	18.5%	18.1%	16.7%	14.4%	11.1%	8.5%	8.0%	7.8%	6.8%	6.5%	6.3%
Consumer	14.6%	15.2%	14.2%	13.4%	14.1%	12.1%	10.8%	10.5%	10.1%	10.1%	10.0%	9.8%	9.7%
Military & Civil Aerospace	12.4%	13.5%	11.8%	11.9%	10.7%	9.2%	6.9%	4.5%	3.4%	3.2%	3.1%	2.8%	2.9%
Transportation	5.0%	6.1%	7.0%	7.0%	8.8%	11.8%	13.3%	14.0%	13.9%	14.1%	14.9%	14.2%	13.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-10
French Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	12.9%	12.2%	12.5%	11.1%	8.9%	7.7%	7.7%	7.2%	7.2%	7.2%	6.9%	6.9%	7.0%
Communications	15.6%	14.8%	15.0%	13.4%	13.0%	12.6%	12.3%	13.4%	13.5%	13.2%	13.4%	13.5%	13.5%
Industrial	13.9%	14.1%	14.4%	12.8%	11.5%	10.9%	10.7%	9.0%	9.0%	8.9%	8.0%	8.1%	8.1%
Consumer	11.6%	11.4%	11.2%	9.6%	11.9%	10.8%	10.5%	11.1%	11.1%	11.0%	10.9%	11.0%	11.0%
Military & Civil Aerospace	29.7%	36.5%	36.9%	34.1%	31.8%	31.5%	31.0%	27.5%	27.7%	27.4%	31.8%	32.0%	32.2%
Transportation	10.8%	12.9%	12.9%	11.0%	11.6%	16.3%	18.1%	18.6%	18.8%	18.6%	20.0%	19.9%	19.9%
Total	14.3%	14.2%	14.3%	12.7%	11.9%	11.2%	10.8%	10.5%	10.5%	10.4%	10.3%	10.3%	10.2%

Source: Dataquest (October 1995 Estimates)

Table 2-11
French Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	10.2%	2.9%	-6.1%	0.5%	30.8%	50.7%	39.3%	25.1%	8.9%	10.8%	20.1%	20.7%
Communications	4.2%	25.4%	-3.1%	8.3%	21.0%	36.2%	54.0%	28.3%	13.7%	14.9%	14.0%	13.3%
Industrial	5.3%	16.4%	-8.4%	-3.8%	2.6%	0.6%	2.8%	15.5%	8.4%	-2.8%	10.6%	12.3%
Consumer	16.0%	3.3%	-11.9%	10.0%	2.4%	15.2%	32.7%	17.7%	10.5%	10.7%	12.9%	14.2%
Military & Civil Aerospace	21.1%	-2.8%	-5.8%	-6.9%	2.4%	-1.6%	-13.2%	-5.5%	1.8%	9.3%	4.9%	17.2%
Transportation	36.6%	26.7%	-6.5%	30.7%	59.7%	46.2%	42.7%	21.9%	12.3%	18.0%	9.5%	11.4%
Total	11.5%	10.7%	-6.6%	4.2%	19.1%	30.1%	35.3%	22.7%	10.8%	12.1%	14.6%	15.6%

Source: Dataquest (October 1995 Estimates)

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Table 2-12
German Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	610	683	692	785	951	1,201	1,866	3,125	3,891	4,272	5,271	6,439	7,915	35.2%	20.4%	67.5%
Communications	403	512	633	741	973	1,158	1,606	2,123	2,711	3,108	3,453	4,004	4,617	27.4%	16.8%	32.2%
Industrial	414	541	620	686	689	722	747	1,008	1,158	1,265	1,370	1,541	1,762	10.2%	11.8%	34.9%
Consumer	499	523	532	566	485	493	585	697	817	909	1,006	1,155	1,344	5.6%	14.0%	19.2%
Military & Civil Aerospace	45	28	27	30	34	34	34	35	33	34	39	42	50	5.9%	7.3%	4.8%
Transportation	280	328	409	462	596	608	843	1,164	1,412	1,599	1,701	1,894	2,147	23.3%	13.0%	38.1%
Total	$2,250	$2,614	$2,913	$3,271	$3,728	$4,216	$5,681	$8,153	$10,021	$11,187	$12,841	$15,075	$17,836	22.9%	16.9%	43.5%

Source: Dataquest (October 1995 Estimates)

Table 2-13
German Semiconductor Consumption by Application
As a Percentage of Total German Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	27.1%	26.1%	23.8%	24.0%	25.5%	28.5%	32.8%	38.3%	38.8%	38.2%	41.0%	42.7%	44.4%
Communications	17.9%	19.6%	21.7%	22.6%	26.1%	27.5%	28.3%	26.0%	27.1%	27.8%	26.9%	26.6%	25.9%
Industrial	18.4%	20.7%	21.3%	21.0%	18.5%	17.1%	13.2%	12.4%	11.6%	11.3%	10.7%	10.2%	9.9%
Consumer	22.2%	20.0%	18.3%	17.3%	13.0%	11.7%	10.3%	8.6%	8.1%	8.1%	7.8%	7.7%	7.5%
Military & Civil Aerospace	2.0%	1.1%	0.9%	0.9%	0.9%	0.8%	0.6%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%
Transportation	12.4%	12.5%	14.0%	14.1%	16.0%	14.4%	14.8%	14.3%	14.1%	14.3%	13.2%	12.6%	12.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-14
German Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	24.0%	23.0%	23.4%	25.0%	24.1%	20.3%	20.7%	23.4%	23.5%	23.4%	25.0%	25.6%	26.2%
Communications	23.2%	26.7%	26.8%	28.9%	34.1%	32.5%	32.1%	30.1%	30.1%	29.9%	29.3%	29.9%	30.4%
Industrial	25.5%	32.1%	32.3%	34.7%	32.6%	31.7%	31.8%	35.1%	35.2%	35.1%	35.1%	35.8%	36.5%
Consumer	32.7%	29.1%	28.3%	29.0%	28.2%	25.4%	25.4%	24.0%	23.9%	23.9%	23.8%	24.3%	24.7%
Military & Civil Aerospace	8.9%	5.6%	5.6%	6.2%	7.0%	6.8%	6.7%	7.2%	7.2%	7.2%	8.8%	9.0%	9.2%
Transportation	50.0%	51.2%	50.4%	51.8%	54.2%	48.4%	50.9%	50.8%	51.0%	51.0%	49.3%	50.0%	50.8%
Total	26.5%	27.5%	28.0%	29.7%	30.5%	27.3%	27.3%	28.1%	28.2%	28.2%	28.6%	29.1%	29.5%

Source: Dataquest (October 1995 Estimates)

Table 2-15
German Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	12.0%	1.4%	13.4%	21.1%	26.3%	55.3%	67.5%	24.5%	9.8%	23.4%	22.2%	22.9%
Communications	27.2%	23.6%	17.1%	31.4%	19.0%	38.7%	32.2%	27.7%	14.6%	11.1%	16.0%	15.3%
Industrial	30.7%	14.6%	10.6%	0.4%	4.7%	3.6%	34.9%	14.9%	9.3%	8.3%	12.4%	14.4%
Consumer	4.8%	1.8%	6.4%	-14.4%	1.6%	18.8%	19.2%	17.1%	11.4%	10.6%	14.9%	16.3%
Military & Civil Aerospace	-38.4%	-4.2%	13.9%	12.4%	0.2%	-1.1%	4.8%	-5.9%	2.6%	15.9%	6.7%	19.3%
Transportation	17.1%	24.9%	13.0%	28.9%	2.0%	38.5%	38.1%	21.3%	13.2%	6.4%	11.3%	13.4%
Total	16.2%	11.4%	12.3%	14.0%	13.1%	34.7%	43.5%	22.9%	11.6%	14.8%	17.4%	18.3%

Source: Dataquest (October 1995 Estimates)

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Table 2-16
Italian Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	383	450	485	457	515	677	866	1,165	1,334	1,435	1,648	1,911	2,162	19.2%	13.2%	34.6%
Communications	178	209	274	266	278	295	402	552	648	728	795	875	929	15.1%	11.0%	37.4%
Industrial	168	154	188	172	186	174	157	170	180	193	190	202	213	-1.9%	4.6%	8.7%
Consumer	116	144	155	137	162	151	158	212	228	249	252	275	294	6.5%	6.7%	34.5%
Military & Civil Aerospace	58	51	52	49	42	41	35	39	34	34	25	26	28	-5.7%	-6.4%	10.5%
Transportation	80	44	58	54	97	119	152	182	203	225	245	259	270	25.7%	8.2%	19.8%
Total	$982	$1,052	$1,212	$1,136	$1,280	$1,456	$1,769	$2,321	$2,628	$2,864	$3,154	$3,548	$3,896	13.9%	10.9%	31.2%

Source: Dataquest (October 1995 Estimates)

Table 2-17
Italian Semiconductor Consumption by Application
As a Percentage of Total Italian Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	39.0%	42.8%	40.0%	40.2%	40.2%	46.5%	48.9%	50.2%	50.8%	50.1%	52.2%	53.9%	55.5%
Communications	18.1%	19.8%	22.6%	23.4%	21.7%	20.2%	22.7%	23.8%	24.7%	25.4%	25.2%	24.7%	23.8%
Industrial	17.1%	14.7%	15.5%	15.2%	14.5%	11.9%	8.9%	7.3%	6.9%	6.7%	6.0%	5.7%	5.5%
Consumer	11.8%	13.6%	12.8%	12.1%	12.7%	10.4%	8.9%	9.1%	8.7%	8.7%	8.0%	7.7%	7.5%
Military & Civil Aerospace	5.9%	4.9%	4.3%	4.4%	3.3%	2.8%	2.0%	1.7%	1.3%	1.2%	0.8%	0.7%	0.7%
Transportation	8.1%	4.2%	4.8%	4.8%	7.6%	8.2%	8.6%	7.8%	7.7%	7.9%	7.8%	7.3%	6.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-18
Italian Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	15.1%	15.2%	16.4%	14.6%	13.1%	11.4%	9.6%	8.7%	8.0%	7.9%	7.8%	7.6%	7.2%
Communications	10.2%	10.9%	11.6%	10.4%	9.7%	8.3%	8.0%	7.8%	7.2%	7.0%	6.8%	6.5%	6.1%
Industrial	10.3%	9.2%	9.8%	8.7%	8.8%	7.6%	6.7%	5.9%	5.5%	5.3%	4.9%	4.7%	4.4%
Consumer	7.6%	8.0%	8.2%	7.0%	9.4%	7.8%	6.9%	7.3%	6.7%	6.5%	6.0%	5.8%	5.4%
Military & Civil Aerospace	11.5%	10.3%	10.9%	10.1%	8.6%	8.1%	7.0%	7.9%	7.3%	7.1%	5.6%	5.5%	5.2%
Transportation	14.2%	6.8%	7.1%	6.1%	8.8%	9.5%	9.2%	8.0%	7.3%	7.2%	7.1%	6.8%	6.4%
Total	11.6%	11.1%	11.6%	10.3%	10.5%	9.4%	8.5%	8.0%	7.4%	7.2%	7.0%	6.8%	6.4%

Source: Dataquest (October 1995 Estimates)

Table 2-19
Italian Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	17.6%	7.7%	-5.8%	12.7%	31.4%	27.9%	34.6%	14.5%	7.5%	14.8%	16.0%	13.1%
Communications	17.4%	31.2%	-2.8%	4.5%	6.0%	36.3%	37.4%	17.4%	12.3%	9.2%	10.1%	6.1%
Industrial	-8.1%	21.7%	-8.2%	7.9%	-6.7%	-9.7%	8.7%	5.7%	7.0%	-1.6%	6.8%	5.3%
Consumer	23.9%	8.1%	-11.7%	18.3%	-6.7%	4.3%	34.5%	7.7%	9.1%	1.0%	9.1%	7.0%
Military & Civil Aerospace	-11.2%	1.7%	-5.5%	-15.1%	-2.6%	-13.8%	10.5%	-13.5%	0.5%	-25.6%	1.3%	9.8%
Transportation	-45.1%	32.6%	-6.2%	78.5%	22.4%	28.1%	19.8%	11.6%	10.9%	8.6%	5.7%	4.3%
Total	7.1%	15.2%	-6.3%	12.7%	13.8%	21.5%	31.2%	13.2%	9.0%	10.1%	12.5%	9.8%

Source: Dataquest (October 1995 Estimates)

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Table 2-20
Nordic Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	86	109	104	103	171	304	558	583	732	848	1,058	1,262	1,532	41.1%	21.3%	4.5%
Communications	243	267	313	320	325	456	757	1,297	1,670	2,021	2,270	2,570	2,926	32.9%	17.7%	71.3%
Industrial	166	153	166	160	141	144	177	334	387	446	488	536	606	15.0%	12.6%	88.9%
Consumer	66	78	75	70	75	88	123	122	145	170	190	213	245	10.2%	14.8%	-0.6%
Military & Civil Aerospace	55	48	43	43	55	61	73	72	68	74	61	64	75	10.7%	0.9%	-1.5%
Transportation	9	9	10	10	12	16	26	36	44	53	60	66	73	28.9%	15.1%	42.5%
Total	$625	$663	$712	$706	$779	$1,067	$1,714	$2,445	$3,045	$3,612	$4,127	$4,711	$5,457	28.0%	17.4%	42.6%

Source: Dataquest (October 1995 Estimates)

Table 2-21
Nordic Semiconductor Consumption by Application
As a Percentage of Total Nordic Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	13.7%	16.4%	14.7%	14.6%	22.0%	28.4%	32.6%	23.9%	24.0%	23.5%	25.6%	26.8%	28.1%
Communications	38.9%	40.3%	44.0%	45.3%	41.7%	42.7%	44.2%	53.1%	54.8%	55.9%	55.0%	54.6%	53.6%
Industrial	26.6%	23.0%	23.3%	22.7%	18.1%	13.5%	10.3%	13.7%	12.7%	12.3%	11.8%	11.4%	11.1%
Consumer	10.5%	11.8%	10.6%	9.9%	9.6%	8.2%	7.2%	5.0%	4.7%	4.7%	4.6%	4.5%	4.5%
Military & Civil Aerospace	8.9%	7.2%	6.1%	6.1%	7.1%	5.7%	4.3%	2.9%	2.2%	2.0%	1.5%	1.4%	1.4%
Transportation	1.4%	1.3%	1.4%	1.4%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.4%	1.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-22
Nordic Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	3.4%	3.7%	3.5%	3.3%	4.3%	5.1%	6.2%	4.4%	4.4%	4.6%	5.0%	5.0%	5.1%
Communications	14.0%	14.0%	13.2%	12.5%	11.4%	12.8%	15.1%	18.4%	18.6%	19.4%	19.3%	19.2%	19.3%
Industrial	10.2%	9.1%	8.6%	8.1%	6.7%	6.3%	7.5%	11.6%	11.8%	12.4%	12.5%	12.5%	12.5%
Consumer	4.3%	4.4%	4.0%	3.6%	4.4%	4.5%	5.4%	4.2%	4.2%	4.5%	4.5%	4.5%	4.5%
Military & Civil Aerospace	11.0%	9.6%	9.1%	8.8%	11.3%	12.1%	14.5%	14.6%	14.7%	15.5%	13.6%	13.6%	13.8%
Transportation	1.6%	1.3%	1.3%	1.1%	1.1%	1.2%	1.5%	1.6%	1.6%	1.7%	1.7%	1.7%	1.7%
Total	7.4%	7.0%	6.8%	6.4%	6.4%	6.9%	8.2%	8.4%	8.6%	9.1%	9.2%	9.1%	9.0%

Source: Dataquest (October 1995 Estimates)

Table 2-23
Nordic Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	26.7%	-3.9%	-1.0%	65.5%	77.5%	84.0%	4.5%	25.5%	15.9%	24.7%	19.3%	21.4%
Communications	9.8%	17.1%	2.1%	1.7%	40.2%	66.2%	71.3%	28.7%	21.0%	12.3%	13.3%	13.9%
Industrial	-8.3%	8.6%	-3.5%	-11.8%	2.1%	22.8%	88.9%	15.8%	15.4%	9.4%	9.8%	12.9%
Consumer	19.1%	-3.6%	-7.2%	7.1%	16.7%	40.7%	-0.6%	18.0%	17.6%	11.8%	12.2%	14.8%
Military & Civil Aerospace	-13.9%	-9.3%	-0.7%	28.0%	10.5%	20.0%	-1.5%	-5.2%	8.4%	-17.2%	4.2%	17.8%
Transportation	-1.4%	18.3%	-1.4%	19.1%	29.2%	64.6%	42.5%	22.3%	19.6%	13.4%	8.7%	12.0%
Total	6.0%	7.4%	-0.8%	10.3%	37.0%	60.6%	42.6%	24.5%	18.6%	14.3%	14.2%	15.8%

Source: Dataquest (October 1995 Estimates)

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Table 2-24
UK and Ireland Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	892	1,073	954	1,033	1,523	2,557	3,923	5,587	6,942	7,663	8,380	9,848	11,727	42.4%	16.0%	42.4%
Communications	430	425	460	515	472	530	693	903	1,151	1,326	1,674	1,868	2,086	14.4%	18.2%	30.3%
Industrial	455	431	433	458	512	509	522	733	841	924	1,059	1,146	1,269	11.1%	11.6%	40.4%
Consumer	288	399	356	361	298	302	357	486	567	635	744	822	926	6.4%	13.8%	36.2%
Military & Civil Aerospace	120	126	106	115	143	141	140	147	138	143	128	132	152	6.8%	0.6%	5.1%
Transportation	45	93	102	110	97	163	185	302	366	416	495	530	582	24.2%	14.0%	63.5%
Total	$2,230	$2,547	$2,411	$2,592	$3,045	$4,203	$5,820	$8,158	$10,005	$11,107	$12,480	$14,345	$16,743	27.6%	15.5%	40.2%

Source: Dataquest (October 1995 Estimates)

Table 2-25
UK and Ireland Semiconductor Consumption by Application
As a Percentage of Total UK and Ireland Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	40.0%	42.1%	39.6%	39.9%	50.0%	60.8%	67.4%	68.5%	69.4%	69.0%	67.1%	68.6%	70.0%
Communications	19.3%	16.7%	19.1%	19.9%	15.5%	12.6%	11.9%	11.1%	11.5%	11.9%	13.4%	13.0%	12.5%
Industrial	20.4%	16.9%	18.0%	17.7%	16.8%	12.1%	9.0%	9.0%	8.4%	8.3%	8.5%	8.0%	7.6%
Consumer	12.9%	15.6%	14.7%	13.9%	9.8%	7.2%	6.1%	6.0%	5.7%	5.7%	6.0%	5.7%	5.5%
Military & Civil Aerospace	5.4%	5.0%	4.4%	4.4%	4.7%	3.4%	2.4%	1.8%	1.4%	1.3%	1.0%	0.9%	0.9%
Transportation	2.0%	3.7%	4.2%	4.2%	3.2%	3.9%	3.2%	3.7%	3.7%	3.7%	4.0%	3.7%	3.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-26
UK and Ireland Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	35.1%	36.2%	32.2%	32.9%	38.6%	43.2%	43.5%	41.8%	41.9%	42.0%	39.7%	39.2%	38.8%
Communications	24.8%	22.2%	19.5%	20.0%	16.5%	14.9%	13.9%	12.8%	12.8%	12.8%	14.2%	14.0%	13.8%
Industrial	28.0%	25.6%	22.6%	23.1%	24.2%	22.3%	22.2%	25.5%	25.6%	25.6%	27.1%	26.6%	26.3%
Consumer	18.9%	22.2%	18.9%	18.5%	17.3%	15.6%	15.5%	16.7%	16.6%	16.7%	17.6%	17.3%	17.0%
Military & Civil Aerospace	23.8%	25.3%	22.2%	23.6%	29.3%	28.0%	27.8%	29.9%	29.9%	30.0%	28.6%	28.2%	27.9%
Transportation	8.0%	14.6%	12.6%	12.3%	8.8%	13.0%	11.2%	13.2%	13.2%	13.3%	14.3%	14.0%	13.8%
Total	26.3%	26.8%	23.1%	23.5%	24.9%	27.2%	28.0%	28.1%	28.2%	28.0%	27.8%	27.7%	27.7%

Source: Dataquest (October 1995 Estimates)

Table 2-27
UK and Ireland Semiconductor Consumption by Application
Annual Growth Rates

Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	20.3%	-11.1%	8.3%	47.4%	67.9%	53.4%	42.4%	24.3%	10.4%	9.4%	17.5%	19.1%
Communications	-1.3%	8.3%	11.8%	-8.3%	12.3%	30.8%	30.3%	27.4%	15.3%	26.3%	11.6%	11.7%
Industrial	-5.3%	0.5%	5.6%	11.9%	-0.6%	2.6%	40.4%	14.7%	9.9%	14.7%	8.2%	10.8%
Consumer	38.6%	-10.8%	1.6%	-17.5%	1.5%	17.9%	36.2%	16.9%	12.0%	17.1%	10.5%	12.7%
Military & Civil Aerospace	4.8%	-16.1%	8.7%	24.1%	-1.2%	-0.9%	5.1%	-6.1%	3.2%	-10.1%	2.6%	15.5%
Transportation	109.0%	9.4%	7.9%	-11.9%	68.4%	13.1%	63.5%	21.1%	13.8%	18.8%	7.1%	9.8%
Total	14.2%	-5.3%	7.5%	17.5%	38.0%	38.5%	40.2%	22.6%	11.0%	12.4%	14.9%	16.7%

Source: Dataquest (October 1995 Estimates)

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Table 2-28
Rest of Europe Semiconductor Consumption by Application
(Millions of US Dollars)

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Electronic Data Processing	122	154	190	239	277	479	769	1,508	1,938	2,152	2,619	3,164	3,847	51.3%	20.6%	96.1%
Communications	90	99	150	194	265	473	679	881	1,161	1,347	1,476	1,693	1,930	42.5%	17.0%	29.7%
Industrial	57	53	74	91	198	333	357	211	250	277	295	328	371	23.3%	12.0%	-40.9%
Consumer	305	365	453	534	397	594	728	946	1,143	1,288	1,420	1,613	1,855	15.9%	14.4%	29.8%
Military & Civil Aerospace	35	31	36	45	26	34	35	34	33	34	31	33	39	-1.1%	2.8%	-3.1%
Transportation	79	78	119	149	160	134	137	164	206	236	237	261	292	6.6%	12.2%	19.9%
Total	$690	$780	$1,022	$1,253	$1,323	$2,048	$2,705	$3,743	$4,731	$5,333	$6,079	$7,091	$8,335	29.6%	17.4%	38.4%

Source: Dataquest (October 1995 Estimates)

Table 2-29
Rest of Europe Semiconductor Consumption by Application
As a Percentage of Total Rest of Europe Region

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	17.7%	19.7%	18.6%	19.1%	20.9%	23.4%	28.4%	40.3%	41.0%	40.4%	43.1%	44.6%	46.2%
Communications	13.1%	12.7%	14.7%	15.5%	20.0%	23.1%	25.1%	23.5%	24.6%	25.3%	24.3%	23.9%	23.2%
Industrial	8.3%	6.8%	7.2%	7.2%	15.0%	16.3%	13.2%	5.6%	5.3%	5.2%	4.9%	4.6%	4.5%
Consumer	44.2%	46.8%	44.3%	42.6%	30.0%	29.0%	26.9%	25.3%	24.2%	24.1%	23.4%	22.7%	22.3%
Military & Civil Aerospace	5.1%	3.9%	3.5%	3.6%	2.0%	1.7%	1.3%	0.9%	0.7%	0.6%	0.5%	0.5%	0.5%
Transportation	11.5%	10.0%	11.6%	11.9%	12.1%	6.6%	5.1%	4.4%	4.3%	4.4%	3.9%	3.7%	3.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 2-30
Rest of Europe Semiconductor Consumption by Application
As a Percentage of Total European Market

Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	4.8%	5.2%	6.4%	7.6%	7.0%	8.1%	8.5%	11.3%	11.7%	11.8%	12.4%	12.6%	12.7%
Communications	5.2%	5.2%	6.3%	7.6%	9.3%	13.3%	13.6%	12.5%	12.9%	13.0%	12.5%	12.6%	12.7%
Industrial	3.5%	3.1%	3.9%	4.6%	9.4%	14.6%	15.2%	7.3%	7.6%	7.7%	7.6%	7.6%	7.7%
Consumer	20.0%	20.3%	24.1%	27.4%	23.1%	30.6%	31.7%	32.6%	33.5%	33.8%	33.7%	33.9%	34.1%
Military & Civil Aerospace	7.0%	6.2%	7.5%	9.3%	5.3%	6.8%	6.9%	6.9%	7.1%	7.2%	7.0%	7.1%	7.1%
Transportation	14.2%	12.2%	14.7%	16.7%	14.5%	10.7%	8.3%	7.2%	7.4%	7.5%	6.9%	6.9%	6.9%
Total	8.1%	8.2%	9.8%	11.4%	10.8%	13.3%	13.0%	12.9%	13.3%	13.4%	13.5%	13.7%	13.8%

Source: Dataquest (October 1995 Estimates)

Table 2-31
Rest of Europe Semiconductor Consumption by Application
Annual Growth Rates

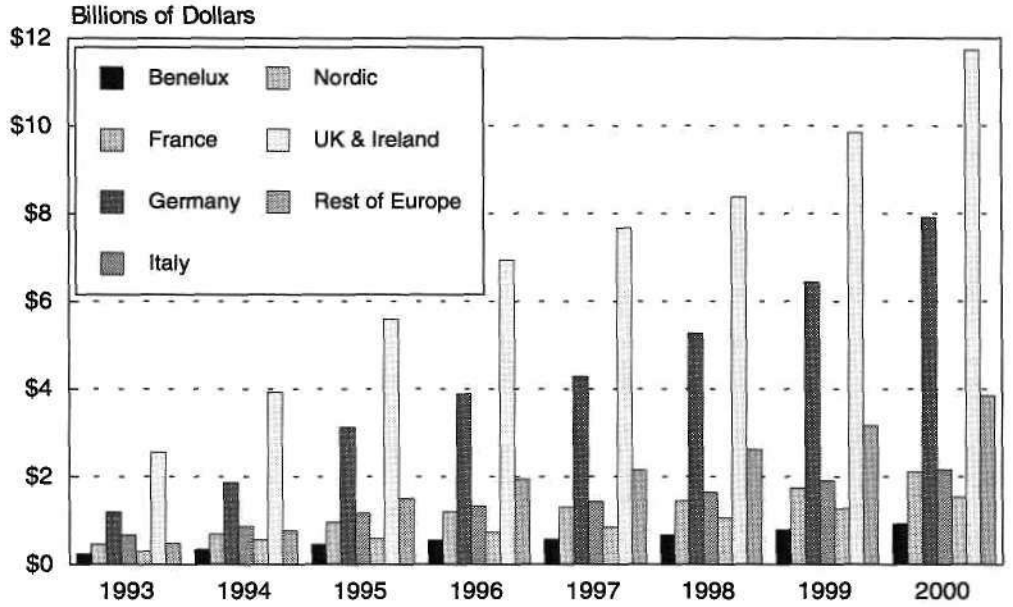
Segment	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electronic Data Processing	25.6%	23.7%	25.7%	15.8%	72.9%	60.5%	96.1%	28.5%	11.1%	21.7%	20.8%	21.6%
Communications	10.4%	50.7%	29.8%	36.3%	78.6%	43.5%	29.7%	31.8%	16.0%	9.6%	14.7%	14.0%
Industrial	-7.8%	39.8%	22.6%	118.2%	68.3%	7.1%	-40.9%	18.6%	10.6%	6.8%	11.2%	13.1%
Consumer	19.6%	24.1%	17.9%	-25.7%	49.6%	22.6%	29.8%	20.9%	12.7%	10.3%	13.6%	15.0%
Military & Civil Aerospace	-13.3%	16.8%	26.2%	-42.7%	31.8%	2.2%	-3.1%	-2.9%	3.8%	-8.7%	5.5%	18.0%
Transportation	-1.4%	52.3%	25.3%	7.3%	-16.1%	2.0%	19.9%	25.3%	14.6%	0.5%	10.1%	12.1%
Total	13.1%	31.0%	22.6%	5.6%	54.8%	32.1%	38.4%	26.4%	12.7%	14.0%	16.6%	17.5%

Source: Dataquest (October 1995 Estimates)

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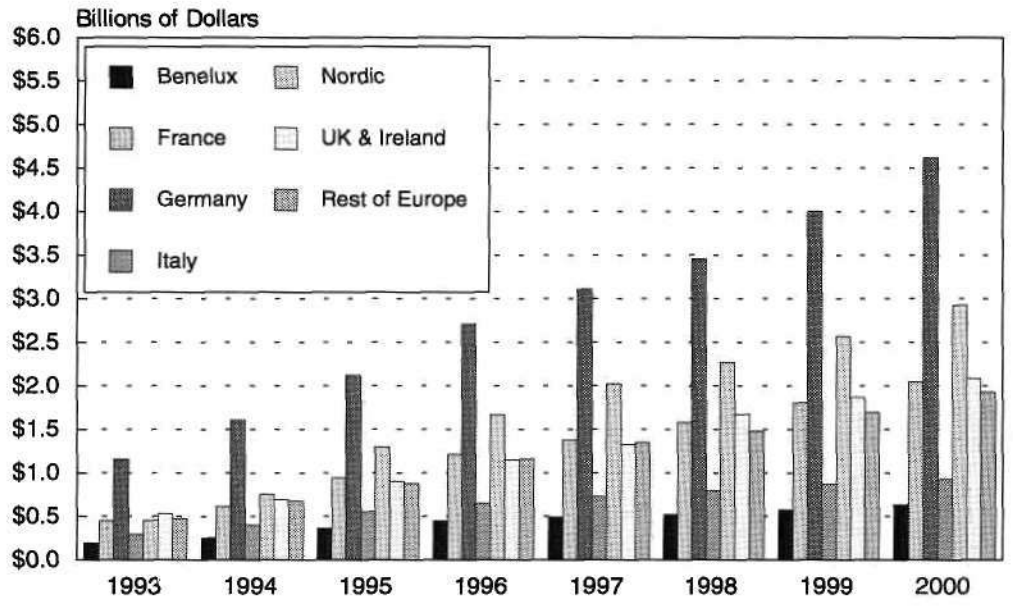
Chapter 3
Consumption by Application Segment

Figure 3-1
European Semiconductor Consumption by Country, Electronic Data Processing
Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

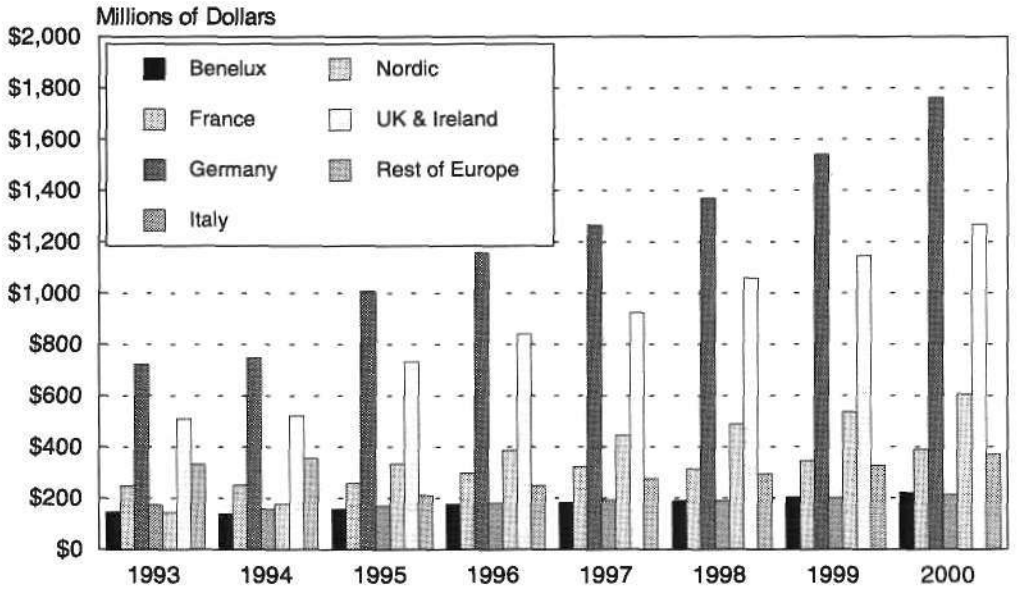
Figure 3-2
European Semiconductor Consumption by Country, Communications
Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

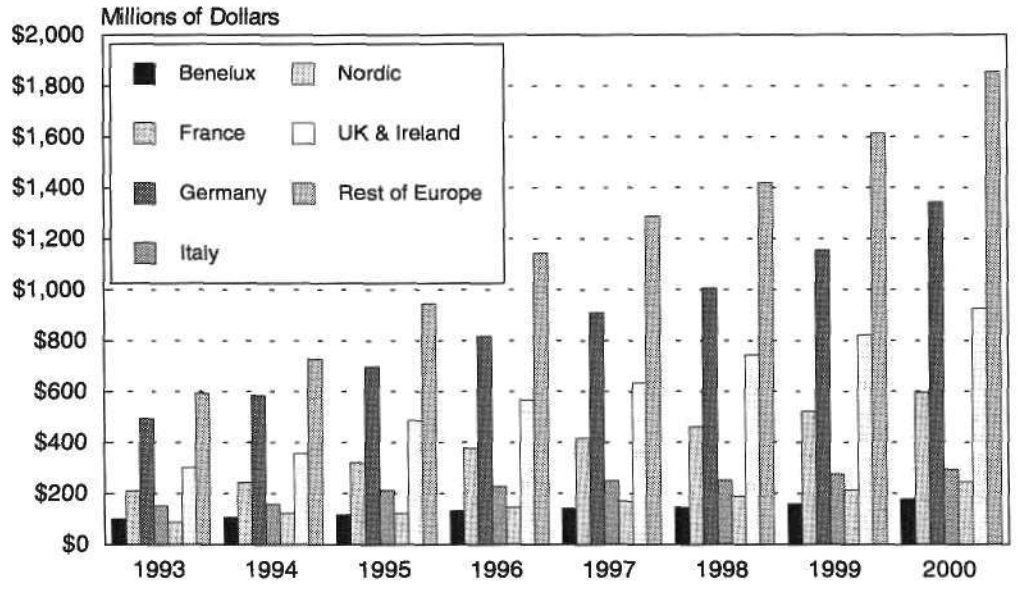
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Figure 3-3
European Semiconductor Consumption by Country, Industrial Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

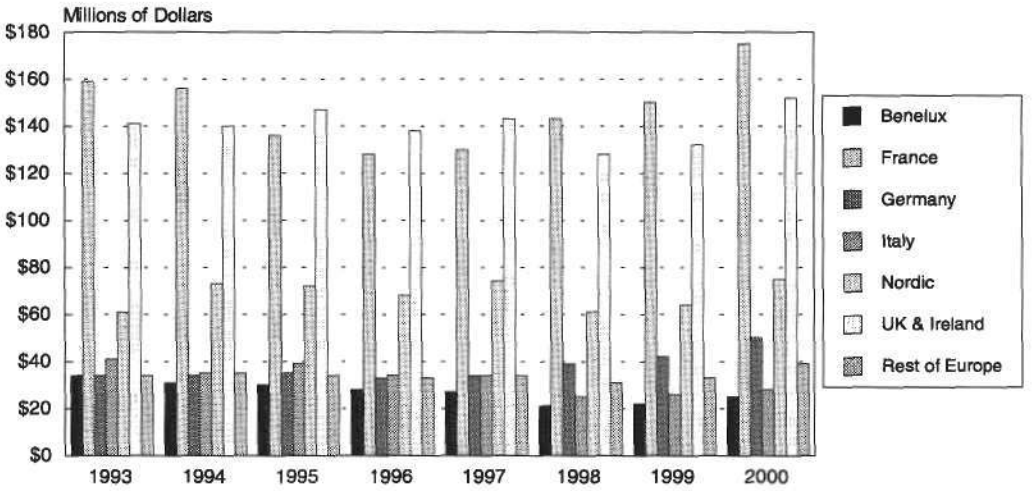
Figure 3-4
European Semiconductor Consumption by Country, Consumer Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

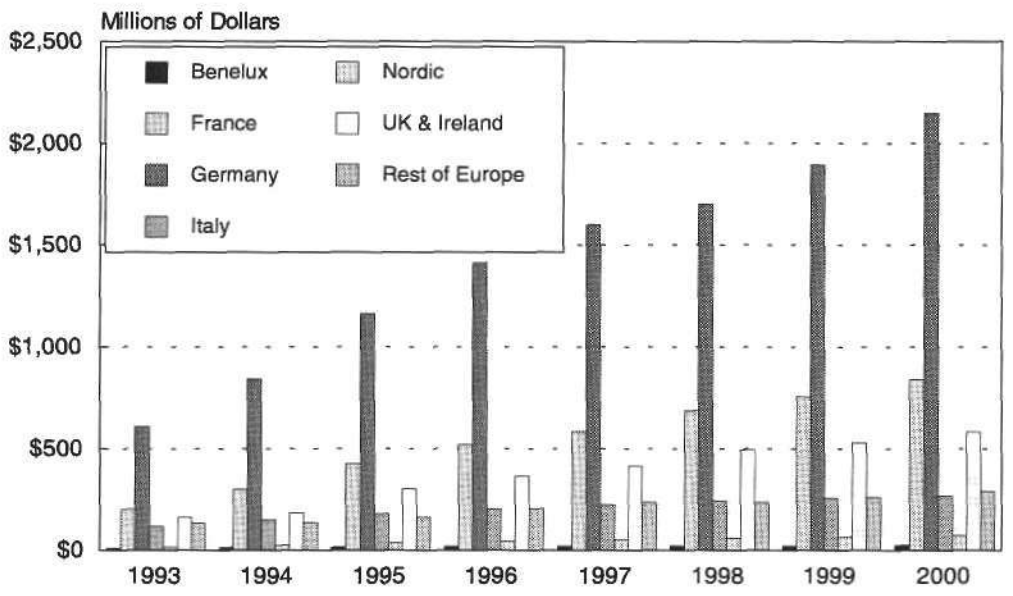
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Figure 3-5
European Semiconductor Consumption by Country, Military and Civil Aerospace
Market Forecast, 1993-2000



Source: Dataquest (October 1995 Estimates)

Figure 3-6
European Semiconductor Consumption by Country, Transportation
Market Forecast



Source: Dataquest (October 1995 Estimates)

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Table 3-1
European Semiconductor Consumption by Country, All Segments
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	504	493	651	661	610	730	880	1,130	1,351	1,431	1,575	1,771	2,008	11.7%	12.2%	28.4%
France	1,210	1,349	1,494	1,395	1,453	1,730	2,250	3,045	3,736	4,140	4,639	5,318	6,147	15.3%	15.1%	35.3%
Germany	2,250	2,614	2,913	3,271	3,728	4,216	5,681	8,153	10,021	11,187	12,841	15,075	17,836	22.9%	16.9%	43.5%
Italy	982	1,052	1,212	1,136	1,280	1,456	1,769	2,321	2,628	2,864	3,154	3,548	3,896	13.9%	10.9%	31.2%
Nordic	625	663	712	706	779	1,067	1,714	2,445	3,045	3,612	4,127	4,711	5,457	28.0%	17.4%	42.6%
UK & Ireland	2,230	2,547	2,411	2,592	3,045	4,203	5,820	8,158	10,005	11,107	12,480	14,345	16,743	27.6%	15.5%	40.2%
Rest of Europe	690	780	1,022	1,253	1,323	2,048	2,705	3,743	4,731	5,333	6,079	7,091	8,335	29.6%	17.4%	38.4%
Total	$8,491	$9,498	$10,415	$11,014	$12,218	$15,450	$20,819	$28,995	$35,517	$39,674	$44,895	$51,859	$60,422	22.7%	15.8%	39.3%

Source: Dataquest (October 1995 Estimates)

Table 3-2
European Semiconductor Consumption by Country, All Segments
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	5.9%	5.2%	6.3%	6.0%	5.0%	4.7%	4.2%	3.9%	3.8%	3.6%	3.5%	3.4%	3.3%
France	14.3%	14.2%	14.3%	12.7%	11.9%	11.2%	10.8%	10.5%	10.5%	10.4%	10.3%	10.3%	10.2%
Germany	26.5%	27.5%	28.0%	29.7%	30.5%	27.3%	27.3%	28.1%	28.2%	28.2%	28.6%	29.1%	29.5%
Italy	11.6%	11.1%	11.6%	10.3%	10.5%	9.4%	8.5%	8.0%	7.4%	7.2%	7.0%	6.8%	6.4%
Nordic	7.4%	7.0%	6.8%	6.4%	6.4%	6.9%	8.2%	8.4%	8.6%	9.1%	9.2%	9.1%	9.0%
UK & Ireland	26.3%	26.8%	23.1%	23.5%	24.9%	27.2%	28.0%	28.1%	28.2%	28.0%	27.8%	27.7%	27.7%
Rest of Europe	8.1%	8.2%	9.8%	11.4%	10.8%	13.3%	13.0%	12.9%	13.3%	13.4%	13.5%	13.7%	13.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Table 3-3
European Semiconductor Consumption by Country, All Segments
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	-2.2%	32.0%	1.5%	-7.7%	19.7%	20.5%	28.4%	19.6%	5.9%	10.1%	12.4%	13.4%
France	11.5%	10.7%	-6.6%	4.2%	19.1%	30.1%	35.3%	22.7%	10.8%	12.1%	14.6%	15.6%
Germany	16.2%	11.4%	12.3%	14.0%	13.1%	34.7%	43.5%	22.9%	11.6%	14.8%	17.4%	18.3%
Italy	7.1%	15.2%	-6.3%	12.7%	13.8%	21.5%	31.2%	13.2%	9.0%	10.1%	12.5%	9.8%
Nordic	6.0%	7.4%	-0.8%	10.3%	37.0%	60.6%	42.6%	24.5%	18.6%	14.3%	14.2%	15.8%
UK & Ireland	14.2%	-5.3%	7.5%	17.5%	38.0%	38.5%	40.2%	22.6%	11.0%	12.4%	14.9%	16.7%
Rest of Europe	13.1%	31.0%	22.6%	5.6%	54.8%	32.1%	38.4%	26.4%	12.7%	14.0%	16.6%	17.5%
Total	11.9%	9.7%	5.8%	10.9%	26.5%	34.8%	39.3%	22.5%	11.7%	13.2%	15.5%	16.5%

Source: Dataquest (October 1995 Estimates)

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Table 3-4
European Semiconductor Consumption by Country, Electronic Data Processing
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	120	136	166	170	159	240	339	451	548	572	676	787	924	22.1%	15.4%	33.2%
France	327	360	371	348	350	458	690	960	1,201	1,308	1,450	1,741	2,103	21.0%	17.0%	39.3%
Germany	610	683	692	785	951	1,201	1,866	3,125	3,891	4,272	5,271	6,439	7,915	35.2%	20.4%	67.5%
Italy	383	450	485	457	515	677	866	1,165	1,334	1,435	1,648	1,911	2,162	19.2%	13.2%	34.6%
Nordic	86	109	104	103	171	304	558	583	732	848	1,058	1,262	1,532	41.1%	21.3%	4.5%
UK & Ireland	892	1,073	954	1,033	1,523	2,557	3,923	5,587	6,942	7,663	8,380	9,848	11,727	42.4%	16.0%	42.4%
Rest of Europe	122	154	190	239	277	479	769	1,508	1,938	2,152	2,619	3,164	3,847	51.3%	20.6%	96.1%
Total	$2,540	$2,965	$2,963	$3,136	$3,946	$5,915	$9,010	$13,380	$16,586	$18,250	$21,101	$25,152	$30,210	35.2%	17.7%	48.5%

Source: Dataquest (October 1995 Estimates)

Table 3-5
European Semiconductor Consumption by Country, Electronic Data Processing
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	1.4%	1.4%	1.6%	1.5%	1.3%	1.6%	1.6%	1.6%	1.5%	1.4%	1.5%	1.5%	1.5%
France	3.8%	3.8%	3.6%	3.2%	2.9%	3.0%	3.3%	3.3%	3.4%	3.3%	3.2%	3.4%	3.5%
Germany	7.2%	7.2%	6.6%	7.1%	7.8%	7.8%	9.0%	10.8%	11.0%	10.8%	11.7%	12.4%	13.1%
Italy	4.5%	4.7%	4.7%	4.1%	4.2%	4.4%	4.2%	4.0%	3.8%	3.6%	3.7%	3.7%	3.6%
Nordic	1.0%	1.1%	1.0%	0.9%	1.4%	2.0%	2.7%	2.0%	2.1%	2.1%	2.4%	2.4%	2.5%
UK & Ireland	10.5%	11.3%	9.2%	9.4%	12.5%	16.5%	18.8%	19.3%	19.5%	19.3%	18.7%	19.0%	19.4%
Rest of Europe	1.4%	1.6%	1.8%	2.2%	2.3%	3.1%	3.7%	5.2%	5.5%	5.4%	5.8%	6.1%	6.4%
Total	29.9%	31.2%	28.4%	28.5%	32.3%	38.3%	43.3%	46.1%	46.7%	46.0%	47.0%	48.5%	50.0%

Source: Dataquest (October 1995 Estimates)

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Table 3-6
European Semiconductor Consumption by Country, Electronic Data Processing
As a Percentage of Total European EDP Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	4.7%	4.6%	5.6%	5.4%	4.0%	4.1%	3.8%	3.4%	3.3%	3.1%	3.2%	3.1%	3.1%
France	12.9%	12.2%	12.5%	11.1%	8.9%	7.7%	7.7%	7.2%	7.2%	7.2%	6.9%	6.9%	7.0%
Germany	24.0%	23.0%	23.4%	25.0%	24.1%	20.3%	20.7%	23.4%	23.5%	23.4%	25.0%	25.6%	26.2%
Italy	15.1%	15.2%	16.4%	14.6%	13.1%	11.4%	9.6%	8.7%	8.0%	7.9%	7.8%	7.6%	7.2%
Nordic	3.4%	3.7%	3.5%	3.3%	4.3%	5.1%	6.2%	4.4%	4.4%	4.6%	5.0%	5.0%	5.1%
UK & Ireland	35.1%	36.2%	32.2%	32.9%	38.6%	43.2%	43.5%	41.8%	41.9%	42.0%	39.7%	39.2%	38.8%
Rest of Europe	4.8%	5.2%	6.4%	7.6%	7.0%	8.1%	8.5%	11.3%	11.7%	11.8%	12.4%	12.6%	12.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-7
European Semiconductor Consumption by Country, Electronic Data Processing
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	13.1%	21.9%	2.2%	-6.3%	50.9%	41.2%	33.2%	21.4%	4.4%	18.2%	16.5%	17.4%
France	10.2%	2.9%	-6.1%	0.5%	30.8%	50.7%	39.3%	25.1%	8.9%	10.8%	20.1%	20.7%
Germany	12.0%	1.4%	13.4%	21.1%	26.3%	55.3%	67.5%	24.5%	9.8%	23.4%	22.2%	22.9%
Italy	17.6%	7.7%	-5.8%	12.7%	31.4%	27.9%	34.6%	14.5%	7.5%	14.8%	16.0%	13.1%
Nordic	26.7%	-3.9%	-1.0%	65.5%	77.5%	84.0%	4.5%	25.5%	15.9%	24.7%	19.3%	21.4%
UK & Ireland	20.3%	-11.1%	8.3%	47.4%	67.9%	53.4%	42.4%	24.3%	10.4%	9.4%	17.5%	19.1%
Rest of Europe	25.6%	23.7%	25.7%	15.8%	72.9%	60.5%	96.1%	28.5%	11.1%	21.7%	20.8%	21.6%
Total	16.7%	-0.1%	5.8%	25.8%	49.9%	52.3%	48.5%	24.0%	10.0%	15.6%	19.2%	20.1%

Source: Dataquest (October 1995 Estimates)

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Table 3-8
European Semiconductor Consumption by Country, Communications
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	121	120	178	188	169	197	250	360	448	489	520	575	634	15.1%	12.0%	44.2%
France	271	283	354	343	372	450	613	944	1,211	1,377	1,582	1,804	2,043	21.6%	16.7%	54.0%
Germany	403	512	633	741	973	1,158	1,606	2,123	2,711	3,108	3,453	4,004	4,617	27.4%	16.8%	32.2%
Italy	178	209	274	266	278	295	402	552	648	728	795	875	929	15.1%	11.0%	37.4%
Nordic	243	267	313	320	325	456	757	1,297	1,670	2,021	2,270	2,570	2,926	32.9%	17.7%	71.3%
UK & Ireland	430	425	460	515	472	530	693	903	1,151	1,326	1,674	1,868	2,086	14.4%	18.2%	30.3%
Rest of Europe	90	99	150	194	265	473	679	881	1,161	1,347	1,476	1,693	1,930	42.5%	17.0%	29.7%
Total	$1,736	$1,915	$2,362	$2,567	$2,854	$3,559	$5,000	$7,060	$9,000	$10,395	$11,771	$13,390	$15,166	24.5%	16.5%	41.2%

Source: Dataquest (October 1995 Estimates)

Table 3-9
European Semiconductor Consumption by Country, Communications
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	1.4%	1.3%	1.7%	1.7%	1.4%	1.3%	1.2%	1.2%	1.3%	1.2%	1.2%	1.1%	1.0%
France	3.2%	3.0%	3.4%	3.1%	3.0%	2.9%	2.9%	3.3%	3.4%	3.5%	3.5%	3.5%	3.4%
Germany	4.7%	5.4%	6.1%	6.7%	8.0%	7.5%	7.7%	7.3%	7.6%	7.8%	7.7%	7.7%	7.6%
Italy	2.1%	2.2%	2.6%	2.4%	2.3%	1.9%	1.9%	1.9%	1.8%	1.8%	1.8%	1.7%	1.5%
Nordic	2.9%	2.8%	3.0%	2.9%	2.7%	2.9%	3.6%	4.5%	4.7%	5.1%	5.1%	5.0%	4.8%
UK & Ireland	5.1%	4.5%	4.4%	4.7%	3.9%	3.4%	3.3%	3.1%	3.2%	3.3%	3.7%	3.6%	3.5%
Rest of Europe	1.1%	1.0%	1.4%	1.8%	2.2%	3.1%	3.3%	3.0%	3.3%	3.4%	3.3%	3.3%	3.2%
Total	20.4%	20.2%	22.7%	23.3%	23.4%	23.0%	24.0%	24.3%	25.3%	26.2%	26.2%	25.8%	25.1%

Source: Dataquest (October 1995 Estimates)

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Table 3-10
European Semiconductor Consumption by Country, Communications
As a Percentage of Total European Communications Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	7.0%	6.3%	7.5%	7.3%	5.9%	5.5%	5.0%	5.1%	5.0%	4.7%	4.4%	4.3%	4.2%
France	15.6%	14.8%	15.0%	13.4%	13.0%	12.6%	12.3%	13.4%	13.5%	13.2%	13.4%	13.5%	13.5%
Germany	23.2%	26.7%	26.8%	28.9%	34.1%	32.5%	32.1%	30.1%	30.1%	29.9%	29.3%	29.9%	30.4%
Italy	10.2%	10.9%	11.6%	10.4%	9.7%	8.3%	8.0%	7.8%	7.2%	7.0%	6.8%	6.5%	6.1%
Nordic	14.0%	14.0%	13.2%	12.5%	11.4%	12.8%	15.1%	18.4%	18.6%	19.4%	19.3%	19.2%	19.3%
UK & Ireland	24.8%	22.2%	19.5%	20.0%	16.5%	14.9%	13.9%	12.8%	12.8%	12.8%	14.2%	14.0%	13.8%
Rest of Europe	5.2%	5.2%	6.3%	7.6%	9.3%	13.3%	13.6%	12.5%	12.9%	13.0%	12.5%	12.6%	12.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-11
European Semiconductor Consumption by Country, Communications
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	-0.8%	48.4%	5.5%	-10.1%	16.6%	26.8%	44.2%	24.6%	9.0%	6.4%	10.6%	10.1%
France	4.2%	25.4%	-3.1%	8.3%	21.0%	36.2%	54.0%	28.3%	13.7%	14.9%	14.0%	13.3%
Germany	27.2%	23.6%	17.1%	31.4%	19.0%	38.7%	32.2%	27.7%	14.6%	11.1%	16.0%	15.3%
Italy	17.4%	31.2%	-2.8%	4.5%	6.0%	36.3%	37.4%	17.4%	12.3%	9.2%	10.1%	6.1%
Nordic	9.8%	17.1%	2.1%	1.7%	40.2%	66.2%	71.3%	28.7%	21.0%	12.3%	13.3%	13.9%
UK & Ireland	-1.3%	8.3%	11.8%	-8.3%	12.3%	30.8%	30.3%	27.4%	15.3%	26.3%	11.6%	11.7%
Rest of Europe	10.4%	50.7%	29.8%	36.3%	78.6%	43.5%	29.7%	31.8%	16.0%	9.6%	14.7%	14.0%
Total	10.3%	23.3%	8.7%	11.2%	24.7%	40.5%	41.2%	27.5%	15.5%	13.2%	13.8%	13.3%

Source: Dataquest (October 1995 Estimates)

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Table 3-12
European Semiconductor Consumption by Country, Industrial
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	140	116	160	160	143	147	140	157	176	183	190	204	222	-0.4%	7.2%	12.6%
France	225	237	276	253	243	249	251	258	298	323	314	347	390	-1.3%	8.6%	2.8%
Germany	414	541	620	686	689	722	747	1,008	1,158	1,265	1,370	1,541	1,762	10.2%	11.8%	34.9%
Italy	168	154	188	172	186	174	157	170	180	193	190	202	213	-1.9%	4.6%	8.7%
Nordic	166	153	166	160	141	144	177	334	387	446	488	536	606	15.0%	12.6%	88.9%
UK & Ireland	455	431	433	458	512	509	522	733	841	924	1,059	1,146	1,269	11.1%	11.6%	40.4%
Rest of Europe	57	53	74	91	198	333	357	211	250	277	295	328	371	23.3%	12.0%	-40.9%
Total	$1,625	$1,685	$1,917	$1,979	$2,112	$2,278	$2,350	$2,871	$3,289	$3,610	$3,906	$4,304	$4,834	8.4%	11.0%	22.2%

Source: Dataquest (October 1995 Estimates)

Table 3-13
European Semiconductor Consumption by Country, Industrial
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	1.6%	1.2%	1.5%	1.5%	1.2%	1.0%	0.7%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%
France	2.7%	2.5%	2.6%	2.3%	2.0%	1.6%	1.2%	0.9%	0.8%	0.8%	0.7%	0.7%	0.6%
Germany	4.9%	5.7%	6.0%	6.2%	5.6%	4.7%	3.6%	3.5%	3.3%	3.2%	3.1%	3.0%	2.9%
Italy	2.0%	1.6%	1.8%	1.6%	1.5%	1.1%	0.8%	0.6%	0.5%	0.5%	0.4%	0.4%	0.4%
Nordic	2.0%	1.6%	1.6%	1.5%	1.2%	0.9%	0.8%	1.2%	1.1%	1.1%	1.1%	1.0%	1.0%
UK & Ireland	5.4%	4.5%	4.2%	4.2%	4.2%	3.3%	2.5%	2.5%	2.4%	2.3%	2.4%	2.2%	2.1%
Rest of Europe	0.7%	0.6%	0.7%	0.8%	1.6%	2.2%	1.7%	0.7%	0.7%	0.7%	0.7%	0.6%	0.6%
Total	19.1%	17.7%	18.4%	18.0%	17.3%	14.7%	11.3%	9.9%	9.3%	9.1%	8.7%	8.3%	8.0%

Source: Dataquest (October 1995 Estimates)

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Table 3-14
European Semiconductor Consumption by Country, Industrial
As a Percentage of Total European Industrial Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	8.6%	6.9%	8.4%	8.1%	6.8%	6.5%	5.9%	5.5%	5.4%	5.1%	4.9%	4.7%	4.6%
France	13.9%	14.1%	14.4%	12.8%	11.5%	10.9%	10.7%	9.0%	9.0%	8.9%	8.0%	8.1%	8.1%
Germany	25.5%	32.1%	32.3%	34.7%	32.6%	31.7%	31.8%	35.1%	35.2%	35.1%	35.1%	35.8%	36.5%
Italy	10.3%	9.2%	9.8%	8.7%	8.8%	7.6%	6.7%	5.9%	5.5%	5.3%	4.9%	4.7%	4.4%
Nordic	10.2%	9.1%	8.6%	8.1%	6.7%	6.3%	7.5%	11.6%	11.8%	12.4%	12.5%	12.5%	12.5%
UK & Ireland	28.0%	25.6%	22.6%	23.1%	24.2%	22.3%	22.2%	25.5%	25.6%	25.6%	27.1%	26.6%	26.3%
Rest of Europe	3.5%	3.1%	3.9%	4.6%	9.4%	14.6%	15.2%	7.3%	7.6%	7.7%	7.6%	7.6%	7.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-15
European Semiconductor Consumption by Country, Industrial
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	-16.6%	37.8%	-0.3%	-10.6%	3.1%	-5.3%	12.6%	12.1%	3.9%	3.7%	7.2%	9.3%
France	5.3%	16.4%	-8.4%	-3.8%	2.6%	0.6%	2.8%	15.5%	8.4%	-2.8%	10.6%	12.3%
Germany	30.7%	14.6%	10.6%	0.4%	4.7%	3.6%	34.9%	14.9%	9.3%	8.3%	12.4%	14.4%
Italy	-8.1%	21.7%	-8.2%	7.9%	-6.7%	-9.7%	8.7%	5.7%	7.0%	-1.6%	6.8%	5.3%
Nordic	-8.3%	8.6%	-3.5%	-11.8%	2.1%	22.8%	88.9%	15.8%	15.4%	9.4%	9.8%	12.9%
UK & Ireland	-5.3%	0.5%	5.6%	11.9%	-0.6%	2.6%	40.4%	14.7%	9.9%	14.7%	8.2%	10.8%
Rest of Europe	-7.8%	39.8%	22.6%	118.2%	68.3%	7.1%	-40.9%	18.6%	10.6%	6.8%	11.2%	13.1%
Total	3.7%	13.8%	3.2%	6.7%	7.9%	3.2%	22.2%	14.6%	9.8%	8.2%	10.2%	12.3%

Source: Dataquest (October 1995 Estimates)

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Table 3-16
European Semiconductor Consumption by Country, Consumer
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	76	82	100	96	96	100	107	116	132	140	146	160	178	3.0%	9.0%	8.3%
France	177	205	212	186	205	210	242	321	378	417	462	522	596	8.7%	13.2%	32.7%
Germany	499	523	532	566	485	493	585	697	817	909	1,006	1,155	1,344	5.6%	14.0%	19.2%
Italy	116	144	155	137	162	151	158	212	228	249	252	275	294	6.5%	6.7%	34.5%
Nordic	66	78	75	70	75	88	123	122	145	170	190	213	245	10.2%	14.8%	-0.6%
UK & Ireland	288	399	356	361	298	302	357	486	567	635	744	822	926	6.4%	13.8%	36.2%
Rest of Europe	305	365	453	534	397	594	728	946	1,143	1,288	1,420	1,613	1,855	15.9%	14.4%	29.8%
Total	$1,526	$1,795	$1,883	$1,951	$1,718	$1,938	$2,300	$2,900	$3,410	$3,809	$4,220	$4,760	$5,438	9.0%	13.4%	26.1%

Source: Dataquest (October 1995 Estimates)

Table 3-17
European Semiconductor Consumption by Country, Consumer
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	0.9%	0.9%	1.0%	0.9%	0.8%	0.6%	0.5%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%
France	2.1%	2.2%	2.0%	1.7%	1.7%	1.4%	1.2%	1.1%	1.1%	1.1%	1.0%	1.0%	1.0%
Germany	5.9%	5.5%	5.1%	5.1%	4.0%	3.2%	2.8%	2.4%	2.3%	2.3%	2.2%	2.2%	2.2%
Italy	1.4%	1.5%	1.5%	1.2%	1.3%	1.0%	0.8%	0.7%	0.6%	0.6%	0.6%	0.5%	0.5%
Nordic	0.8%	0.8%	0.7%	0.6%	0.6%	0.6%	0.6%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
UK & Ireland	3.4%	4.2%	3.4%	3.3%	2.4%	2.0%	1.7%	1.7%	1.6%	1.6%	1.7%	1.6%	1.5%
Rest of Europe	3.6%	3.8%	4.3%	4.9%	3.2%	3.8%	3.5%	3.3%	3.2%	3.2%	3.2%	3.1%	3.1%
Total	18.0%	18.9%	18.1%	17.7%	14.1%	12.5%	11.0%	10.0%	9.6%	9.6%	9.4%	9.2%	9.0%

Source: Dataquest (October 1995 Estimates)

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Table 3-18
European Semiconductor Consumption by Country, Consumer
As a Percentage of Total European Consumer Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	5.0%	4.6%	5.3%	4.9%	5.6%	5.2%	4.7%	4.0%	3.9%	3.7%	3.5%	3.4%	3.3%
France	11.6%	11.4%	11.2%	9.6%	11.9%	10.8%	10.5%	11.1%	11.1%	11.0%	10.9%	11.0%	11.0%
Germany	32.7%	29.1%	28.3%	29.0%	28.2%	25.4%	25.4%	24.0%	23.9%	23.9%	23.8%	24.3%	24.7%
Italy	7.6%	8.0%	8.2%	7.0%	9.4%	7.8%	6.9%	7.3%	6.7%	6.5%	6.0%	5.8%	5.4%
Nordic	4.3%	4.4%	4.0%	3.6%	4.4%	4.5%	5.4%	4.2%	4.2%	4.5%	4.5%	4.5%	4.5%
UK & Ireland	18.9%	22.2%	18.9%	18.5%	17.3%	15.6%	15.5%	16.7%	16.6%	16.7%	17.6%	17.3%	17.0%
Rest of Europe	20.0%	20.3%	24.1%	27.4%	23.1%	30.6%	31.7%	32.6%	33.5%	33.8%	33.7%	33.9%	34.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-19
European Semiconductor Consumption by Country, Consumer
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	8.1%	22.3%	-4.1%	0.2%	4.4%	6.7%	8.3%	14.2%	5.9%	4.5%	9.5%	11.1%
France	16.0%	3.3%	-11.9%	10.0%	2.4%	15.2%	32.7%	17.7%	10.5%	10.7%	12.9%	14.2%
Germany	4.8%	1.8%	6.4%	-14.4%	1.6%	18.8%	19.2%	17.1%	11.4%	10.6%	14.9%	16.3%
Italy	23.9%	8.1%	-11.7%	18.3%	-6.7%	4.3%	34.5%	7.7%	9.1%	1.0%	9.1%	7.0%
Nordic	19.1%	-3.6%	-7.2%	7.1%	16.7%	40.7%	-0.6%	18.0%	17.6%	11.8%	12.2%	14.8%
UK & Ireland	38.6%	-10.8%	1.6%	-17.5%	1.5%	17.9%	36.2%	16.9%	12.0%	17.1%	10.5%	12.7%
Rest of Europe	19.6%	24.1%	17.9%	-25.7%	49.6%	22.6%	29.8%	20.9%	12.7%	10.3%	13.6%	15.0%
Total	17.6%	4.9%	3.6%	-11.9%	12.8%	18.7%	26.1%	17.6%	11.7%	10.8%	12.8%	14.2%

Source: Dataquest (October 1995 Estimates)

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Table 3-20
European Semiconductor Consumption by Country, Military and Civil Aerospace
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	41	33	37	38	33	34	31	30	28	27	21	22	25	-4.2%	-4.0%	-2.1%
France	150	182	177	166	155	159	156	136	128	130	143	150	175	-5.1%	5.3%	-13.2%
Germany	45	28	27	30	34	34	34	35	33	34	39	42	50	5.9%	7.3%	4.8%
Italy	58	51	52	49	42	41	35	39	34	34	25	26	28	-5.7%	-6.4%	10.5%
Nordic	55	48	43	43	55	61	73	72	68	74	61	64	75	10.7%	0.9%	-1.5%
UK & Ireland	120	126	106	115	143	141	140	147	138	143	128	132	152	6.8%	0.6%	5.1%
Rest of Europe	35	31	36	45	26	34	35	34	33	34	31	33	39	-1.1%	2.8%	-3.1%
Total	$505	$498	$478	$488	$488	$504	$504	$493	$462	$476	$449	$467	$544	0.6%	2.0%	-2.2%

Source: Dataquest (October 1995 Estimates)

Table 3-21
European Semiconductor Consumption by Country, Military and Civil Aerospace
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	0.5%	0.3%	0.4%	0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
France	1.8%	1.9%	1.7%	1.5%	1.3%	1.0%	0.8%	0.5%	0.4%	0.3%	0.3%	0.3%	0.3%
Germany	0.5%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Italy	0.7%	0.5%	0.5%	0.4%	0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Nordic	0.7%	0.5%	0.4%	0.4%	0.5%	0.4%	0.4%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%
UK & Ireland	1.4%	1.3%	1.0%	1.0%	1.2%	0.9%	0.7%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%
Rest of Europe	0.4%	0.3%	0.3%	0.4%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Total	5.9%	5.2%	4.6%	4.4%	4.0%	3.3%	2.4%	1.7%	1.3%	1.2%	1.0%	0.9%	0.9%

Source: Dataquest (October 1995 Estimates)

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Table 3-22
European Semiconductor Consumption by Country, Military and Civil Aerospace
As a Percentage of Total European Military/Aerospace Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	8.1%	6.5%	7.8%	7.9%	6.8%	6.7%	6.1%	6.1%	6.0%	5.7%	4.7%	4.6%	4.5%
France	29.7%	36.5%	36.9%	34.1%	31.8%	31.5%	31.0%	27.5%	27.7%	27.4%	31.8%	32.0%	32.2%
Germany	8.9%	5.6%	5.6%	6.2%	7.0%	6.8%	6.7%	7.2%	7.2%	7.2%	8.8%	9.0%	9.2%
Italy	11.5%	10.3%	10.9%	10.1%	8.6%	8.1%	7.0%	7.9%	7.3%	7.1%	5.6%	5.5%	5.2%
Nordic	11.0%	9.6%	9.1%	8.8%	11.3%	12.1%	14.5%	14.6%	14.7%	15.5%	13.6%	13.6%	13.8%
UK & Ireland	23.8%	25.3%	22.2%	23.6%	29.3%	28.0%	27.8%	29.9%	29.9%	30.0%	28.6%	28.2%	27.9%
Rest of Europe	7.0%	6.2%	7.5%	9.3%	5.3%	6.8%	6.9%	6.9%	7.1%	7.2%	7.0%	7.1%	7.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-23
European Semiconductor Consumption by Country, Military and Civil Aerospace
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	-20.4%	15.1%	2.6%	-14.0%	2.7%	-9.2%	-2.1%	-8.2%	-2.4%	-21.6%	1.7%	13.9%
France	21.1%	-2.8%	-5.8%	-6.9%	2.4%	-1.6%	-13.2%	-5.5%	1.8%	9.3%	4.9%	17.2%
Germany	-38.4%	-4.2%	13.9%	12.4%	0.2%	-1.1%	4.8%	-5.9%	2.6%	15.9%	6.7%	19.3%
Italy	-11.2%	1.7%	-5.5%	-15.1%	-2.6%	-13.8%	10.5%	-13.5%	0.5%	-25.6%	1.3%	9.8%
Nordic	-13.9%	-9.3%	-0.7%	28.0%	10.5%	20.0%	-1.5%	-5.2%	8.4%	-17.2%	4.2%	17.8%
UK & Ireland	4.8%	-16.1%	8.7%	24.1%	-1.2%	-0.9%	5.1%	-6.1%	3.2%	-10.1%	2.6%	15.5%
Rest of Europe	-13.3%	16.8%	26.2%	-42.7%	31.8%	2.2%	-3.1%	-2.9%	3.8%	-8.7%	5.5%	18.0%
Total	-1.4%	-4.0%	2.1%	0.0%	3.3%	0.0%	-2.2%	-6.3%	3.0%	-5.7%	4.0%	16.5%

Source: Dataquest (October 1995 Estimates)

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Table 3-24
European Semiconductor Consumption by Country, Transportation
(Millions of US Dollars)

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR 90>95	CAGR 95>00	AGR 94>95
Benelux	7	6	9	9	10	12	14	16	19	20	22	23	25	12.0%	9.5%	11.2%
France	61	83	105	98	128	204	299	426	520	584	689	754	840	32.4%	14.5%	42.7%
Germany	280	328	409	462	596	608	843	1,164	1,412	1,599	1,701	1,894	2,147	23.3%	13.0%	38.1%
Italy	80	44	58	54	97	119	152	182	203	225	245	259	270	25.7%	8.2%	19.8%
Nordic	9	9	10	10	12	16	26	36	44	53	60	66	73	28.9%	15.1%	42.5%
UK & Ireland	45	93	102	110	97	163	185	302	366	416	495	530	582	24.2%	14.0%	63.5%
Rest of Europe	79	78	119	149	160	134	137	164	206	236	237	261	292	6.6%	12.2%	19.9%
Total	$559	$640	$812	$893	$1,100	$1,256	$1,655	$2,291	$2,770	$3,134	$3,448	$3,786	$4,230	23.1%	13.0%	38.4%

Source: Dataquest (October 1995 Estimates)

Table 3-25
European Semiconductor Consumption by Country, Transportation
As a Percentage of Total European Region

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
France	0.7%	0.9%	1.0%	0.9%	1.0%	1.3%	1.4%	1.5%	1.5%	1.5%	1.5%	1.5%	1.4%
Germany	3.3%	3.4%	3.9%	4.2%	4.9%	3.9%	4.0%	4.0%	4.0%	4.0%	3.8%	3.7%	3.6%
Italy	0.9%	0.5%	0.6%	0.5%	0.8%	0.8%	0.7%	0.6%	0.6%	0.6%	0.5%	0.5%	0.4%
Nordic	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
UK & Ireland	0.5%	1.0%	1.0%	1.0%	0.8%	1.1%	0.9%	1.0%	1.0%	1.0%	1.1%	1.0%	1.0%
Rest of Europe	0.9%	0.8%	1.1%	1.4%	1.3%	0.9%	0.7%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%
Total	6.6%	6.7%	7.8%	8.1%	9.0%	8.1%	7.9%	7.9%	7.8%	7.9%	7.7%	7.3%	7.0%

Source: Dataquest (October 1995 Estimates)

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Table 3-26
European Semiconductor Consumption by Country, Transportation
As a Percentage of Total European Transportation Market

Region	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	1.2%	0.9%	1.1%	1.0%	0.9%	0.9%	0.9%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%
France	10.8%	12.9%	12.9%	11.0%	11.6%	16.3%	18.1%	18.6%	18.8%	18.6%	20.0%	19.9%	19.9%
Germany	50.0%	51.2%	50.4%	51.8%	54.2%	48.4%	50.9%	50.8%	51.0%	51.0%	49.3%	50.0%	50.8%
Italy	14.2%	6.8%	7.1%	6.1%	8.8%	9.5%	9.2%	8.0%	7.3%	7.2%	7.1%	6.8%	6.4%
Nordic	1.6%	1.3%	1.3%	1.1%	1.1%	1.2%	1.5%	1.6%	1.6%	1.7%	1.7%	1.7%	1.7%
UK & Ireland	8.0%	14.6%	12.6%	12.3%	8.8%	13.0%	11.2%	13.2%	13.2%	13.3%	14.3%	14.0%	13.8%
Rest of Europe	14.2%	12.2%	14.7%	16.7%	14.5%	10.7%	8.3%	7.2%	7.4%	7.5%	6.9%	6.9%	6.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

Table 3-27
European Semiconductor Consumption by Country, Transportation
Annual Growth Rates

Region	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Benelux	-8.4%	50.0%	1.8%	9.1%	15.7%	23.2%	11.2%	18.4%	7.7%	7.4%	6.2%	8.3%
France	36.6%	26.7%	-6.5%	30.7%	59.7%	46.2%	42.7%	21.9%	12.3%	18.0%	9.5%	11.4%
Germany	17.1%	24.9%	13.0%	28.9%	2.0%	38.5%	38.1%	21.3%	13.2%	6.4%	11.3%	13.4%
Italy	-45.1%	32.6%	-6.2%	78.5%	22.4%	28.1%	19.8%	11.6%	10.9%	8.6%	5.7%	4.3%
Nordic	-1.4%	18.3%	-1.4%	19.1%	29.2%	64.6%	42.5%	22.3%	19.6%	13.4%	8.7%	12.0%
UK & Ireland	109.0%	9.4%	7.9%	-11.9%	68.4%	13.1%	63.5%	21.1%	13.8%	18.8%	7.1%	9.8%
Rest of Europe	-1.4%	52.3%	25.3%	7.3%	-16.1%	2.0%	19.9%	25.3%	14.6%	0.5%	10.1%	12.1%
Total	14.5%	26.9%	10.0%	23.2%	14.2%	31.8%	38.4%	20.9%3	13.1%	10.0%	9.8%	11.7%

Source: Dataquest (October 1995 Estimates)

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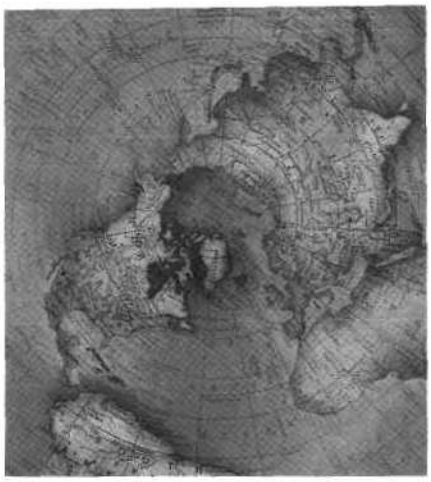
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1995 High-Volume Electronic Equipment Unit Production Forecast and Semiconductor Analysis—Europe

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Chapter 1
Introduction and Definitions

Introduction

This Market Statistics report represents our second forecast for European electronic systems by value, unit volume, semiconductor content and market forecast. Dataquest has selected 22 key application systems that have high-volume production worldwide. These key systems are identified by Dataquest as being leading indicators of semiconductor consumption trends by end-application market segment. These data are derived from research by Dataquest analysts in all its four major regions: United States, Japan, Europe, and Asia/Pacific.

The 22 leading indicators selected by Dataquest are as follows:

- Electronic Data Processing:
  - Personal computers
  - Workstations
  - Rigid disk drives (RDD)
  - Optical disk drives (ODD)
  - Page (laser) printers
  - Serial printers
- Communications:
  - Fax machines
  - LAN cards
  - Modems
  - Answering machines
  - Corded telephones
  - Cordless telephones
  - Central office (CO)/premise line cards
  - Cellular telephones
  - Pagers
- Consumer:
  - Personal/portable stereos
  - Color televisions
  - Videocassette recorders (VCRs)
  - Camcorders
  - Set-top boxes
- Automotive:
  - Auto stereos
  - Engine control units

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This document contains detailed information on Dataquest's view of the European electronic equipment production. Electronic equipment production is an important determinant of semiconductor market activity because semiconductor demand is derived, in part, from the underlying demand for the systems that use semiconductors. Therefore, the forecast of expected electronics systems production is an essential component to assessing future semiconductor market activity.

The report contains tables detailing the spring 1995 electronics equipment production forecast. European production is estimated for the years 1994 to 1999. Production tables contain both historical data and forecasts. In most tables, historical data begin with 1994, while forecast data provide estimates for 1995 through 1999. Tables detail the type of production data by system application market and unit of measure.

Exchange Rates

Dataquest uses an average annual exchange rate for each European country for converting revenue US dollar values. When forecasting electronic equipment production, it is important to maintain consistency and continuity; thus, we maintain exchange rates at constant 1994 calendar year. This prevents any inconsistencies in the conversion of growth projections and currency fluctuations. The 1994 exchange rate estimate uses actual average monthly exchange rates from January through December (these data are gathered and supplied by the Dun & Bradstreet Corporation). The annual rate is estimated as the arithmetic mean of the 12 monthly rates. Exchange rates are provided in Table 1-1 for your reference. Exchange rates for historical years are available on request.

Table 1-1
1994 Exchange Rates Table

	Foreign Currency per US Dollar	US Dollar per Foreign Currency
Austria (Schilling)	11.40	0.08784
Belgium (Franc)	33.36	0.03003
Denmark (Krone)	6.35	0.15772
ECU	0.84	1.18691
Finland (Markka)	5.21	0.19278
France (Franc)	5.54	0.18090
Germany (Mark)	1.62	0.61828
Greece (Drachma)	242.06	0.00413
Ireland (Punt)	0.67	1.50115
Italy (Lira)	1609.34	0.00062
Netherlands (Gulden)	1.82	0.55137
Norway (Krone)	7.04	0.14218
Portugal (Escudo)	165.63	0.00605
Spain (Peseta)	133.48	0.00750
Sweden (Krona)	7.70	0.13004
Switzerland (Franc)	1.37	0.73356
United Kingdom (Pound)	0.65	1.53068

Source: Dun & Bradstreet, Dataquest (October 1995)

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Definitions

Regional Definitions

- **Europe:** Western Europe includes Benelux (Belgium, Netherlands, Luxembourg), France, Italy, Germany (including former east Germany), Scandinavia (Denmark, Finland, Norway, Sweden, and Iceland), United Kingdom and Eire (Ireland), and Rest of Western Europe (Austria, Gibraltar, Greece, Liechtenstein, Malta, Monaco, Portugal, San Marino, Spain, Switzerland, Turkey, Andorra, Vatican City, and Eastern Europe).
  - *Eastern Europe:* Includes Albania, Bulgaria, Czech Republic, Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Republics of former Yugoslavia, Ukraine, Belarus, Georgia, Russian Federation, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, Turkmenistan.

Line Item Definitions

The objective of analysing electronic systems production is to estimate its important implications for semiconductor consumption.

The value of production is estimated as factory revenue. Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes. For purposes of this report Dataquest defines factory revenue as the derived production revenue—from the factory value.

The equipment production data presented here are used in conjunction with estimated average semiconductor content derived from electronic equipment teardown analysis and in some cases from other electronic equipment manufacturing industry sources. We have interviewed more than 200 leading electronics manufacturers that have given us proprietary information on their semiconductor procurement, their captive production, and their relationships to the equipment or divisions in which the devices are used.

Data Sources

The historical information presented in the production data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. From time to time, we conduct production surveys for specific types of electronic equipment and the data gathered are also incorporated into the database. Our other sources include the following:

- Dataquest's estimates of systems manufacturers' end-user revenue
- Trade association data
- Various European Union and government agency statistics
- Japanese government and trade association (MITI, MOF, and EIAJ) intelligence
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices
- Other Dataquest research groups (including Computer Systems, Telecommunications and Document Management)

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Unlike in Japan and the United States where government bodies supply regular production statistics, Europe-wide statistic programs are in their infancy; we believe that the estimates presented here are the most reliable and meaningful generally as they applies to the components manufacturers.

Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide and European macroeconomic conditions are assessed and forecast. Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies—the Group of Seven (G7) countries. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from other Dataquest industry sources (as identified earlier), Dataquest estimates the overall business climates in which the electronic systems market will operate.

Second, Dataquest analyses and forecasts the significant long-range trend and outlook in the various electronic system research groups (within Dataquest). This establishes a five-year trend growth path for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about market trends so that the two do not inexplicably diverge. Dataquest anticipates that in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

Because the time series data contained in this document in general comprise annual observations, and are sparse in terms of the number of observations, the data generally do not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time series models. Therefore, in most cases, we have used judgmental models (that is, intuitive judgements, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

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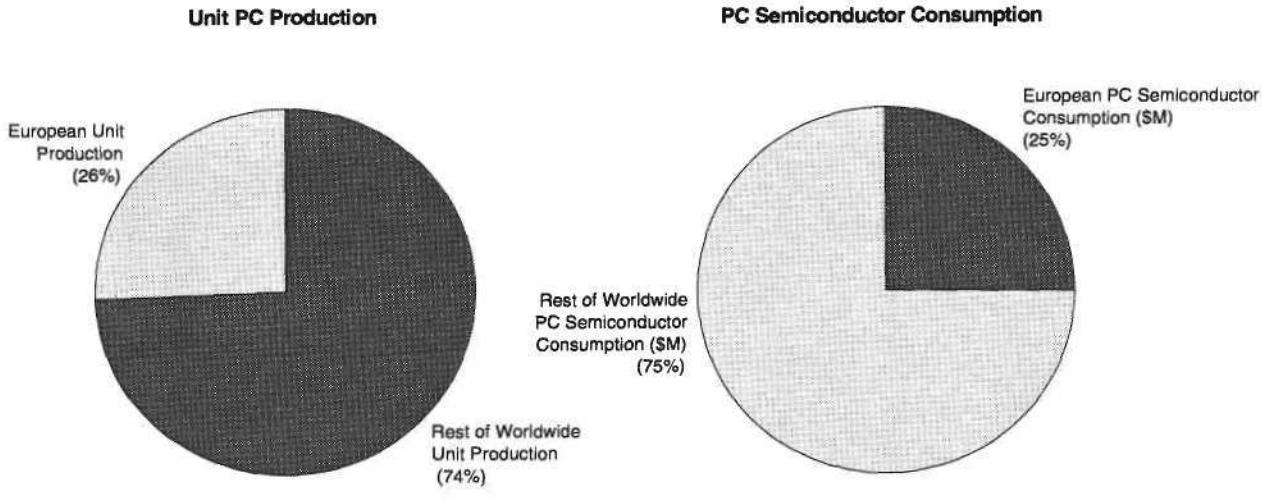
Chapter 2
Electronic Data Processing

Table 2-1
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—PCs

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
PCs							
Units (K)	13,000	16,300	18,400	21,500	24,700	28,300	16.8%
Factory ASP ($)	1,502	1,552	1,527	1,521	1,498	1,494	-0.1%
Factory Revenue ($M)	19,526	25,298	28,097	32,702	37,001	42,280	16.7%
Semiconductor Content ($)*	521	627	700	780	812	829	9.7%
Semiconductor TAM ($M)	6,773	10,220	12,880	16,770	20,056	23,447	28.2%

* Includes graphics, SIO/PIO, storage adpaters, memory SIMMs
Source: Dataquest (October 1995 Estimates)

Figure 2-1
1995 European PC Production and PC Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

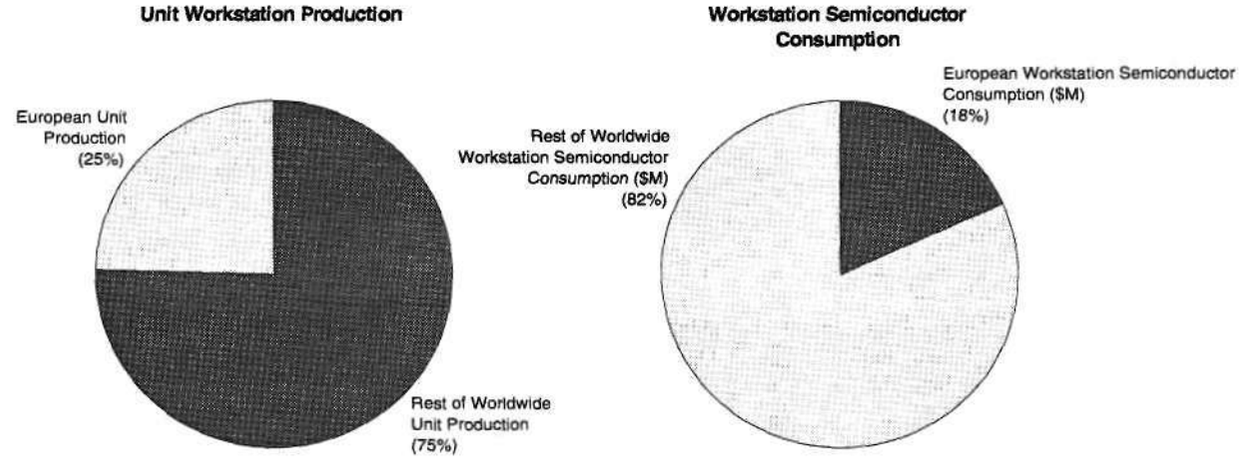
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Table 2-2
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—Workstations

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Workstations							
Units (K)	193	211	227	242	291	358	13.2%
Factory ASP ($)	11,968	12,656	13,422	12,779	13,378	13,828	2.9%
Factory Revenue ($M)	2,310	2,670	3,047	3,093	3,893	4,950	16.5%
Semiconductor Content ($)	1,100	1,460	1,755	1,658	1,583	1,683	8.9%
Semiconductor TAM ($M)	212	308	398	401	461	603	23.2%

Source: Dataquest (October 1995 Estimates)

Figure 2-2
1995 European Workstation Production and Workstation Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

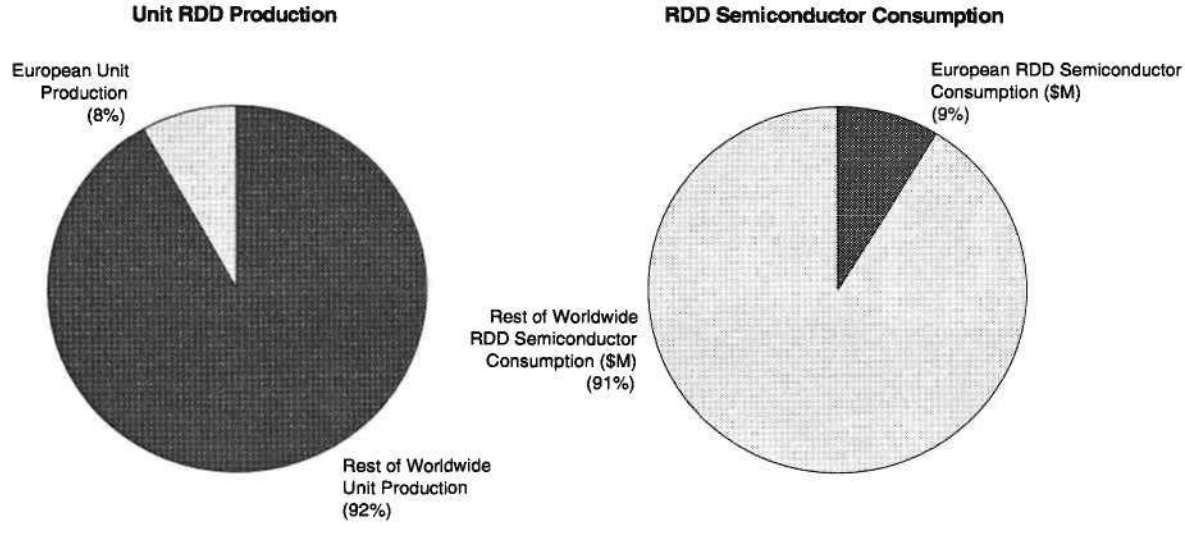
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Table 2-3
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—Rigid Disk Drives

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Rigid Disk Drives							
Units (K)	4,530	6,610	8,922	11,393	15,115	16,963	30.2%
Factory ASP ($)	265	230	215	195	180	175	-8.0%
Factory Revenue ($M)	1,200	1,520	1,918	2,222	2,721	2,969	19.9%
Semiconductor Content ($)	39	38	37	35	33	32	-3.8%
Semiconductor TAM ($M)	176	251	329	401	491	543	25.2%

Source: Dataquest (October 1995 Estimates)

Figure 2-3
1995 European Rigid Disk Drive Production and Rigid Disk Drive Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

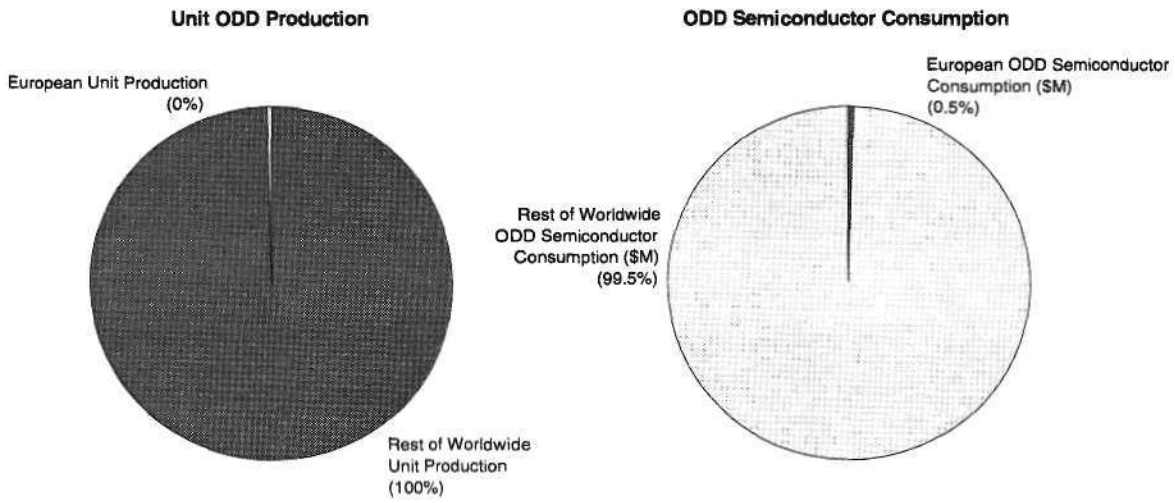
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Table 2-4
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—Optical Disk Drives

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Optical Disk Drives							
Units (K)	91	108	118	122	125	129	7.2%
Factory ASP ($)	362	379	333	397	233	210	-10.3%
Factory Revenue ($M)	33	41	39	48	29	27	-3.8%
Semiconductor Content ($)	55	49	44	40	38	34	-9.2%
Semiconductor TAM ($M)	5	5	5	5	5	4	-2.6%

Source: Dataquest (October 1995 Estimates)

Figure 2-4
1995 European Optical Disk Drive Production and Optical Disk Drive Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

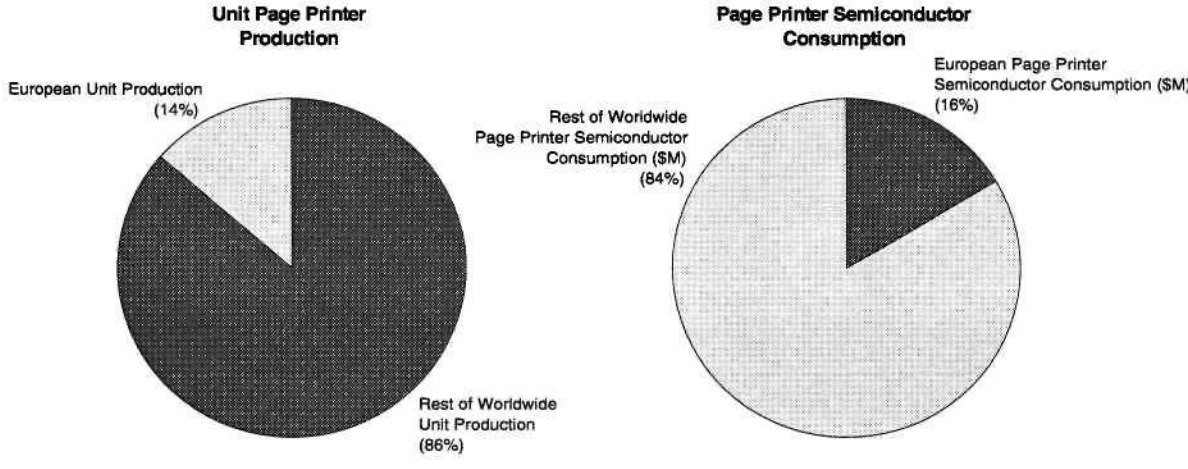
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Table 2-5
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—Page (Laser) Printers

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Page (Laser) Printers							
Units (K)	906	1,087	1,251	1,376	1,486	1,575	11.7%
Factory ASP ($)	827	765	726	698	678	651	-4.7%
Factory Revenue ($M)	750	832	908	961	1,007	1,025	6.5%
Semiconductor Content ($)	148	162	158	136	120	110	-5.8%
Semiconductor TAM ($M)	134	176	198	187	178	173	5.2%

Source: Dataquest (October 1995 Estimates)

Figure 2-5
1995 European Page (Laser) Printer Production and Page (Laser) Printer Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

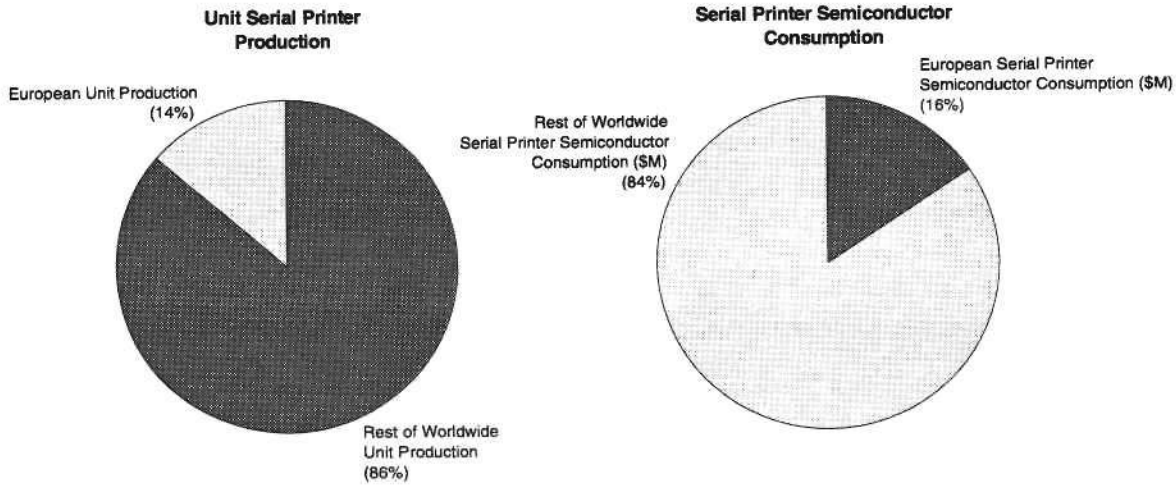
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Table 2-6
High-Volume Electronic Equipment Production
Region: Europe
Category: Electronic Data Processing—Serial Printers

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Serial Printers							
Units (K)	2,945	3,323	3,400	4,226	5,979	7,688	21.2%
Factory ASP ($)	296	297	291	289	285	283	-0.9%
Factory Revenue ($M)	872	987	990	1,221	1,704	2,176	20.1%
Semiconductor Content ($)	27	31	31	31	30	29	1.4%
Semiconductor TAM ($M)	80	103	105	131	179	223	22.9%

Source: Dataquest (October 1995 Estimates)

Figure 2-6
1995 European Serial Printer Production and Serial Printer Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

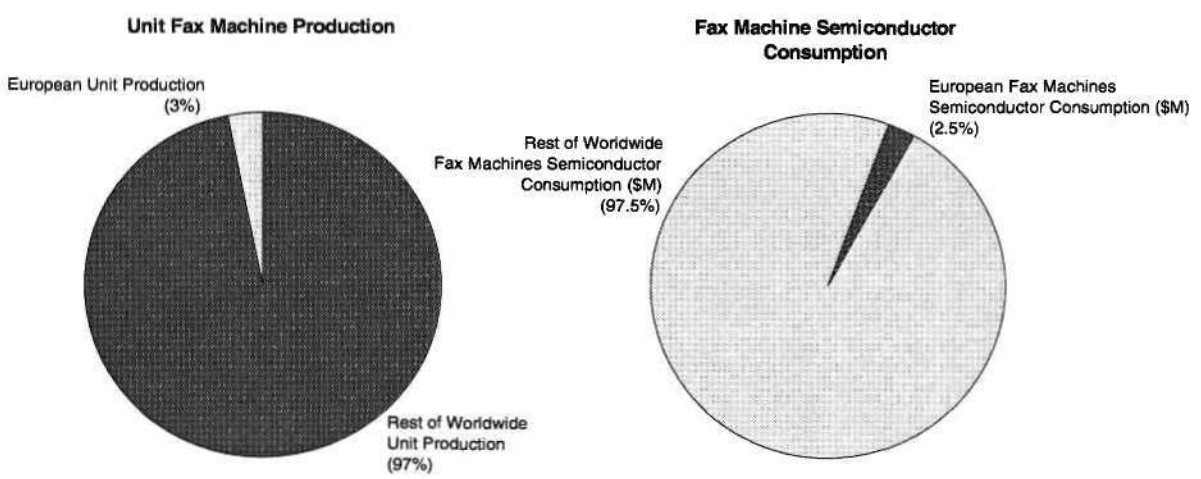
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Table 3-1
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Fax Machines

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Fax Machines							
Units (K)	262	319	378	464	525	610	18.4%
Factory ASP ($)	597	545	480	426	380	321	-11.7%
Factory Revenue ($M)	156	174	182	198	199	196	4.6%
Semiconductor Content ($)	67	63	56	52	48	42	-8.9%
Semiconductor TAM ($M)	18	20	21	24	25	26	7.8%

Source: Dataquest (October 1995 Estimates)

Figure 3-1
1995 European Fax Machine Production and Fax Machine Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

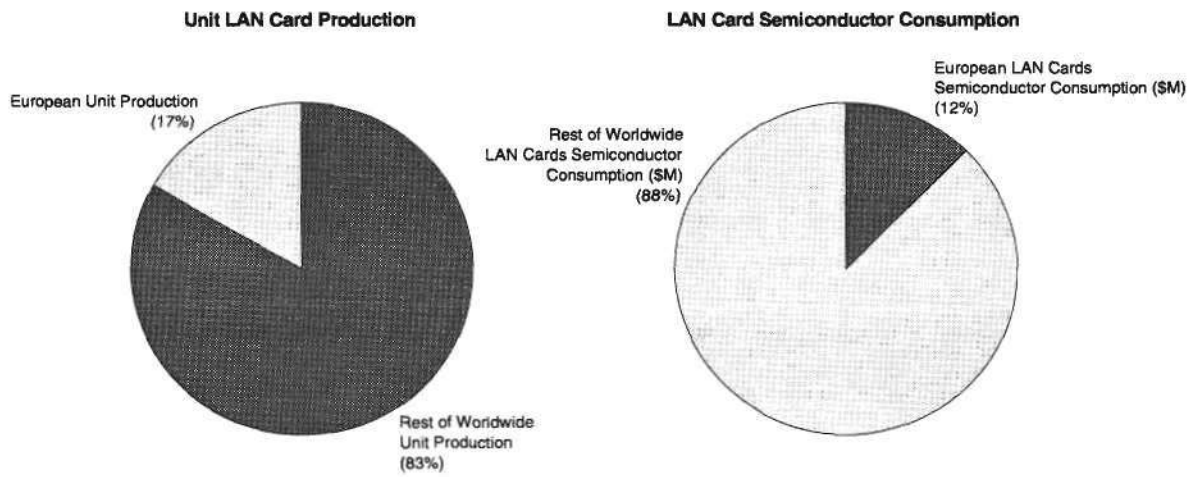
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Table 3-2
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—LAN Cards

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
LAN Cards							
Units (K)	4,060	5,480	7,000	8,670	10,530	11,960	24.1%
Factory ASP ($)	146	141	129	120	108	95	-8.1%
Factory Revenue ($M)	591	775	900	1,042	1,138	1,142	14.1%
Semiconductor Content ($)	31	30	27	25	23	21	-7.2%
Semiconductor TAM ($M)	124	163	189	219	245	251	15.1%

Source: Dataquest (October 1995 Estimates)

Figure 3-2
1995 European LAN Card Production and LAN Card Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

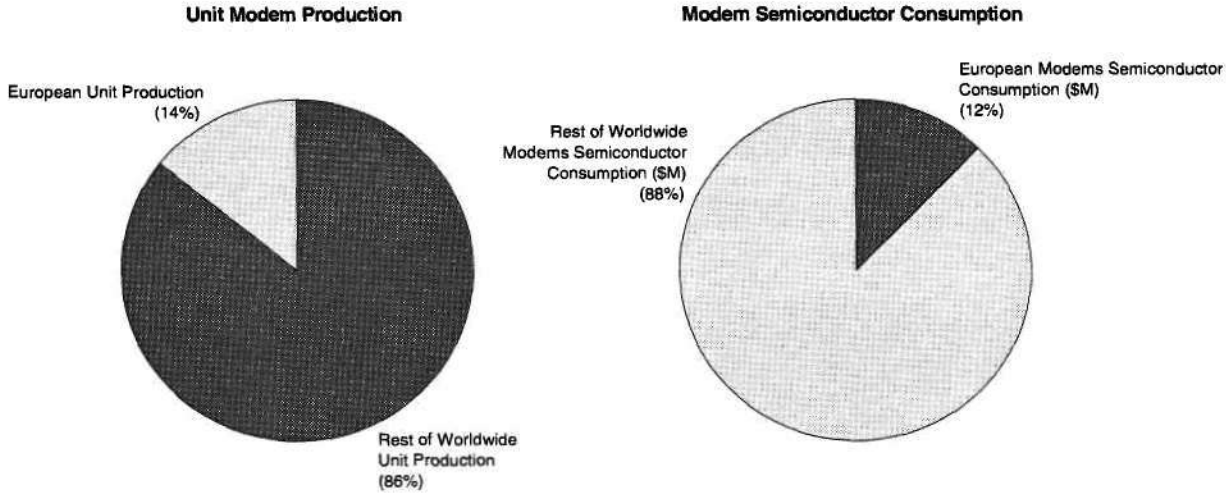
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Table 3-3
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Modems

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Modems*							
Units (K)	1,640	2,074	2,486	2,896	3,186	3,476	16.2%
Factory ASP ($)	197	148	114	94	83	74	-17.8%
Factory Revenue ($M)	323	306	283	271	263	258	-4.4%
Semiconductor Content ($)	37	31	27	25	23	21	-11.2%
Semiconductor TAM ($M)	61	64	68	73	74	72	3.3%

* External and internal, data and fax
Source: Dataquest (October 1995 Estimates)

Figure 3-3
1995 European Modem Production and Modem Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

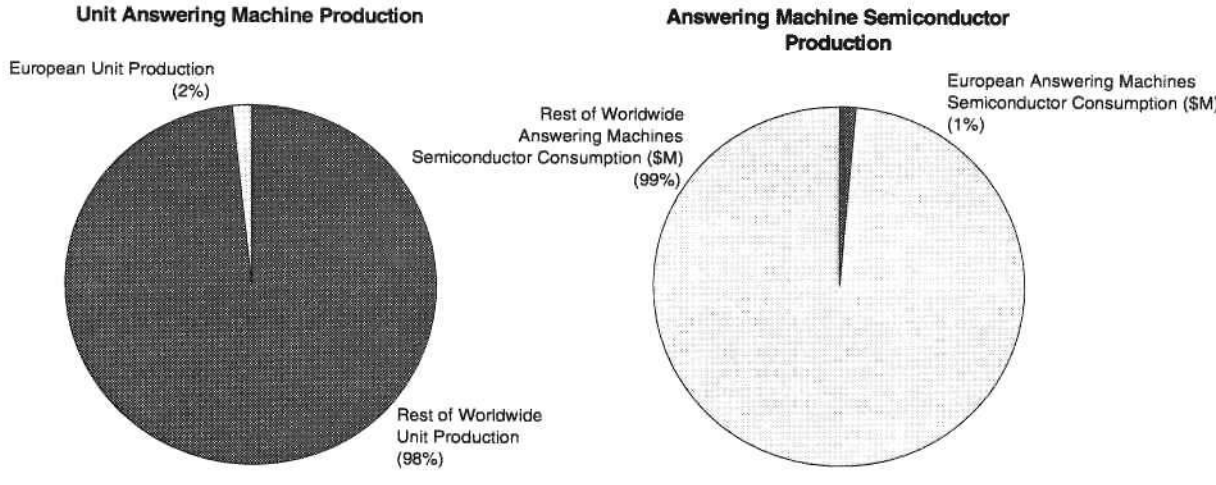
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Table 3-4
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Answering Machines

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Answering Machines							
Units (K)	378	472	628	818	1,048	1,256	27.1%
Factory ASP ($)	113	107	102	94	88	81	-6.4%
Factory Revenue ($M)	43	51	64	77	92	102	19.0%
Semiconductor Content ($)	9	10	12	14	16	17	13.5%
Semiconductor TAM ($M)	3	5	8	12	17	21	44.3%

Source: Dataquest (October 1995 Estimates)

Figure 3-4
1995 European Answering Machine Production and Answering Machine Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

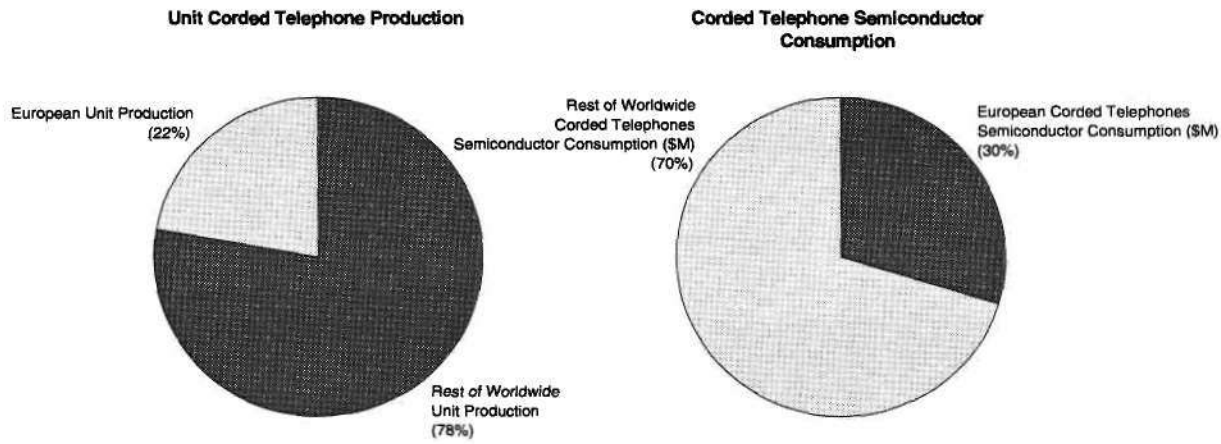
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Table 3-5
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Corded Telephones

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Corded Telephones							
Units (K)	23,670	22,070	21,663	21,732	21,879	22,040	-1.4%
Factory ASP ($)	33	33	33	32	32	32	-0.6%
Factory Revenue ($M)	781	728	715	695	700	705	-2.0%
Semiconductor Content ($)	6	7	7	7	7	8	4.1%
Semiconductor TAM ($M)	148	146	150	153	161	169	2.7%

Source: Dataquest (October 1995 Estimates)

Figure 3-5
1995 European Corded Telephone Production and Corded Telephone Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

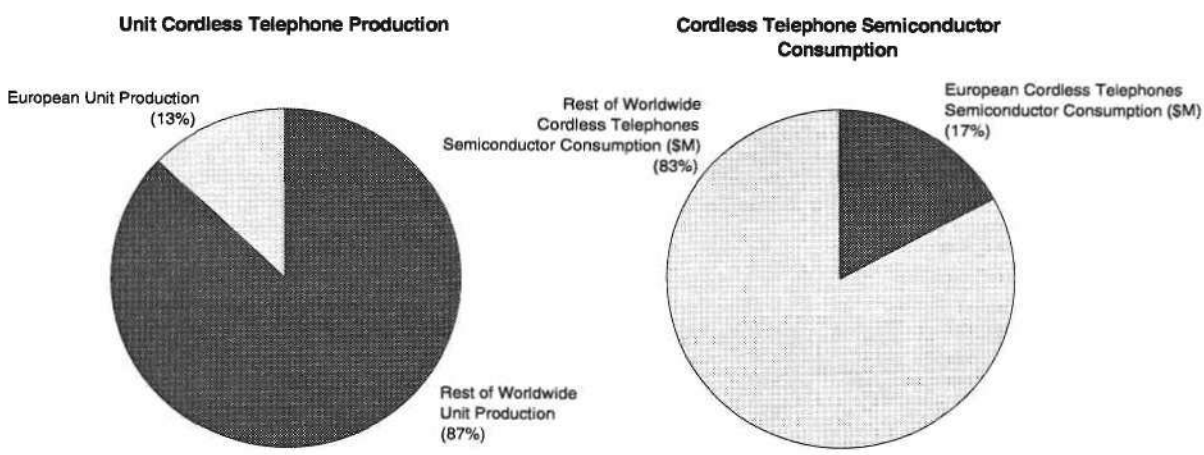
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Table 3-6
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Cordless Telephones

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Cordless Telephones							
Units (K)	3,839	5,029	6,113	7,147	8,243	9,350	19.5%
Factory ASP ($)	116	110	103	99	95	90	-4.9%
Factory Revenue ($M)	445	553	630	708	783	841	13.6%
Semiconductor Content ($)	17	20	19	20	20	20	2.6%
Semiconductor TAM ($M)	67	100	116	142	168	185	22.6%

Source: Dataquest (October 1995 Estimates)

Figure 3-6
1995 European Cordless Telephone Production and Cordless Telephone Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

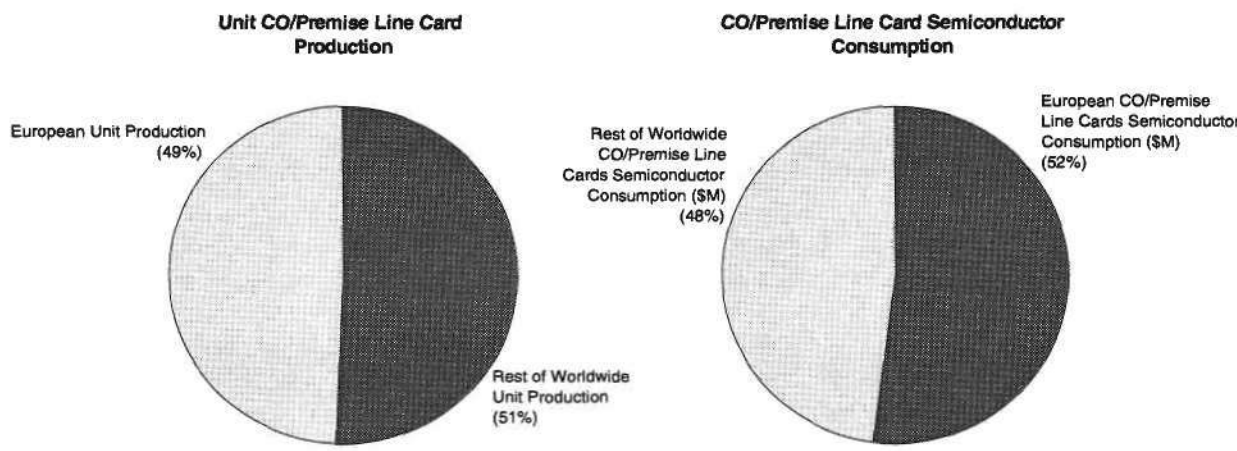
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Table 3-7
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—CO/Premise Line Cards

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
CO/Premise Line Cards							
Units (K) [Lines]	42,335	43,681	45,246	46,423	47,898	49,643	3.2%
Factory ASP ($) [per Line]	113	108	102	97	92	90	-4.4%
Factory Revenue ($M)	4,784	4,718	4,615	4,503	4,407	4,468	-1.4%
Semiconductor Content ($)	15	16	17	18	18	19	4.6%
Semiconductor TAM ($M)	644	706	762	814	875	943	7.9%

Source: Dataquest (October 1995 Estimates)

Figure 3-7
1995 European CO/Premise Line Card Production and CO/Premise Line Card Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

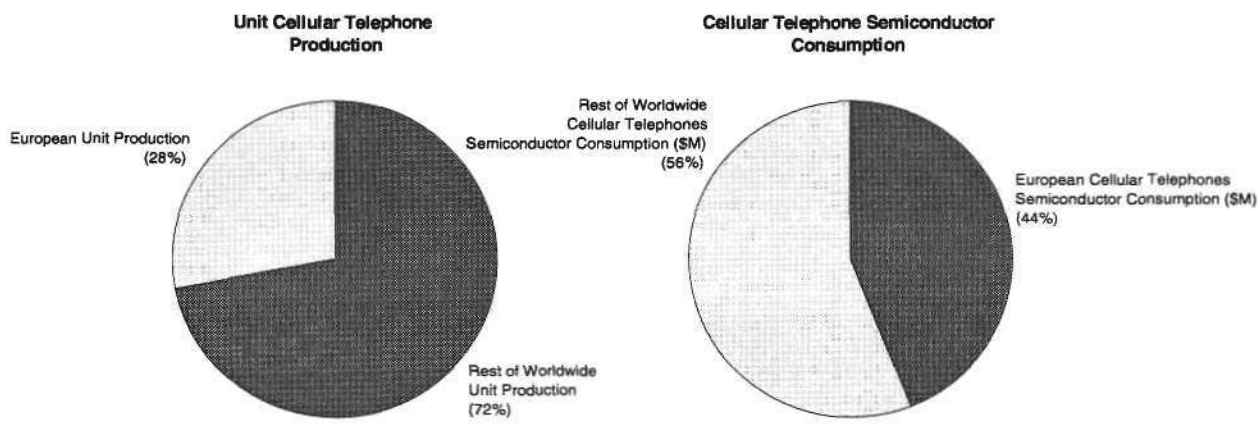
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Table 3-8
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Cellular Telephones

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Cellular Telephones							
Units (K)	7,497	10,583	14,963	20,170	26,807	32,077	33.7%
Factory ASP ($)	458	414	377	338	301	261	-10.6%
Factory Revenue ($M)	3,432	4,386	5,639	6,823	8,063	8,381	19.6%
Semiconductor Content ($)	107	101	93	87	84	75	-6.7%
Semiconductor TAM ($M)	800	1,069	1,388	1,753	2,240	2,416	24.8%

Source: Dataquest (October 1995 Estimates)

Figure 3-8
1995 European Cellular Telephone Production and Cellular Telephone Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

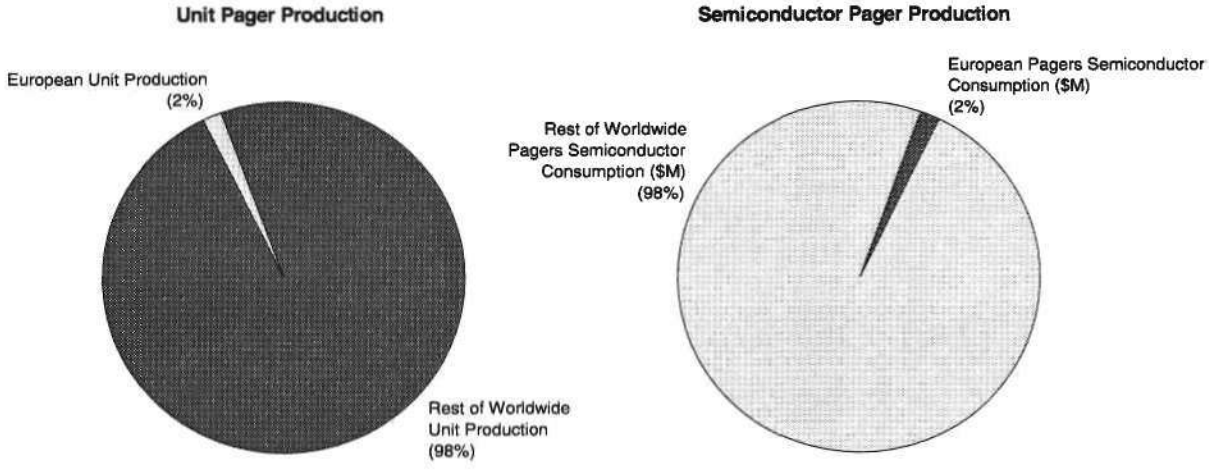
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Table 3-9
High-Volume Electronic Equipment Production
Region: Europe
Category: Communications—Pagers

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Pagers							
Units (K)	395	502	676	860	1,110	1,471	30.1%
Factory ASP ($)	129	124	120	116	113	109	-3.4%
Factory Revenue ($M)	51	62	81	100	125	160	25.7%
Semiconductor Content ($)	13	13	13	13	14	14	1.1%
Semiconductor TAM ($M)	5	7	9	11	15	20	31.5%

Source: Dataquest (October 1995 Estimates)

Figure 3-9
1995 European Pager Production and Pager Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

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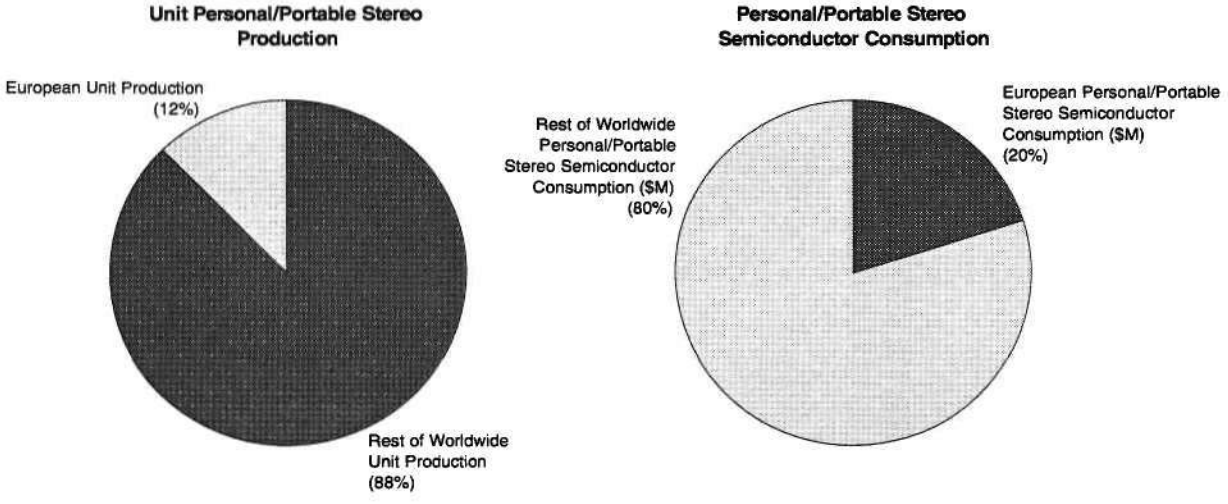
Chapter 4
Consumer

Table 4-1
High-Volume Electronic Equipment Production
Region: Europe
Category: Consumer—Personal/Portable Stereos

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Personal/Portable Stereos							
Units (K)	15,366	15,383	15,400	15,396	15,398	16,014	0.8%
Factory ASP ($)	21	21	21	21	21	21	0.4%
Factory Revenue ($M)	317	316	319	319	323	336	1.2%
Semiconductor Content ($)*	12	12	12	13	13	13	1.6%
Semiconductor TAM ($M)	184	188	191	192	194	208	2.5%

* Including handheld
Source: Dataquest (October 1995 Estimates)

Figure 4-1
1995 European Personal/Portable Stereo Production and Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

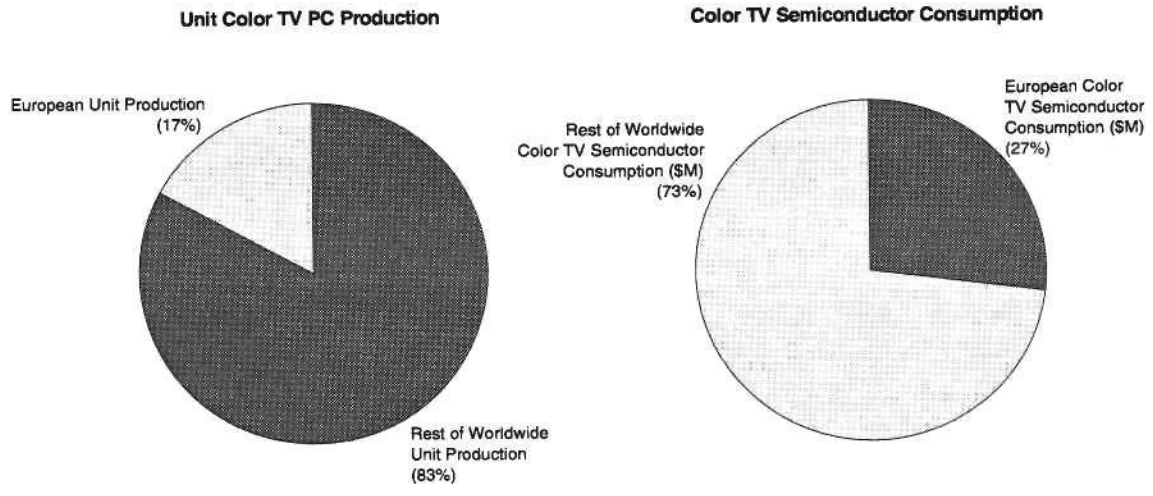
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Table 4-2
High-Volume Electronic Equipment Production
Region: Europe
Category: Consumer—Color TVs

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Color TVs							
Units (K)	19,692	19,998	20,740	20,796	21,034	21,271	1.6%
Factory ASP ($)	130	135	145	150	160	170	5.5%
Factory Revenue ($M)	2,560	2,700	3,007	3,119	3,365	3,616	7.2%
Semiconductor Content ($)	45	47	51	52	56	65	7.4%
Semiconductor TAM ($M)	888	945	1,068	1,082	1,178	1,374	9.1%

Source: Dataquest (October 1995 Estimates)

Figure 4-2
1995 European Color TV Production and Color TV Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

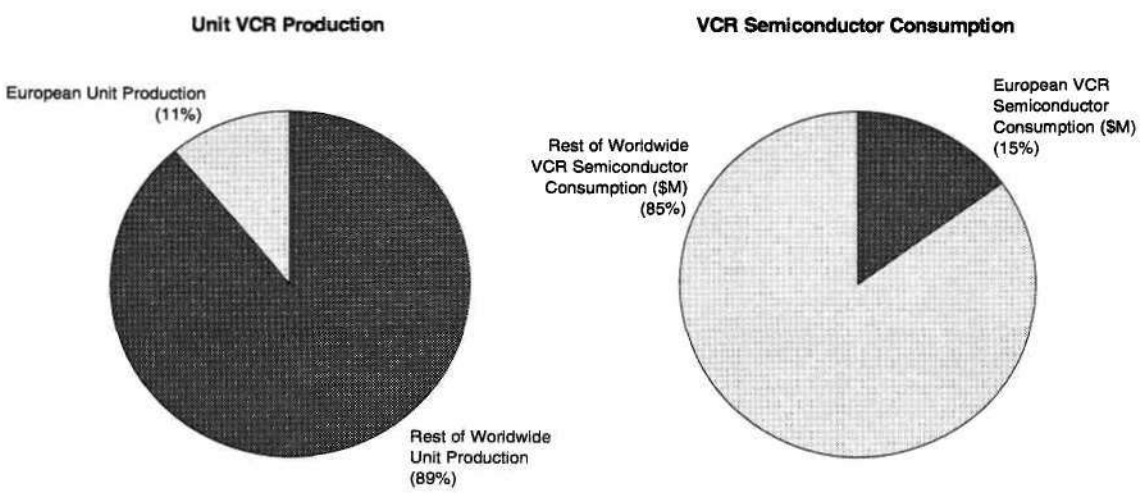
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Table 4-3
High-Volume Electronic Equipment Production
Region: Europe
Category: Consumer—VCRs

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
VCRs							
Units (K)	5,929	6,888	8,004	8,951	9,384	10,526	12.2%
Factory ASP ($)	165	160	158	158	158	158	-0.9%
Factory Revenue ($M)	978	1,102	1,265	1,414	1,483	1,663	11.2%
Semiconductor Content ($)	56	59	60	60	60	60	1.4%
Semiconductor TAM ($M)	333	408	481	537	563	632	13.7%

Source: Dataquest (October 1995 Estimates)

Figure 4-3
1995 European VCR Production and VCR Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

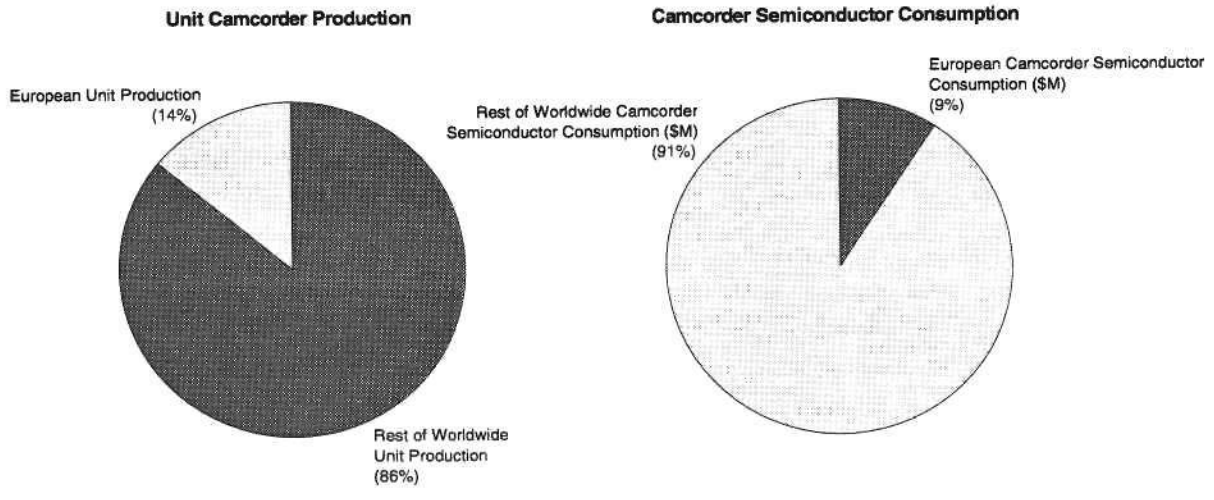
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Table 4-4
High-Volume Electronic Equipment Production
Region: Europe
Category: Consumer—Camcorders

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Camcorders							
Units (K)	1,174	1,601	1,954	2,251	2,650	2,996	20.6%
Factory ASP ($)	350	340	335	330	320	315	-2.1%
Factory Revenue ($M)	411	544	655	743	848	942	18.1%
Semiconductor Content ($)	81	82	84	86	86	88	1.8%
Semiconductor TAM ($M)	94	131	164	193	229	264	22.8%

Source: Dataquest (October 1995 Estimates)

Figure 4-4
1995 European Camcorder Production and Camcorder Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

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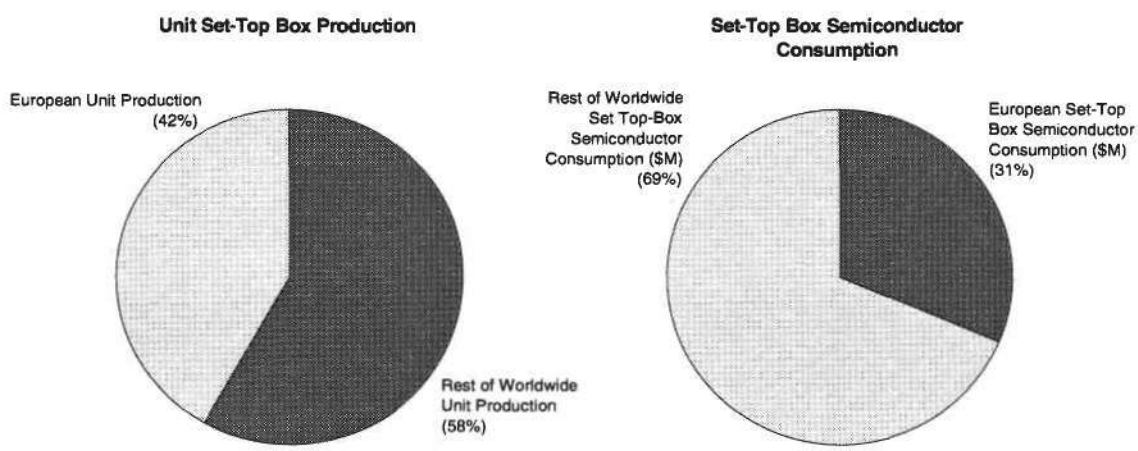
Table 4-5
High-Volume Electronic Equipment Production
Region: Europe
Category: Consumer—Set-Top Boxes

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Set-Top Boxes							
Units (K)	5,010	5,874	6,746	7,701	8,690	9,840	14.5%
Factory ASP ($)	194	202	210	222	229	229	3.3%
Factory Revenue ($M)	974	1,188	1,418	1,706	1,993	2,250	18.2%
Semiconductor Content ($)*	43	47	50	54	55	56	5.4%
Semiconductor TAM ($M)	216	274	339	412	482	554	20.7%

* Including handheld

Source: Dataquest (October 1995 Estimates)

Figure 4-5
1995 European Set-Top Box Production and Set-Top Box Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

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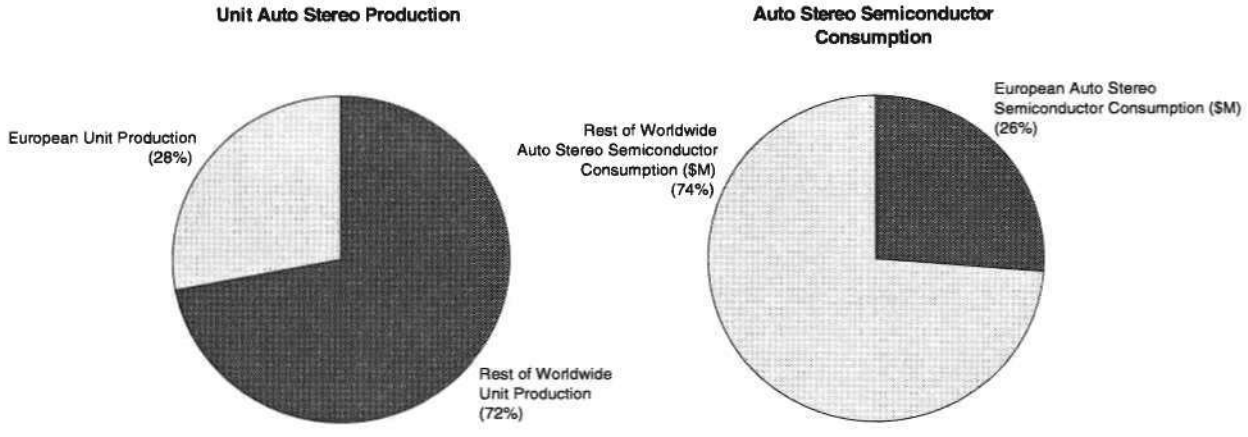
Chapter 5
Automotive

Table 5-1
High-Volume Electronic Equipment Production
Region: Europe
Category: Automotive—Auto Stereos (All)

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Auto Stereo (All)							
Units (K)	14,160	14,125	14,300	14,388	14,417	14,607	0.6%
Factory ASP ($)	55	57	59	61	63	66	3.7%
Factory Revenue ($M)	779	805	844	878	908	964	4.4%
Semiconductor Content ($)	15	15	16	17	18	19	4.8%
Semiconductor TAM ($M)	212	212	229	245	260	278	5.5%

Source: Dataquest (October 1995 Estimates)

Figure 5-1
1995 European Auto Stereo Production and Auto Stereo Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

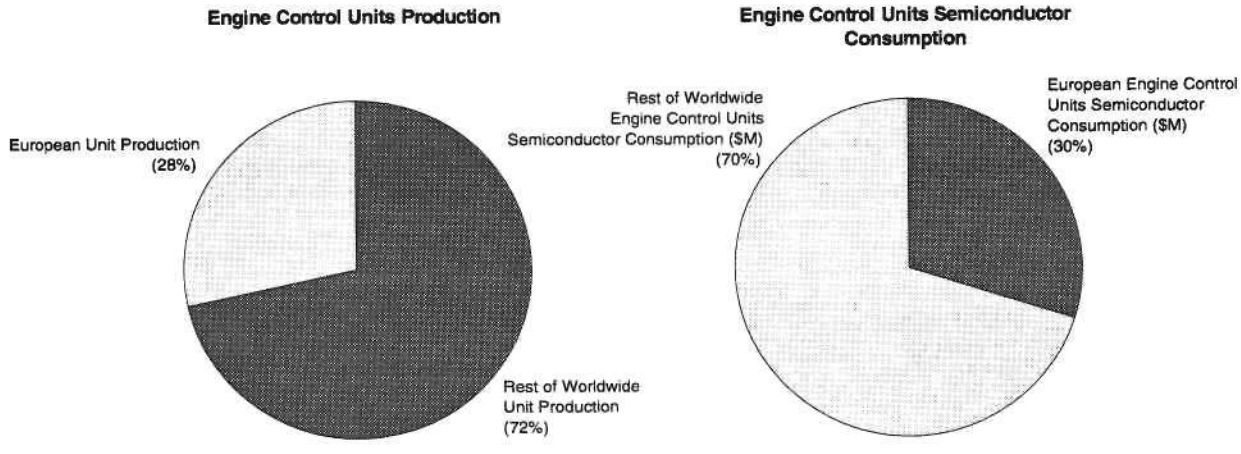
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Table 5-2
High-Volume Electronic Equipment Production
Region: Europe
Category: Automotive—Engine Control Units

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Engine Control Units							
Units (K)	9,500	10,790	11,299	11,685	12,190	12,210	5.1%
Factory ASP ($)	245	230	222	218	215	210	-3.0%
Factory Revenue ($M)	2,328	2,482	2,508	2,547	2,621	2,564	2.0%
Semiconductor Content ($)	36	36	36	36	37	37	0.3%
Semiconductor TAM ($M)	344	393	407	424	446	449	5.4%

Source: Dataquest (October 1995 Estimates)

Figure 5-2
1995 European Engine Control Unit Production and Engine Control Unit Semiconductor Consumption as Percentage of Worldwide



Source: Dataquest (October 1995 Estimates)

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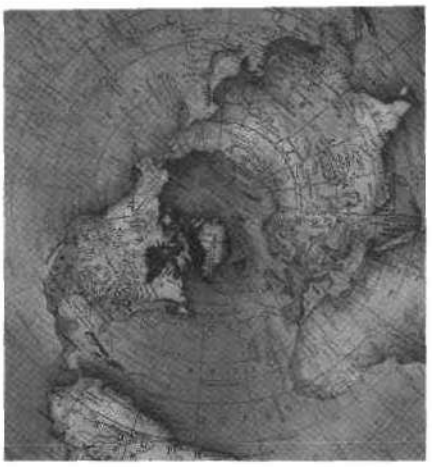
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European Semiconductor Market Trends

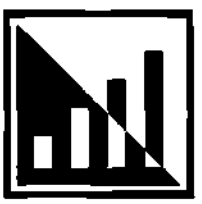


Market Trends

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European Semiconductor Market Trends



Market Trends

1995

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Filing: Market Analysis

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Chapter 1
Report Introduction

This report presents Dataquest's European applications history and forecast for semiconductor products and equipment for the period 1988 to 1998. The European regions included in this forecast are:

- **Benelux:** Belgium, Netherlands, Luxembourg
- **France:** France
- **Germany:** The former east and west Germany
- **Italy:** Italy
- **Nordic:** Denmark, Norway, Sweden, Finland
- **UK and Ireland:** United Kingdom and Ireland
- **Rest of Europe:** Western Europe, Eastern Europe
  - *Western Europe:* Austria, Switzerland, Spain, Portugal, Greece, Cyprus, Gibraltar, Liechtenstein, Malta, San Marino, Iceland, Turkey, Andorra, Vatican City
  - *Eastern Europe:* Albania, Bulgaria, Czech Republic, Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Republics of the former Yugoslavia, Ukraine, Belarus, Georgia, Russian Federation, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, Turkmenistan

In 1993 we included Eastern Europe in our analysis of Europe; in the past our research concentrated only on Western Europe.

Assumptions

The equipment and semiconductor forecast is made assuming certain facts and conditions. The behavior of the market will alter if these basic assumptions change. The factors we allow for in our forecast include:

- Exchange rates
- Political environments
- Economic conditions
- Technologies
- Semiconductor production capacity
- End-use applications

Exchange Rates

In a region that encompasses more than 50 countries it is important to be clear on how this report deals with exchange rates. The three currencies that have most impact on prices in Europe are the dollar, the yen and the deutsche mark, in order of importance. The worldwide semiconductor market behaves predominantly as a dollar-based market.

The exchange rates used for the forecast are fixed and are based on the average for 1994. The regional currencies are as follows:

- **Benelux:** Dutch gulden (Fl)
- **France:** French francs (FF)
- **Italy:** Lira (L)

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- **Nordic:** Swedish kronor (SKr)
- **UK/Ireland:** UK pounds sterling (£)
- **Rest of Europe:** Spanish pesetas (Pta)

The actual annual exchange rates used in the period covered by this report are given in Table 1-1.

Table 1-1
1994 Exchange Rates

	Foreign Currency per US Dollar	US Dollar per Foreign Currency
Austria (Schilling)	11.40	0.08784
Belgium (Franc)	33.36	0.03003
Denmark (Krone)	6.35	0.15772
ECU	0.84	1.18691
Finland (Markka)	5.21	0.19278
France (Franc)	5.54	0.18090
Germany (Mark)	1.62	0.61828
Greece (Drachma)	242.06	0.00413
Ireland (Punt)	0.67	1.50115
Italy (Lira)	1609.34	0.00062
Netherlands (Gulden)	1.82	0.55137
Norway (Krone)	7.04	0.14218
Portugal (Escudo)	165.63	0.00605
Spain (Peseta)	133.48	0.00750
Sweden (Krona)	7.70	0.13004
Switzerland (Franc)	1.37	0.73356
United Kingdom (Pound)	0.65	1.53068

Source: Dun & Bradstreet, Dataquest (July 1995)

Political Conditions

This forecast assumes there will be no major political changes within Europe that will affect the semiconductor market. However, this may be less likely than in previous forecasts. Areas where there is political instability include the parts of Eastern Europe and the Russian Federation that are under development. Both of these could affect demand from the market; any changes could have a dramatic effect, worsening the imbalance between supply and demand.

The developments in the General Agreement on Tariffs and Trade (GATT) have contributed to a more optimistic longer-term forecast, as the expected reduction in tariffs should stimulate trade and production. This has been allowed for in the current forecast, and we do not expect any major trade developments to counter the expected increase in semiconductor consumption.

Economic Conditions

Europe has been going through a long period of weak economic growth, but now there are strong signs of recovery across Europe. The countries that comprise the region are at different stages of their recovery, but the assumption is that the region as a whole will grow consistently over the period of this forecast. Table 1-2 gives the latest Organization for Economic Cooperation and Development (OECD) forecast for short-term gross domestic product (GDP) growth in selected countries in Europe, and all of them show increasing GDP growth for 1995 and 1996.

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Table 1-2
GDP Growth Rates in Europe
(Percent Change)

Country	1994	1995	1996
Belgium	2.3	2.7	2.6
France	2.7	3.0	3.2
Germany	2.9	2.9	2.7
Netherlands	2.5	3.1	2.7
Italy	2.2	3.0	2.9
Spain	2.0	3.0	3.2
Sweden	2.2	2.5	2.4
Switzerland	2.1	1.7	2.3
United Kingdom	3.8	3.4	3.0

Source: OECD, June 1995

Applications

The longer-term outlook is affected by demand for applications more than any other factor. While the economies across Europe have been weak, semiconductor demand has shown stronger growth, and this is mainly due to strong demand for specific applications. These include the development of mobile communications, and increasing demand for personal computing. We expect these applications to continue to influence semiconductor demand, but there are new applications emerging which will add to the market, particularly towards the latter part of the forecast. However, the influence of the PC will grow, and by 1998 we expect the PC to account for around 30 percent of semiconductor demand in Europe.

Production Capacity

The balance between supply and demand is currently tipped in favor of supply, with demand exceeding supply in many areas. This is as a result of underinvestment in worldwide production facilities, especially in memory products. This is particularly so in the higher-technology 0.5 µm and 8-inch wafer facilities. In the longer term, many of the emerging applications demand this type of facility, so a capacity shortfall may affect supply of the products, and hence the growth of the market in Europe. The greatest impact, though, is likely to be on semiconductor component prices, and as demand exceeds supply prices will rise, as happened in 1994. Over the past 18 months we have seen the average price across all semiconductor components rise by about 30 percent—a significant contribution to market growth.

Changes from the 1994 Forecast

Dataquest is now more optimistic about the future of the semiconductor market in Europe as a result of growing demand for high-technology equipment. In addition, the forecast now includes Central and Eastern European and Russian Federation states, these adding to the market in the longer term.

We have increased our forecast for memory and microcomponent products as a result of increased expectation for PC demand. In addition, there is a worldwide shortfall of production capacity for memory, increasing prices. The microprocessor market is also well managed from the supply side, and prices are increasing here—also adding to the market estimates.

Consumer demand is recovering ahead of expectations, and mobile communications, particularly digital cellular telephony, has shown a remarkable growth—also ahead of our expectations.

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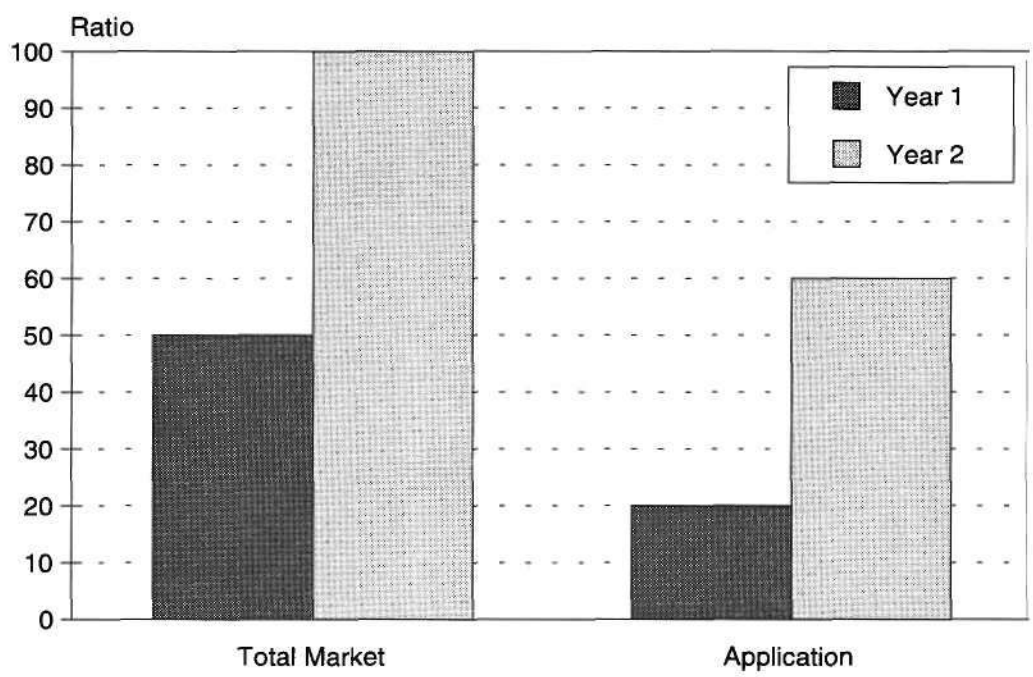
Chapter 2
Total European Electronic Equipment Production

The following six chapters give additional detail for the growth of the applications that Dataquest tracks in Europe, including historical data, together with forecast data.

Each chapter includes figures that forecast the ratio of semiconductors revenue to equipment revenue, annual growth rates, and annual contribution to growth by application. Annual contribution to growth is used to provide more meaningful data than growth rates or absolute annual revenue; it is a combination of both. It is a measure of how much an application's absolute revenue growth contributed to the total semiconductor market revenue growth. In the example in Figure 2-1, the total market grew from 50 to 100, and the application grew from 20 to 60. Therefore, the application contributed 40 to the market growth of 50, or an 80 percent contribution to the annual growth.

European equipment production is expected to grow to $212 billion by 1999, as shown in Table 2-2. Over the forecast period 1994 to 1999, total equipment production will show a compound annual growth rate (CAGR) of 6.2 percent. This compares with the historical modest growth of 4.9 percent CAGR, shown in Table 2-1. Overall, we are optimistic for continued further growth of the European electronics industry. We expect the electronic data processing (EDP), communications, industrial and transportation (automotive) segments all to grow faster than the industry average. The growth in semiconductor demand from these main segments is greater than equipment production growth. This indicates a continuing increase in the ratio of semiconductor revenue to equipment revenue.

Figure 2-1
Annual Contribution to European Semiconductor Market Growth



Source: Dataquest (July 1995 Estimates)

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Table 2-1
Segment Summary, Total European Electronic Equipment Production—History
(Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Equipment	**$123,954**	**$139,089**	**$142,540**	**$143,603**	**$148,991**	**$157,375**	**4.9%**
Electronic Data Processing	$31,776	$37,469	$36,859	$34,899	$37,160	$39,982	4.7%
Communications	$25,030	$28,698	$31,087	$32,899	$35,116	$37,983	8.7%
Industrial	$21,244	$26,078	$26,196	$27,491	$26,295	$27,217	5.1%
Consumer	$18,964	$19,606	$20,410	$19,450	$20,415	$21,389	2.4%
Military and Civil Aerospace	$21,749	$20,976	$21,171	$21,055	$21,447	$20,851	-0.8%
Transportation	$5,191	$6,262	$6,818	$7,809	$8,558	$9,953	13.9%

Source: Dataquest (July 1995 Estimates)

Table 2-2
Segment Summary, Total European Electronic Equipment Production—Forecast
(Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Total Equipment	**$157,375**	**$167,771**	**$178,231**	**$188,571**	**$201,884**	**$212,782**	**6.2%**
Electronic Data Processing	$39,982	$43,475	$45,875	$48,285	$52,940	$56,715	7.2%
Communications	$37,983	$41,317	$45,116	$48,429	$51,813	$53,234	7.0%
Industrial	$27,217	$28,525	$30,196	$32,202	$34,539	$37,359	6.5%
Consumer	$21,389	$22,595	$23,949	$25,305	$26,753	$28,217	5.7%
Military and Civil Aerospace	$20,851	$20,628	$20,489	$20,275	$20,075	$19,719	-1.1%
Transportation	$9,953	$11,231	$12,606	$14,075	$15,763	$17,538	12.0%

Source: Dataquest (July 1995 Estimates)

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Chapter 3
Electronic Data Processing

Electronic data processing equipment production is expected to grow at 7.2 percent CAGR between 1994 and 1999, as shown in Table 3-2. EDP is expected to remain the largest single equipment market. It has held this position through the period 1989 to 1994, as shown in Table 3-1.

Figure 3-1 shows the changing ratio of semiconductor revenue to equipment revenue in the EDP segment. In 1994 the ratio was 22.5 percent, and this is expected to rise to 34 percent in 1999. Figure 3-2 compares the annualized growth rates of the total semiconductor and the EDP semiconductor markets. The EDP segment is growing faster than the market in 1994 and 1995; beyond this, the market is growing faster than EDP. Although the annual growth rate will slow down, Figure 3-3 shows the significance of EDP's annual contribution to growth of the semiconductor market.

In 1994, the EDP semiconductor market grew to $9 billion. Figure 3-4 shows this market split by subsegment. The computer subsegment dominates, accounting for 83 percent of this segment. The dedicated systems subsegment has shown good growth, keeping pace with the computer subsegment. Input/output systems, which include printers, keyboards, displays and so on, are still growing, but this segment is now overshadowed by computers and even dedicated systems.

Within the EDP segment the computer subsegment dominates. Semiconductor consumption by the computer segment has been the main driver for growth in EDP. Tables 3-3 and 3-4 show that semiconductor consumption of computers as a percentage of EDP will grow from 73 percent in 1989 to 87 percent in 1999. The reason for this increase is the spectacular rise in European PC production.

In 1994, European PC semiconductor demand was $6.2 billion, driven by the 13 million PCs produced in the region. We expect PC production to rise to 28.3 million units by 1999, leading a $16.1 billion PC semiconductor market. This growing PC semiconductor market is accounted for by three factors: growth of PC unit production; increasingly complex microprocessors; and increasing system memory.

Of the 13 million PCs produced in 1994, 85 percent were x486-class processors. By 1997, PC production will have grown to 21.5 million units, of which 62 percent will be Pentium-class. We forecast that by 1999, 69 percent of the 28.3 million PCs will have P6-class processors. The increasing complexity of software and processors also has an impact on the demand for memory. In 1994, PC system memory was an average 7.2MB; this is expected to rise to 32MB by 1999.

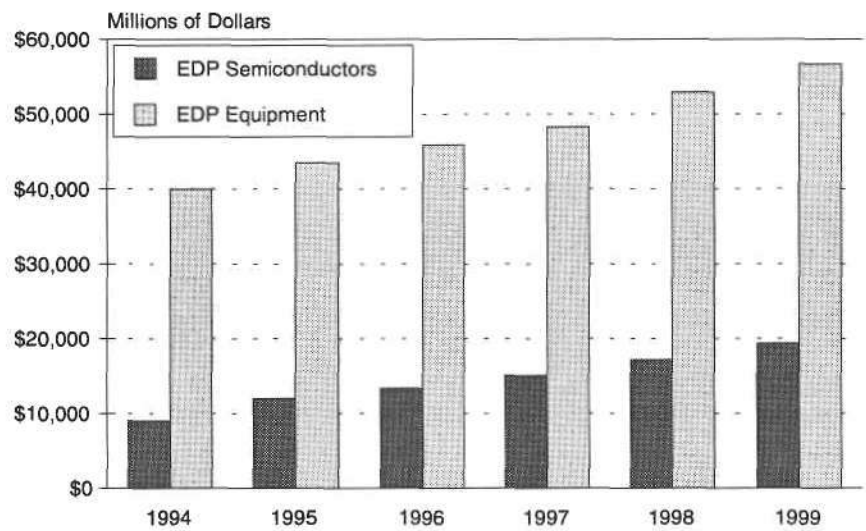
The EDP forecast is heavily dependent on the continued strength of PC production in Europe. All indications show our forecast to be conservative, with expectations that our PC unit production forecast may need to be increased, for the final years of our forecast period. There are two areas which may have a negative impact on the EDP semiconductor forecast. The medium-term forecast relies on memory pricing remaining high, as demand continues to exceed supply. If the demand supply mismatch comes into balance or oversupply, this could have a serious negative affect on memory pricing.

The high-end processor market is dominated by Intel. Intel has had to offer fair pricing for its products to maintain its strategy of rapid introduction and acceptance of each successive generation of microprocessors. Our forecast assumes that the average price of a microprocessor will steadily increase. Intel will not meet much competition, from either the PowerPC or Pentium- and P6-class offerings from AMD, Cyrix, NexGen and UMC.

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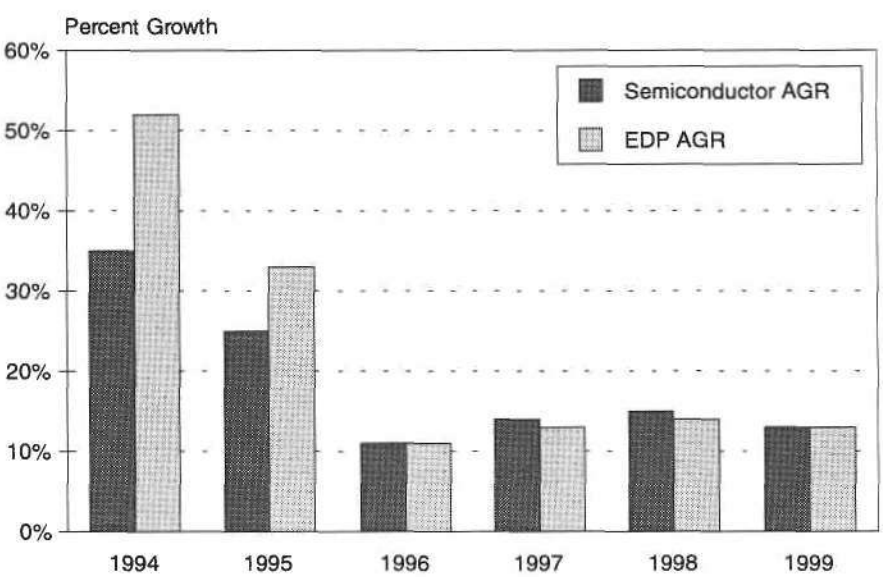
The EDP market also benefits from the expected growth in dedicated systems. This subsegment will show the highest growth rate over the forecast period—20.3 percent CAGR from 1994 to 1999, as shown in Table 3-4. By 1999, semiconductor demand from dedicated systems will have grown to $1.7 billion. Growth here will be provided by the dramatic rise we expect in the production of chip and smart cards in Europe. We estimate that 370 million cards were produced in Europe in 1994, expected to rise to a massive 1.8 billion by 1999. This unit production forecast is conservative. For this forecast, we have assumed that Europe will remain the prime region for smart card production. The semiconductor market could therefore be smaller if production does move outside Europe.

Figure 3-1
European EDP Semiconductor Market versus EDP Equipment Production



Source: Dataquest (July 1995 Estimates)

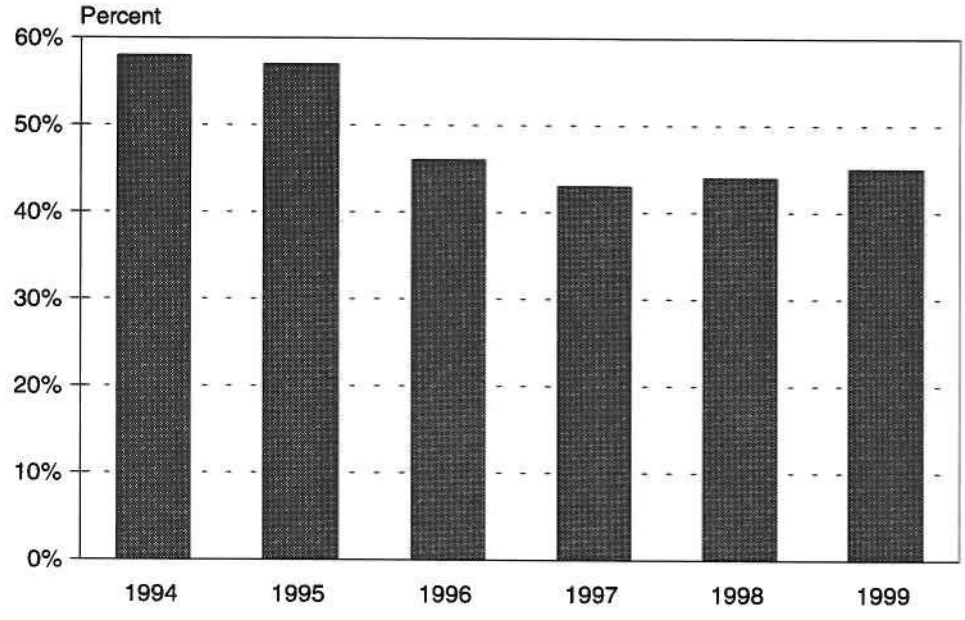
Figure 3-2
Total Semiconductor versus EDP Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

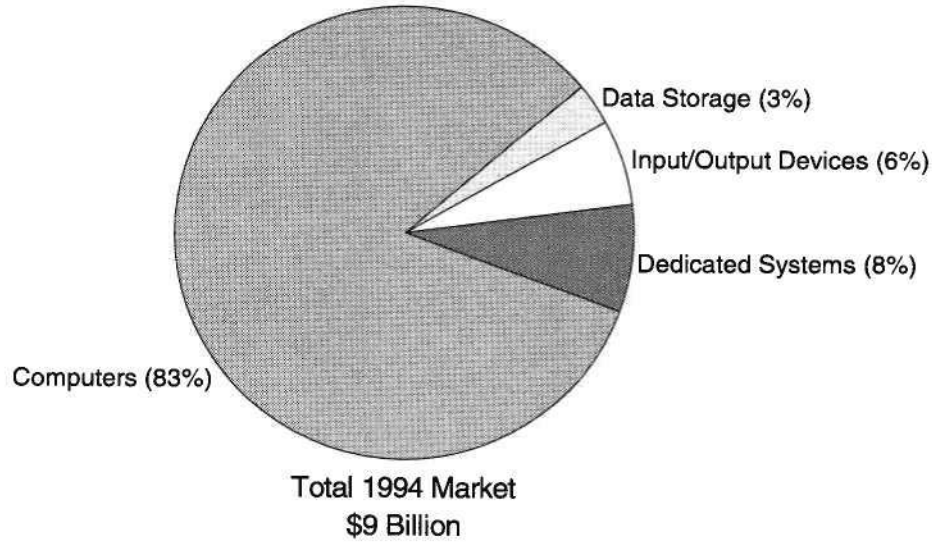
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Figure 3-3
EDP Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

Figure 3-4
1994 European EDP Semiconductor Market by Subsegment



Source: Dataquest (July 1995 Estimates)

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Table 3-1
EDP Segment Summary, European Electronic Equipment Production—History
(Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Electronic Data Processing	**$31,776**	**$37,469**	**$36,859**	**$34,899**	**$37,160**	**$39,982**	**4.7%**
Computers	$24,767	$30,430	$28,719	$26,658	$27,323	$29,401	3.5%
Data Storage	$668	$908	$1,298	$1,418	$1,673	$2,040	25.0%
Input/Ouput Devices	$4,105	$3,879	$4,385	$4,185	$4,877	$4,564	2.1%
Dedicated Systems	$2,236	$2,252	$2,458	$2,639	$3,287	$3,976	12.2%

Source: Dataquest (July 1995 Estimates)

Table 3-2
EDP Segment Summary, European Electronic Equipment Production—Forecast
(Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Electronic Data Processing	**$39,982**	**$43,475**	**$45,875**	**$48,285**	**$52,940**	**$56,715**	**7.2%**
Computers	$29,401	$32,789	$34,773	$37,125	$40,478	$44,066	8.4%
Data Storage	$2,040	$1,797	$1,841	$1,357	$1,252	$1,086	-11.8%
Input/Ouput Devices	$4,564	$4,894	$5,003	$5,516	$6,317	$6,847	8.4%
Dedicated Systems	$3,976	$3,995	$4,259	$4,288	$4,893	$4,715	3.5%

Source: Dataquest (July 1995 Estimates)

Table 3-3
EDP Segment Overview, European Semiconductor Market—History
(Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Electronic Data Processing	**$2,965**	**$2,963**	**$3,136**	**$3,572**	**$5,915**	**$9,010**	**24.9%**
Computers	$2,181	$2,256	$2,425	$2,760	$4,658	$7,501	28.0%
Data Storage	$73	$99	$115	$159	$222	$269	29.7%
Input/Ouput Devices	$464	$395	$379	$397	$541	$551	3.5%
Dedicated Systems	$246	$213	$217	$256	$494	$689	22.9%

Source: Dataquest (July 1995 Estimates)

Table 3-4
EDP Segment Overview, European Semiconductor Market—Forecast
(Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Electronic Data Processing	**$9,010**	**$12,025**	**$13,347**	**$15,042**	**$17,143**	**$19,351**	**16.5%**
Computers	$7,501	$10,394	$11,470	$13,110	$14,665	$16,751	17.4%
Data Storage	$269	$251	$245	$178	$163	$149	-11.2%
Input/Ouput Devices	$551	$621	$627	$613	$644	$716	5.4%
Dedicated Systems	$689	$759	$1,005	$1,141	$1,671	$1,735	20.3%

Source: Dataquest (July 1995 Estimates)

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Chapter 4
Communications

Communications equipment production is forecast to grow at 7 percent CAGR between 1994 and 1999, as shown in Table 4-2. Communications is expected to remain the second-largest single equipment market. It has dominated this position through the period 1989 to 1994, as shown in Table 4-1. Within the communications segment, public telecoms continues to dominate, but we expect this to be overtaken by the mobile/radio communications segment over the forecast period.

Figure 4-1 shows the changing ratio of semiconductor revenue to equipment revenue in the communications segment. In 1994, the ratio was 13.4 percent and this is expected to rise to 21.6 percent in 1999. Figure 4-2 compares the annualized growth rates of the total semiconductor and the communications semiconductor markets. The communications segment will grow faster than the market from 1994 to 1998; beyond this, the market is growing slightly faster than communications. Figure 4-3 shows the annual contribution that communications makes to the growth of the semiconductor market, peaking in 1996 at more than 35 percent.

In 1994, the communications market grew to $5 billion. Figure 4-4 shows this market split by subsegment. Mobile/radio communications has now become the largest subsegment, accounting for 51 percent of the communications market as a whole. The premise telecoms subsegment has now grown to equal the size of public telecoms, both together accounting for a further 40 percent.

Semiconductor consumption in the communications segment has historically been driven by public and premise telecoms. From 1993 onwards the mobile/radio communications segment became the major semiconductor market, as shown in Tables 4-3 and 4-4. The semiconductor consumption of mobile/radio will grow from 17 percent in 1989 to 60 percent in 1999. The reason for this increase is the dramatic rise in the European market and production of cellular handsets and base stations.

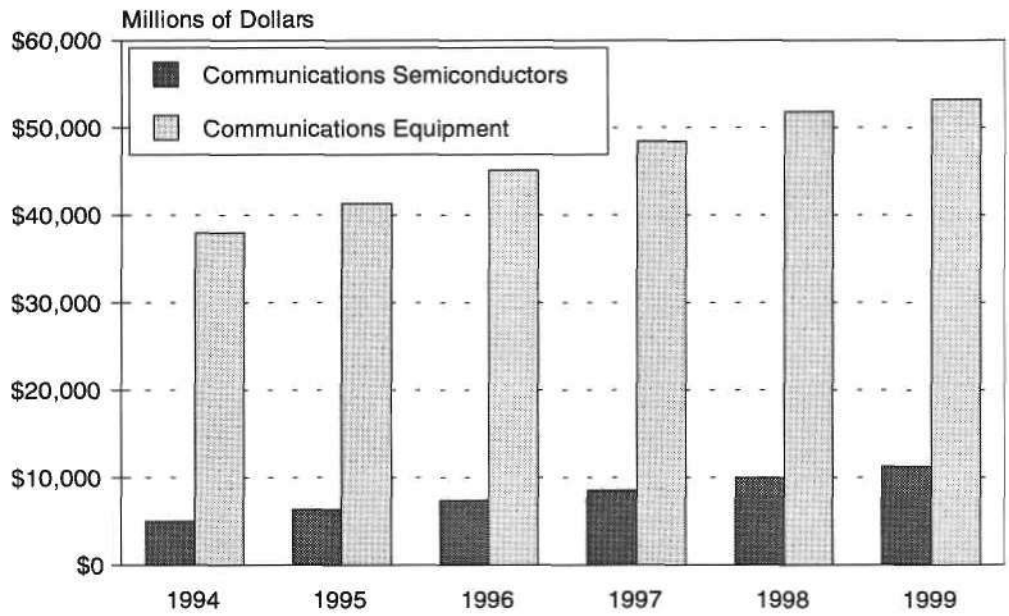
In 1994, European cellular handset semiconductor demand was $800 million, from the 7.4 million handsets produced. We expect production to rise to 32 million units by 1999, driving a $2.4 billion semiconductor market for use in cellular handsets. We estimate the average semiconductor content of a cellular handset to fall from $105 in 1994 to $75 by 1999. These estimates are averages, and there will be some handsets with much lower semiconductor content. The application-specific standard products (ASSPs) developed for digital cellular are complemented by standard commodity memories and microcontrollers. In 1994 the norm was 4MB of flash memory per handset, rising to 8MB in some high-end products. We expect the norm to rise to 16MB by 1999.

Production in cellular telephony will increasingly be digital handsets—more than 95 percent by 1999. This growing cellular semiconductor market is driven by growth of cellular handset production, for both European and export markets. The forecast relies on the continued aggressive growth of the cellular industry. All indications show this new forecast to be conservative; since our last forecast the cellular industry, equipment market and services have grown much faster than expected.

There are two possible scenarios that would revise our forecast downward. This forecast assumes that the majority of European digital cellular demand is provided from European-manufactured handsets. If production moved outside Europe, this would have a major negative impact on the mobile communications subsegment growth and the whole of the communications segment. The forecast also assumes there will be a substantial market for GSM and DCS-1800 products outside Europe, with the majority of this demand being met from European production sites.

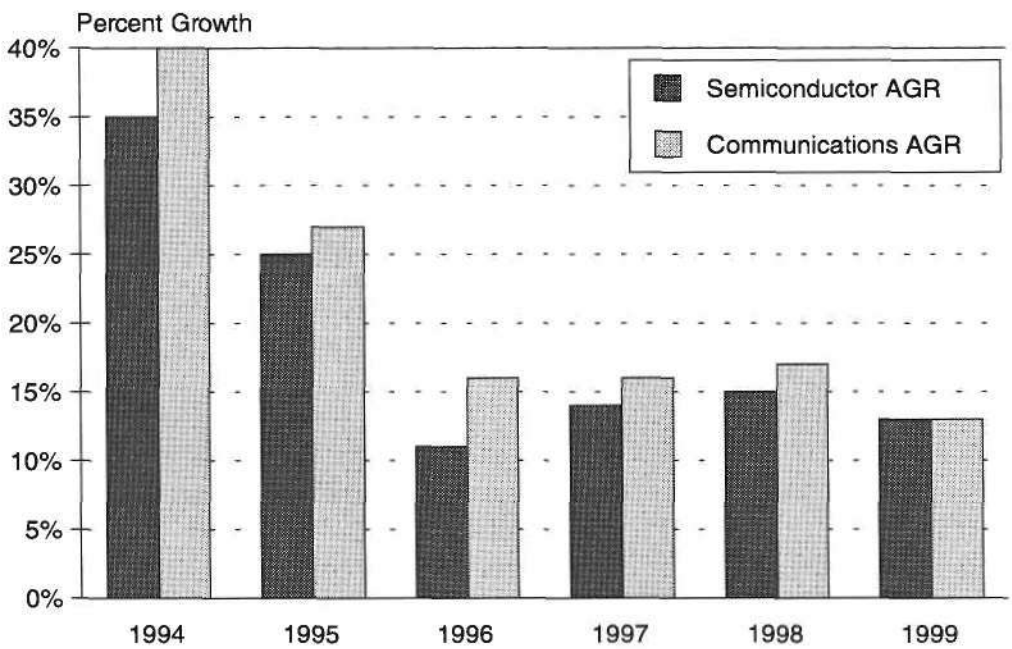
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Figure 4-1
European Communications Semiconductor Market versus Communications Equipment Production



Source: Dataquest (July 1995 Estimates)

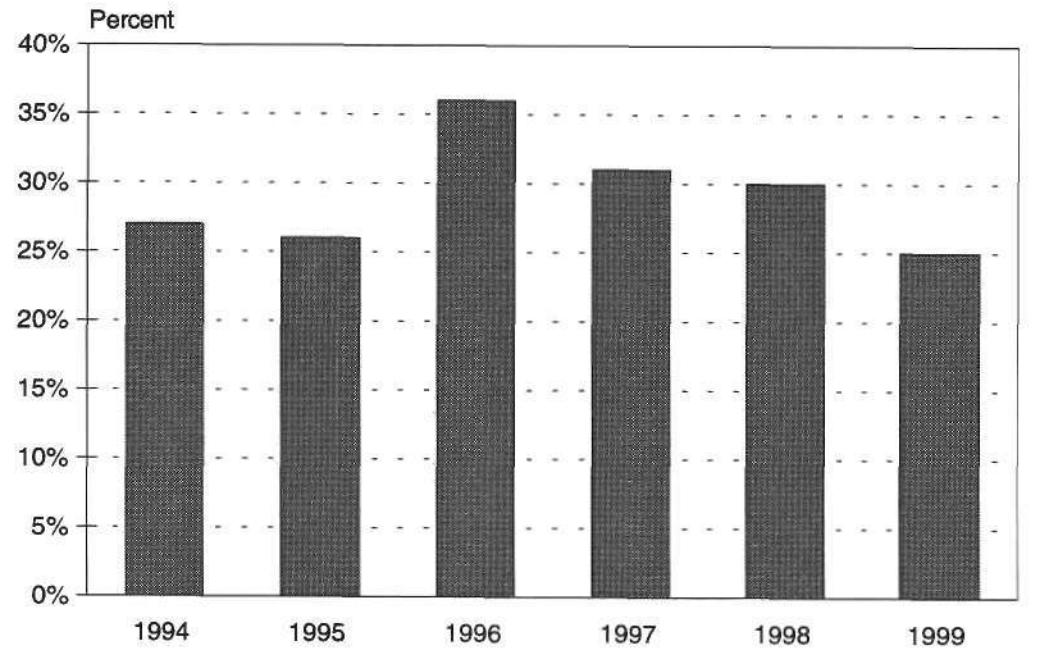
Figure 4-2
Total Semiconductor versus Communications Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

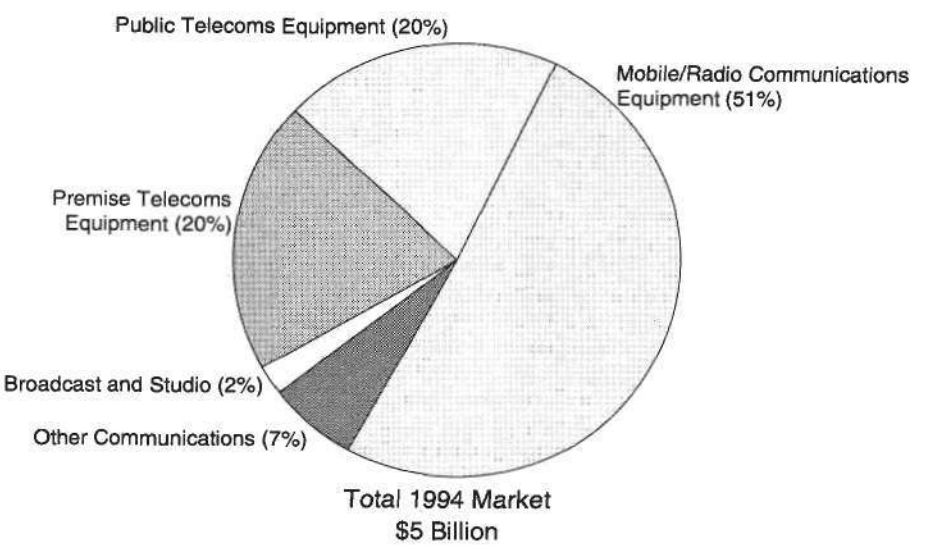
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Figure 4-3
Communications Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

Figure 4-4
1994 European Communications Semiconductor Market by Subsegment



Source: Dataquest (July 1995 Estimates)

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Table 4-1
Communications Segment Summary, European Electronic Equipment Production—History (Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Communications	**$25,030**	**$28,698**	**$31,087**	**$32,899**	**$35,116**	**$37,983**	**8.7%**
Premise Telecoms Equipment	$4,616	$4,943	$5,317	$5,612	$5,798	$6,495	7.1%
Public Telecoms Equipment	$12,587	$14,305	$15,375	$15,186	$15,197	$15,174	3.8%
Mobile/Radio Communications Equipment	$2,286	$2,566	$2,996	$4,793	$8,049	$10,143	34.7%
Other Communications	$4,757	$5,949	$6,510	$6,422	$5,103	$5,337	2.3%
Broadcast and Studio	$784	$935	$890	$885	$970	$834	1.3%

Source: Dataquest (July 1995 Estimates)

Table 4-2
Communications Segment Summary, European Electronic Equipment Production—Forecast (Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Communications	**$37,983**	**$41,317**	**$45,116**	**$48,429**	**$51,813**	**$53,234**	**7.0%**
Premise Telecoms Equipment	$6,495	$7,290	$7,889	$8,613	$9,447	$9,756	8.5%
Public Telecoms Equipment	$15,174	$15,168	$15,186	$15,190	$15,365	$15,534	0.5%
Mobile/Radio Communications Equipment	$10,143	$12,345	$15,122	$17,039	$18,544	$18,899	13.3%
Other Communications	$5,337	$5,665	$5,988	$6,615	$7,459	$8,021	8.5%
Broadcast and Studio	$834	$849	$932	$971	$998	$1,024	4.2%

Source: Dataquest (July 1995 Estimates)

Table 4-3
Communications Segment Overview, European Semiconductor Market—History (Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1994-1999
Communications	**$1,915**	**$2,362**	**$2,567**	**$2,823**	**$3,559**	**$5,000**	**21.2%**
Premise Telecoms Equipment	$603	$683	$746	$780	$845	$1,015	11.0%
Public Telecoms Equipment	$664	$826	$883	$832	$860	$1,005	8.6%
Mobile/Radio Communications Equipment	$326	$418	$510	$818	$1,492	$2,545	50.9%
Other Communications	$266	$346	$350	$319	$264	$325	4.1%
Broadcast and Studio	$56	$89	$79	$74	$98	$109	14.4%

Source: Dataquest (July 1995 Estimates)

Table 4-4
Communications Segment Overview, European Semiconductor Market—Forecast (Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Communications	**$5,000**	**$6,347**	**$7,359**	**$8,564**	**$9,991**	**$11,245**	**17.6%**
Premise Telecoms Equipment	$1,015	$1,257	$1,420	$1,610	$1,829	$2,001	14.5%
Public Telecoms Equipment	$1,005	$1,210	$1,324	$1,452	$1,589	$1,669	10.7%
Mobile/Radio Communications Equipment	$2,545	$3,347	$4,017	$4,830	$5,817	$6,756	21.6%
Other Communications	$325	$400	$449	$505	$570	$618	13.7%
Broadcast and Studio	$109	$133	$149	$166	$186	$201	13.0%

Source: Dataquest (July 1995 Estimates)

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Chapter 5
Industrial

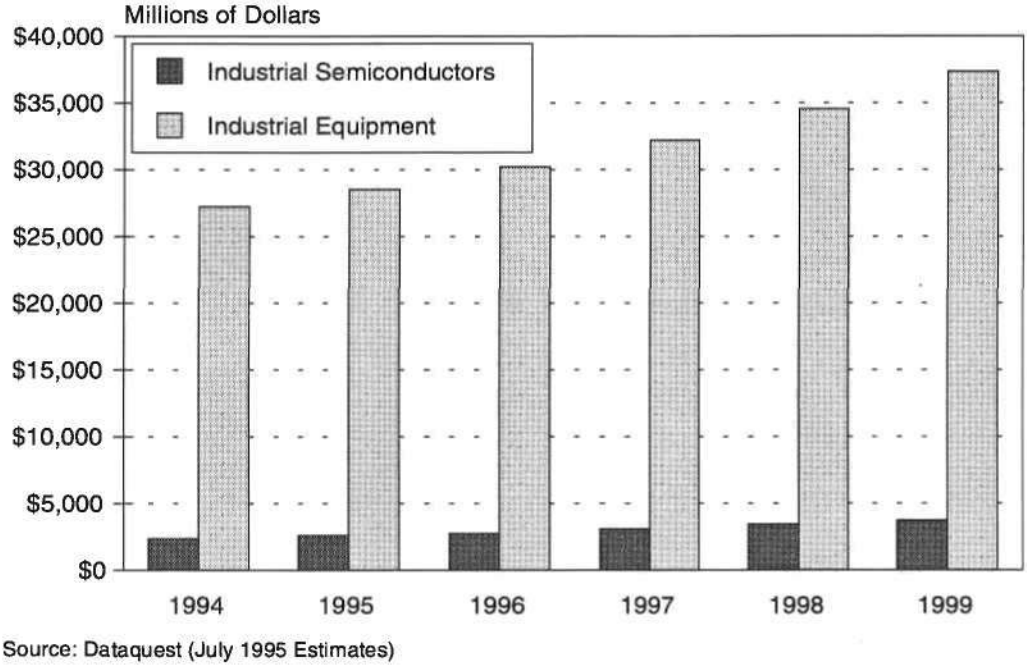
Industrial electronic equipment production is expected to grow at 6.5 percent CAGR between 1994 and 1999, as shown in Table 5-2. Historically, the industrial segment has been the third-largest equipment market for semiconductors, and we expect this continue throughout the forecast period, (see Tables 5-1 and 5-2).

Figure 5-1 shows the changing ratio of semiconductor revenue to equipment revenue in the industrial segment. In 1994, the ratio was 8.6 percent and will show a modest increase to 10 percent in 1999. Figure 5-2 compares the annualized growth rates of the total semiconductor and the industrial semiconductor markets, showing that the industrial segment is growing at a slower rate than the market as whole throughout the forecast period. The annual growth rate will show signs of improvement. Figure 5-3 shows the limited annual contribution to growth that industrial applications give the semiconductor market.

In 1994, the industrial semiconductor market grew to $2.35 billion. Figure 5-4 shows the market split by subsegment. The manufacturing and instrumentation systems subsegment dominates, accounting for 60 percent of this market. Medical electronics is the second-biggest segment at 16 percent, followed by security/energy management systems at 12 percent.

Within the industrial segment, the manufacturing and instrumentation segment dominates, and semiconductor consumption in this subsegment has been the main driver for growth in industrial applications. The fastest-growing segment is security and energy management systems, forecast to grow at 9.8 percent CAGR from 1994 to 1999, as shown in Tables 5-3 and 5-4.

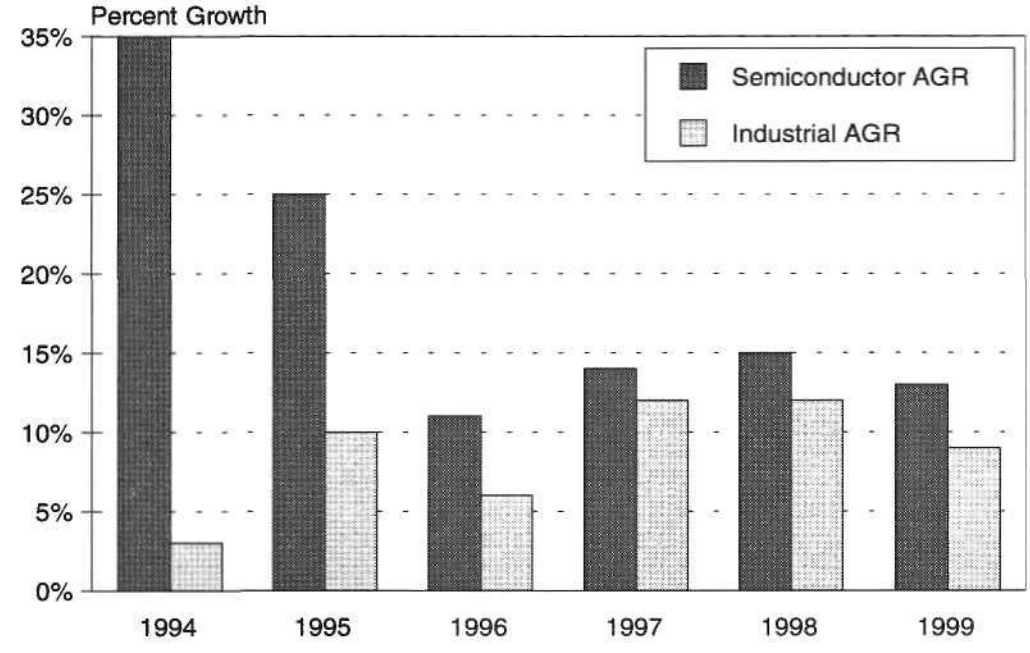
Figure 5-1
European Industrial Semiconductor Market versus Industrial Equipment Production



Source: Dataquest (July 1995 Estimates)

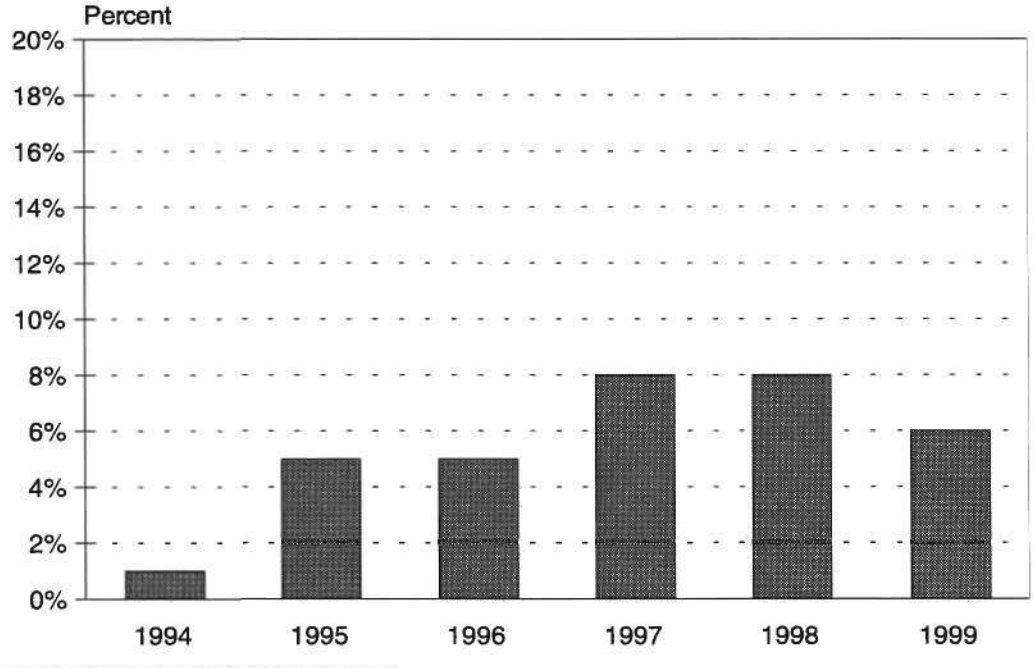
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Figure 5-2
Total Semiconductor versus Industrial Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

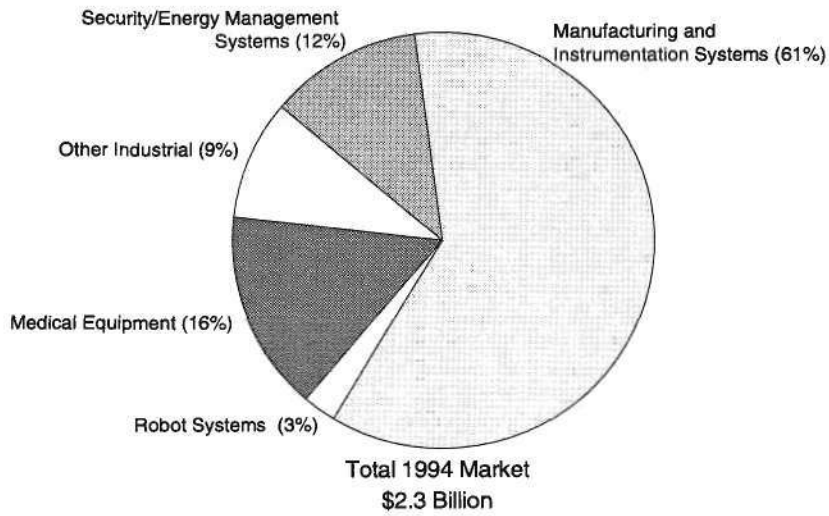
Figure 5-3
Industrial Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

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Figure 5-4
1994 European Industrial Semiconductor Market by Subsegment



Source: Dataquest (July 1995 Estimates)

Table 5-1
Industrial Segment Summary, European Electronic Equipment Production—History (Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Industrial	**$21,244**	**$26,078**	**$26,196**	**$27,491**	**$26,295**	**$27,217**	**5.1%**
Security/Energy Management Systems	$2,587	$2,566	$2,594	$2,668	$2,600	$2,730	1.1%
Manufacturing and Instrumentation Systems	$11,704	$15,698	$15,716	$16,448	$15,553	$15,964	6.4%
Robot Systems	$665	$689	$733	$790	$819	$871	5.5%
Medical Equipment	$2,941	$3,700	$3,692	$4,025	$3,941	$4,169	7.2%
Other Industrial	$3,347	$3,425	$3,461	$3,560	$3,382	$3,483	0.8%

Source: Dataquest (July 1995 Estimates)

Table 5-2
Industrial Segment Summary, European Electronic Equipment Production—Forecast (Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Industrial	**$27,217**	**$28,525**	**$30,196**	**$32,202**	**$34,539**	**$37,359**	**6.5%**
Security/Energy Management Systems	$2,730	$2,921	$3,184	$3,534	$3,923	$4,355	9.8%
Manufacturing and Instrumentation Systems	$15,964	$16,602	$17,432	$18,478	$19,772	$21,354	6.0%
Robot Systems	$871	$938	$1,014	$1,105	$1,215	$1,349	9.1%
Medical Equipment	$4,169	$4,440	$4,726	$4,976	$5,192	$5,465	5.6%
Other Industrial	$3,483	$3,623	$3,840	$4,109	$4,438	$4,837	6.8%

Source: Dataquest (July 1995 Estimates)

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Table 5-3
Industrial Segment Overview, European Semiconductor Market—History
(Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Industrial	**$1,685**	**$1,917**	**$1,979**	**$2,152**	**$2,278**	**$2,350**	**6.9%**
Security/Energy Management Systems	$182	$182	$197	$228	$249	$278	8.7%
Manufacturing and Instrumentation Systems	$981	$1,182	$1,232	$1,319	$1,414	$1,429	7.8%
Robot Systems	$45	$45	$48	$53	$56	$61	6.3%
Medical Equipment	$246	$298	$297	$336	$345	$365	8.2%
Other Industrial	$231	$211	$206	$216	$214	$218	-1.1%

Source: Dataquest (July 1995 Estimates)

Table 5-4
Industrial Segment Overview, European Semiconductor Market—Forecast
(Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Industrial	**$2,350**	**$2,589**	**$2,736**	**$3,066**	**$3,431**	**$3,725**	**9.7%**
Security/Energy Management Systems	$278	$326	$365	$433	$510	$573	15.6%
Manufacturing and Instrumentation Systems	$1,429	$1,553	$1,633	$1,828	$2,051	$2,242	9.4%
Robot Systems	$61	$69	$73	$82	$92	$100	10.6%
Medical Equipment	$365	$405	$420	$451	$477	$487	6.0%
Other Industrial	$218	$236	$244	$271	$301	$324	8.2%

Source: Dataquest (July 1995 Estimates)

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Chapter 6
Consumer

Consumer electronics equipment production is expected to grow at 5.7 percent CAGR between 1994 and 1999, as shown in Table 6-2. This growth is in contrast to the limited growth of 2.4 percent between 1989 and 1994 shown in Table 6-1.

Figure 6-1 shows the changing ratio of semiconductor revenue to equipment revenue in the consumer segment. In 1994, the ratio was 10.8 percent, and this is expected to rise to 15 percent in 1999. Figure 6-2 compares the annualized growth rates of the total semiconductor and the consumer semiconductor markets. The consumer segment falls behind the total market growth in 1994, 1995 and 1996; beyond this, consumer makes a strong recovery. The annual growth rate slowly increases after 1996; Figure 6-3 shows the contribution that consumer applications make to the growth of the semiconductor market.

In 1994, the consumer semiconductor market grew to $2.3 billion. Figure 6-4 shows this market split by subsegment. The video subsegment continues to dominate, now accounting for 67 percent of this market. Audio continues as the second-largest subsegment, now accounting for 16 percent.

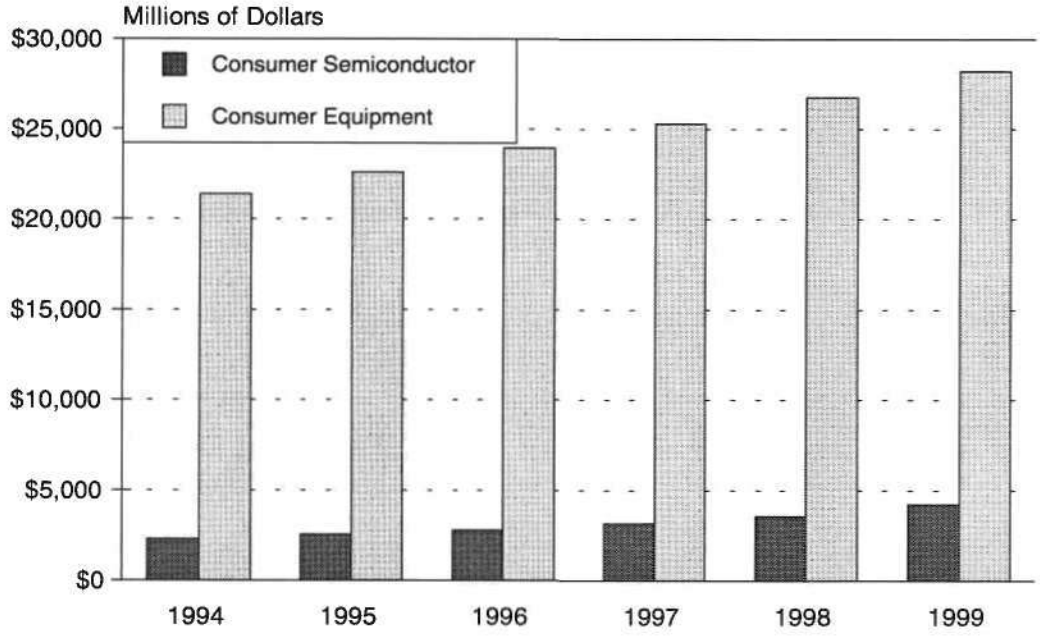
Within the consumer segment, the video subsegment dominates. Semiconductor consumption by the video segment has been the main driver for growth in consumer. Tables 6-3 and 6-4 show how the semiconductor consumption of video will grow from 67 percent in 1989 to 70 percent in 1999. The reason for this increase is the new market opportunity for set-top boxes and the trend to digitize consumer video electronics. The consumer video subsegment includes color (CTV) and black-and-white TVs, VCRs, camcorders, and cable and satellite set-top boxes.

In 1994, European color TV semiconductor demand was $888 million, from the 19.7 million CTVs produced. We expect CTV production to rise to 21.3 million units by 1999 driving a $1.4 billion CTV semiconductor market. This growing CTV semiconductor market is driven partly by an increase in unit production but also by the trend to increase features in European-produced CTVs. The features in these high-end CTVs include automatic tuning, NiCAM, Dolby surround sound, and teletext/fastext. The trend to digitization of CTVs will begin to have an impact towards the end of the forecast period.

The consumer forecast is heavily dependent on the continued strength of CTV production in Europe. Also, we expect set-top box production in Europe to make a significant contribution to growth of the video semiconductor market. The consumer semiconductor forecast could be affected by two factors. If the introduction of digital broadcasting in Europe is delayed, this could reduce the growth of the video semiconductor market. The forecast growth also relies on the successful introduction of digital set-top boxes, which are the delivery mechanism for video-on-demand (VOD)–style services from cable and satellite operators. These VOD services require heavy investment in the infrastructure from the operators. VOD will also be used to deliver additional services, such as the much-discussed home banking and home shopping. Trials currently taking place will determine the consumer demand for these new products and services, and should they fail to prove a compelling need exists, the forecast may be optimistic.

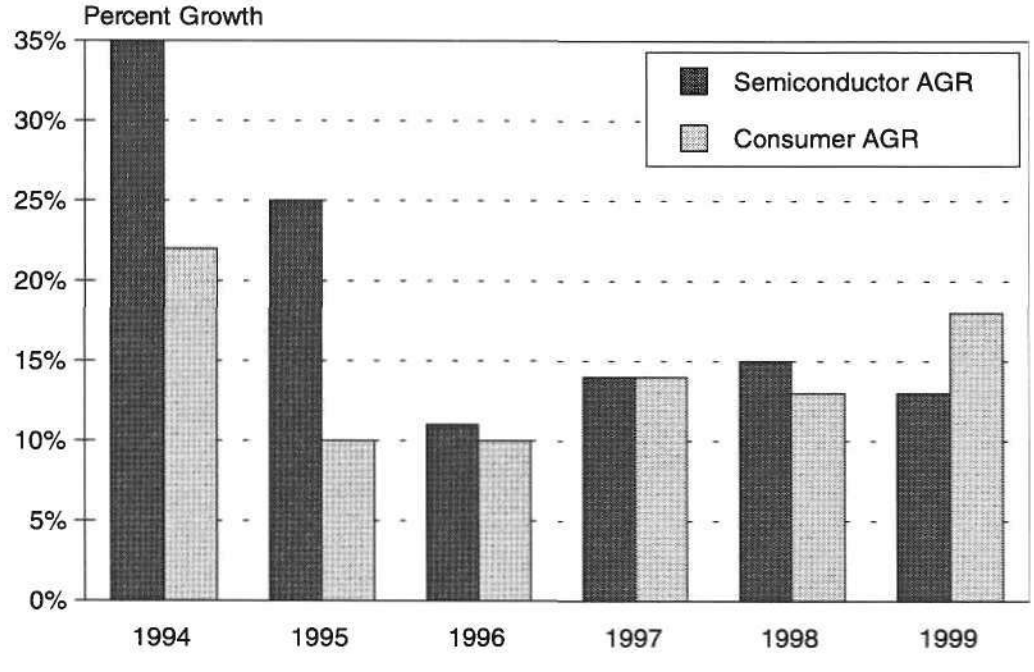
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Figure 6-1
European Consumer Semiconductor Market versus Consumer Equipment Production



Source: Dataquest (July 1995 Estimates)

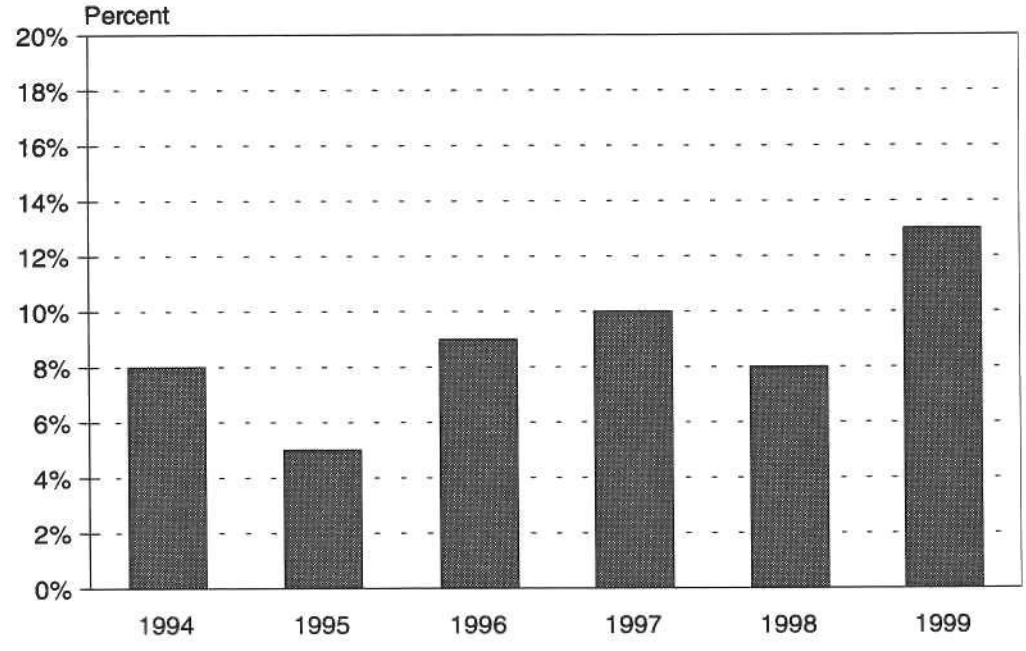
Figure 6-2
Total Semiconductor versus Consumer Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

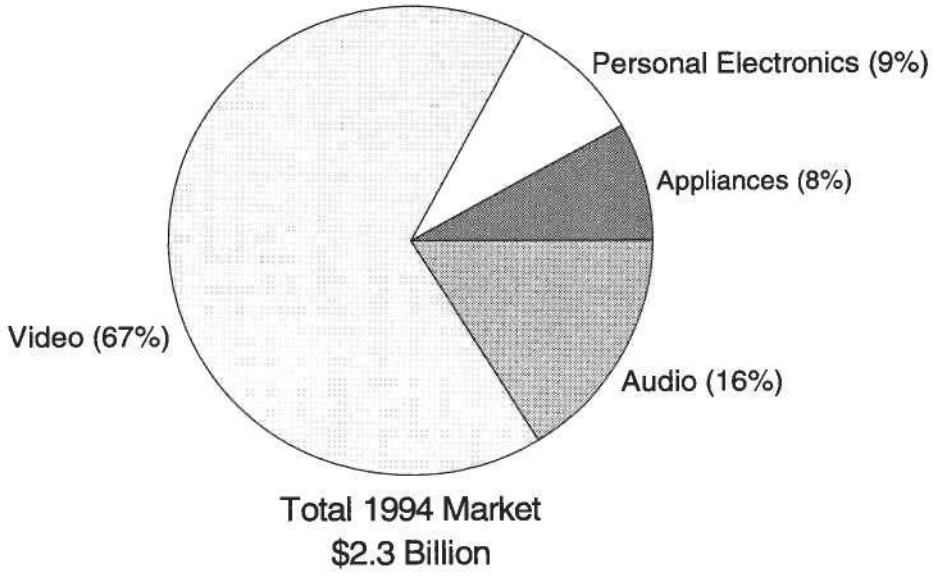
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Figure 6-3
Consumer Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

Figure 6-4
1994 European Consumer Semiconductor Market by Subsegment



Source: Dataquest (July 1995 Estimates)

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Table 6-1
Consumer Segment Summary, European Electronic Equipment Production—History
(Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Consumer	**$18,964**	**$19,606**	**$20,410**	**$19,450**	**$20,415**	**$21,389**	**2.4%**
Audio	$1,394	$1,543	$1,463	$1,352	$1,299	$1,517	1.7%
Video	$4,679	$4,905	$5,648	$5,108	$5,465	$6,000	5.1%
Personal Electronics	$944	$1,148	$1,109	$1,161	$1,207	$1,380	7.9%
Appliances	$11,948	$12,010	$12,190	$11,829	$12,445	$12,492	0.9%

Source: Dataquest (July 1995 Estimates)

Table 6-2
Consumer Segment Summary, European Electronic Equipment Production—Forecast
(Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Consumer	**$21,389**	**$22,595**	**$23,949**	**$25,305**	**$26,753**	**$28,217**	**5.7%**
Audio	$1,517	$1,659	$1,766	$1,937	$2,091	$2,225	8.0%
Video	$6,000	$6,692	$7,543	$8,238	$9,026	$9,907	10.6%
Personal Electronics	$1,380	$1,462	$1,551	$1,658	$1,752	$1,848	6.0%
Appliances	$12,492	$12,782	$13,089	$13,471	$13,884	$14,237	2.6%

Source: Dataquest (July 1995 Estimates)

Table 6-3
Consumer Segment Overview, European Semiconductor Market—History
(Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Consumer	**$1,795**	**$1,883**	**$1,951**	**$2,137**	**$1,938**	**$2,300**	**5.1%**
Audio	$328	$359	$381	$445	$326	$372	2.6%
Video	$1,209	$1,215	$1,249	$1,283	$1,257	$1,532	4.8%
Personal Electronics	$140	$171	$166	$217	$184	$209	8.4%
Appliances	$118	$138	$155	$193	$171	$187	9.6%

Source: Dataquest (July 1995 Estimates)

Table 6-4
Consumer Segment Overview, European Semiconductor Market—Forecast
(Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Consumer	**$2,300**	**$2,541**	**$2,783**	**$3,163**	**$3,571**	**$4,229**	**13.0%**
Audio	$372	$399	$414	$478	$555	$601	10.1%
Video	$1,532	$1,722	$1,928	$2,181	$2,455	$2,971	14.2%
Personal Electronics	$209	$218	$223	$249	$270	$300	7.5%
Appliances	$187	$202	$218	$255	$291	$356	13.8%

Source: Dataquest (July 1995 Estimates)

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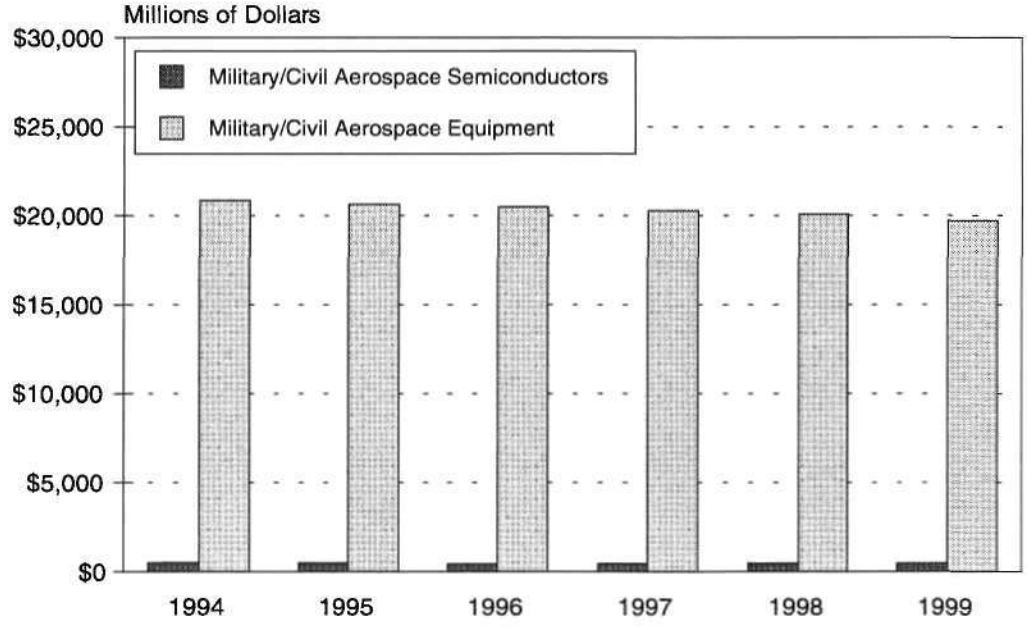
Chapter 7
Military and Civil Aerospace

Military and civil aerospace electronic equipment production is expected to decline at 1.1 percent CAGR between 1994 and 1999, as shown in Table 7-1. This segment is expected to decline in importance; the very limited growth in civil aerospace business has been masked by a more rapid decline in military electronics.

Historically, semiconductor consumption by this segment has performed badly, growing only 0.2 percent CAGR 1989 to 1994, as shown in Table 7-2; and we now expect a decline of 1.4 percent CAGR over the forecast period.

Figure 7-1 shows the changing ratio of semiconductor revenue to equipment revenue in the military and civil aerospace segment. In 1994, the ratio was 16.6 percent, and this is expected to rise to 20 percent in 1999. Figure 7-2 compares the annualized growth rates of the total semiconductor and the military and civil aerospace semiconductor markets. The military and civil aerospace segment, albeit in decline, will show small amounts of growth at the end of the forecast period. Figure 7-3 shows the contribution military and civil aerospace makes to the overall growth of the semiconductor market, although its contribution will diminish over the period.

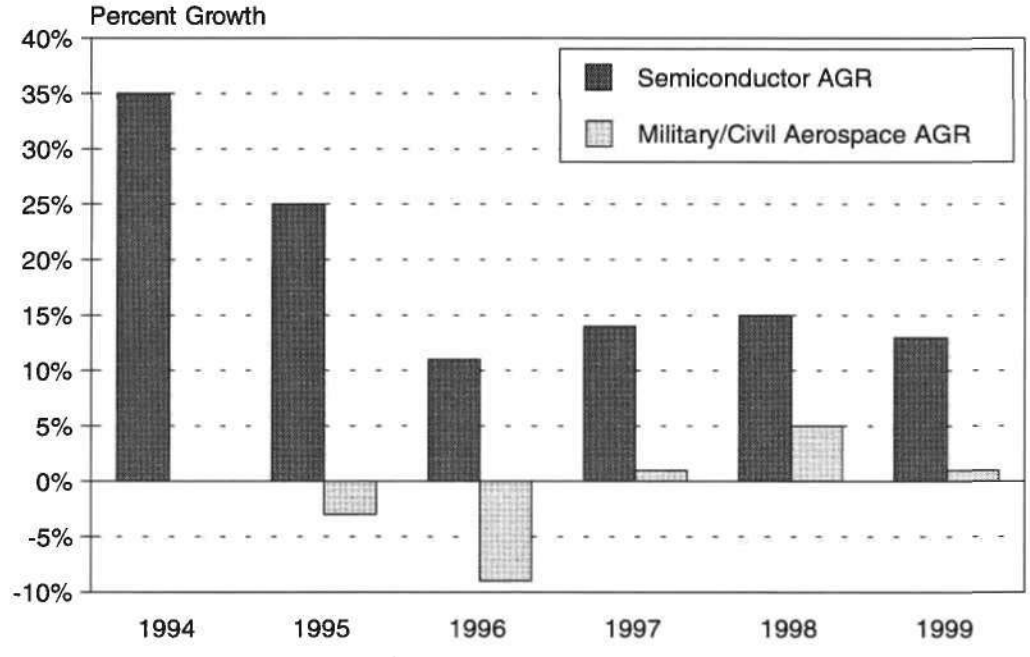
Figure 7-1
European Military and Civil Aerospace Semiconductor Market versus Military and Civil Aerospace Equipment Production



Source: Dataquest (July 1995 Estimates)

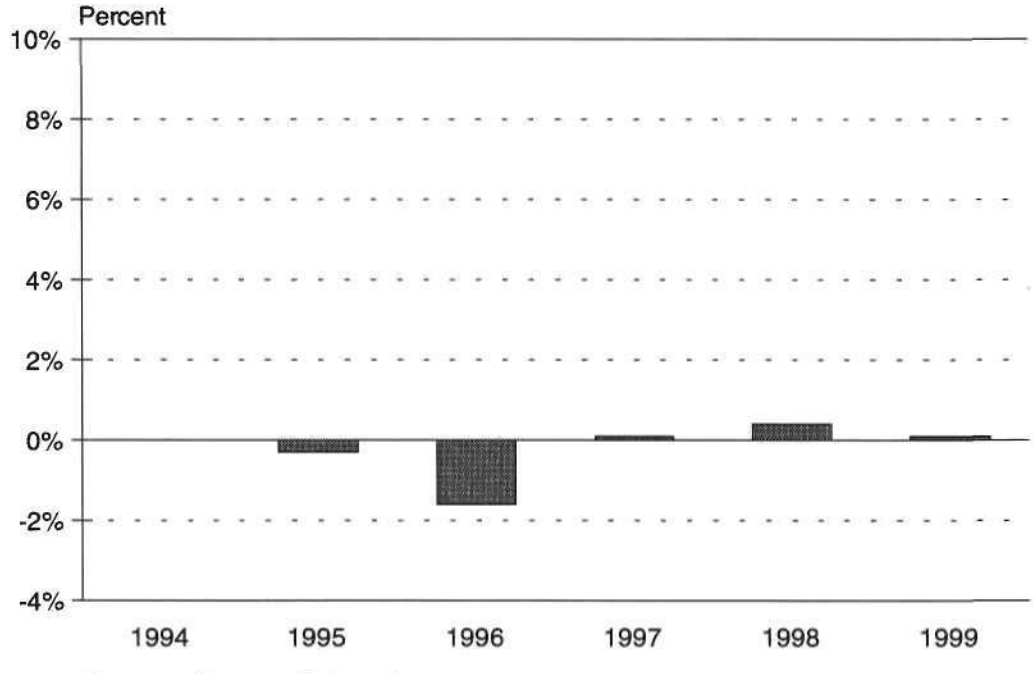
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Figure 7-2
Total Semiconductor versus Military and Civil Aerospace Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

Figure 7-3
Military and Civil Aerospace Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

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Table 7-1
Military and Civil Aerospace Segment Summary, European Electronic Equipment Production—History and Forecast
(Ex-Factory Revenues, Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Military and Civil Aerospace	$21,749	$20,976	$21,171	$21,055	$21,447	$20,851	-0.8%
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**CAGR 1994-1999**
Military and Civil Aerospace	$20,851	$20,628	$20,489	$20,275	$20,075	$19,719	-1.1%

Source: Dataquest (July 1995 Estimates)

Table 7-2
Military and Civil Aerospace Segment Overview, European Semiconductor Market—History and Forecast
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Military and Civil Aerospace	$498	$478	$488	$515	$504	$504	0.2%
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**CAGR 1994-1999**
Military and Civil Aerospace	$504	$490	$443	$448	$468	$471	-1.4%

Source: Dataquest (July 1995 Estimates)

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Chapter 8
Transportation

Transportation (automotive) electronic equipment production is expected to grow at 12 percent CAGR between 1994 and 1999, as shown in Table 8-2. Automotive will remain the smallest single equipment market, although by 1999 it will be close in size to the military and civil aerospace segment. We could well see automotive moving to fifth place early in the next century. The automotive segment has grown faster than any other, with a corresponding increase in semiconductor demand from these applications, and this growth will continue throughout the forecast period, as shown in Table 8-3.

Figure 8-1 shows the changing ratio of semiconductor revenue to equipment revenue in the automotive segment. In 1994, the ratio was 16.6 percent and this is expected to rise to 20 percent in 1999. Figure 8-2 compares the annualized growth rates of the total semiconductor and the automotive semiconductor markets. The automotive segment although growing fast, could not match the market in 1994; beyond this, automotive nearly always outperforms the market. Although the annual growth rate will slow down, Figure 8-3 shows the annual contribution to growth automotive makes to the semiconductor market.

In 1994, the automotive semiconductor market grew to $1.65 billion. Figure 8-4 shows this market split by subsegment. Powertrain and safety and convenience dominate, together accounting for 64 percent of this segment. Driver information systems will become increasingly important in the future, but already account for 19 percent in 1994. In-car entertainment still remains a large market, but the other subsegments are growing much faster, leaving this subsegment only 7 percent of the market in 1994.

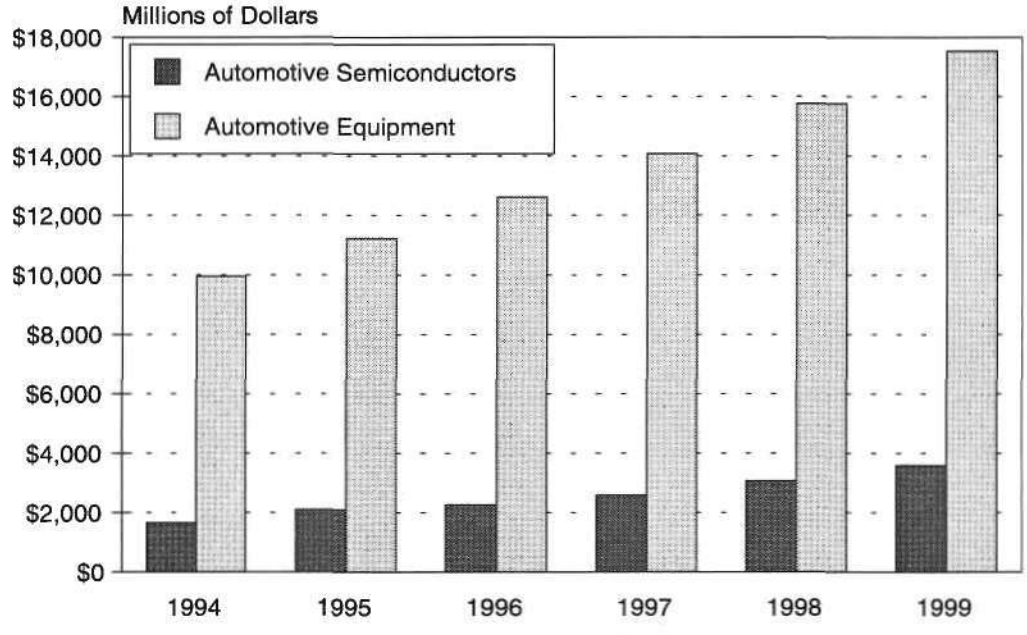
Within the automotive segment the powertrain subsegment dominates. Semiconductor consumption by the automotive segment has consistently shown high growth, as shown in Table 8-3. From 1989 to 1994 semiconductor demand from automotive applications grew by 21 percent CAGR. A high growth rate is expected throughout the forecast period—nearly 17 percent CAGR from 1994 to 1999. The ever-increasing demand for semiconductors by the automotive electronics industry will push the market to $3.6 billion by 1999. This is just $150 million behind the industrial segment, and we therefore expect the automotive segment to become the fourth-largest market by the year 2000. The reason for this increase is that European-produced cars are expected to increase their semiconductor content from an average of $100 in 1994 towards $200 by 1999.

In 1994, powertrain systems and safety and convenience systems are the largest semiconductor markets at $498 and $574 million respectively. Powertrain systems, which include engine management systems, fuel management systems and electronic ignition systems, constitute the most established of all the automotive subsegments. Electronic ignition systems are particularly dominant here, with European unit production expected to rise from 9.5 million in 1994 to 16.8 million in 1999.

The safety and convenience subsegment is dominated by airbag and antilock braking systems (ABS). ABS systems are now being fitted to low-end and midrange cars, increasing the unit demand. European unit production rose from 5.2 million in 1994 to 8.3 million in 1999.

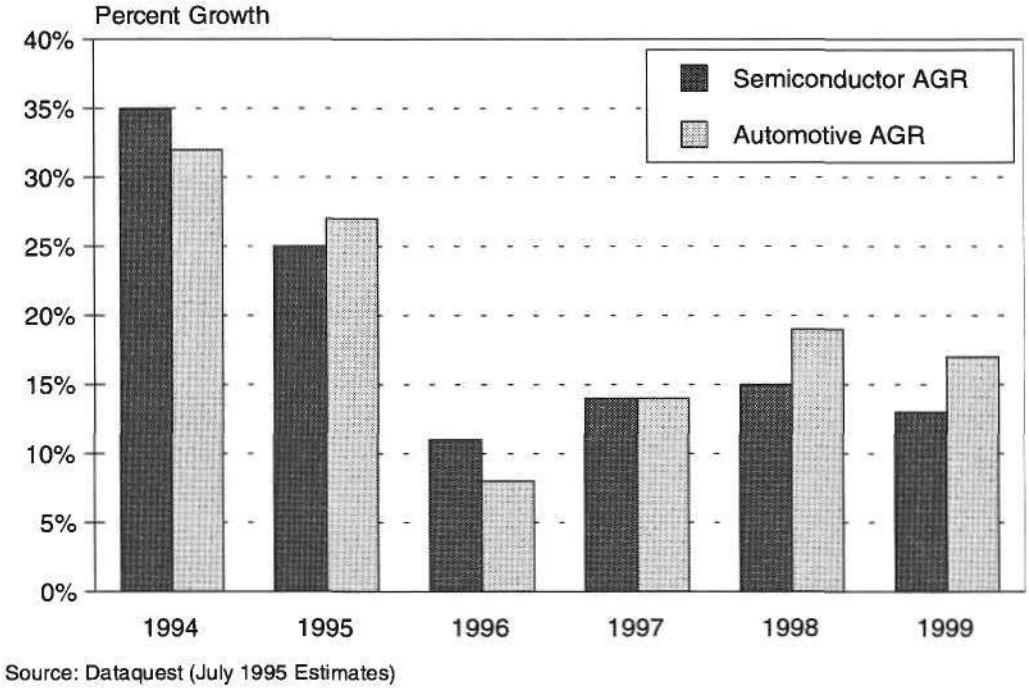
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Figure 8-1
European Transportation Semiconductor Market versus Transportation Equipment Production



Source: Dataquest (July 1995 Estimates)

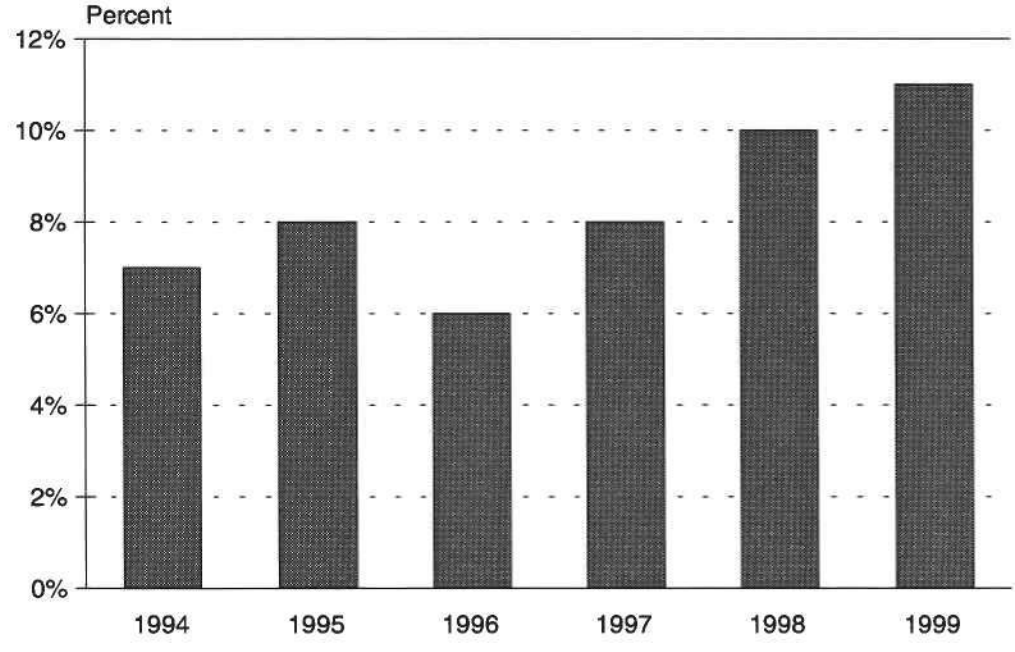
Figure 8-2
Total Semiconductor versus Transportation Semiconductor Market Annual Growth Rates in Europe



Source: Dataquest (July 1995 Estimates)

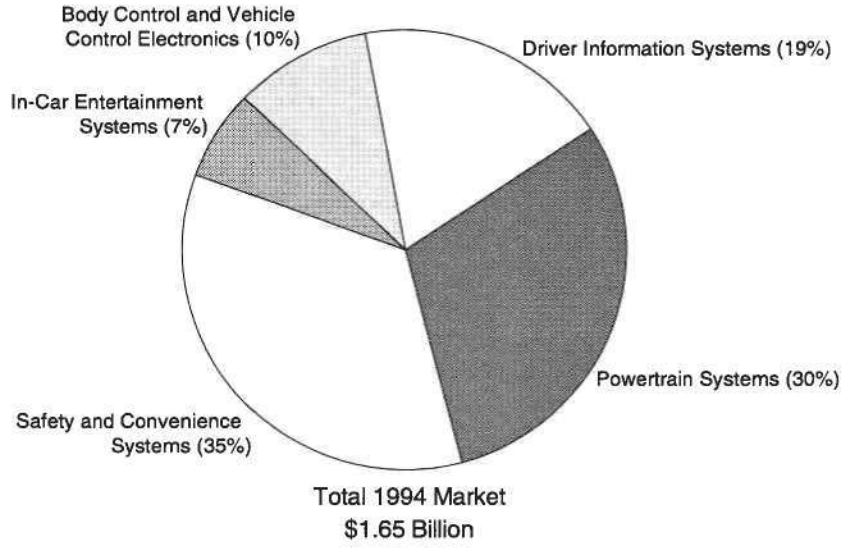
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Figure 8-3
Transportation Contribution to Semiconductor Growth in Europe



Source: Dataquest (July 1995 Estimates)

Figure 8-4
1994 European Transportation Semiconductor Market by Subsegment



Source: Dataquest (July 1995 Estimates)

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Table 8-1
Transportation Segment Summary, European Electronic Equipment Production—History (Ex-Factory Revenues, Millions of Dollars)

Segment	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Transportation	**$5,191**	**$6,262**	**$6,818**	**$7,809**	**$8,558**	**$9,953**	**13.9%**
In-Car Entertainment Systems	$447	$525	$541	$602	$648	$686	8.9%
Body Control and Vehicle Control Electronics	$734	$979	$1,042	$1,154	$1,258	$1,297	12.1%
Driver Information Systems	$717	$851	$918	$1,037	$1,105	$1,404	14.4%
Powertrain Systems	$2,145	$2,538	$2,755	$3,157	$3,360	$3,558	10.6%
Safety and Convenience Systems	$1,148	$1,369	$1,561	$1,860	$2,187	$3,008	21.2%

Source: Dataquest (July 1995 Estimates)

Table 8-2
Transportation Segment Summary, European Electronic Equipment Production—Forecast (Ex-Factory Revenues, Millions of Dollars)

Segment	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Transportation	**$9,953**	**$11,231**	**$12,606**	**$14,075**	**$15,763**	**$17,538**	**12.0%**
In-Car Entertainment Systems	$686	$772	$847	$926	$1,026	$1,135	10.6%
Body Control and Vehicle Control Electronics	$1,297	$1,383	$1,433	$1,490	$1,654	$1,778	6.5%
Driver Information Systems	$1,404	$1,646	$1,859	$2,050	$2,242	$2,465	11.9%
Powertrain Systems	$3,558	$3,807	$4,132	$4,446	$4,700	$4,935	6.8%
Safety and Convenience Systems	$3,008	$3,623	$4,335	$5,163	$6,142	$7,225	19.2%

Source: Dataquest (July 1995 Estimates)

Table 8-3
Transportation Segment Overview, European Semiconductor Market—History and Forecast (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Transportation	$640	$812	$893	$1,018	$1,256	$1,655	20.9%

	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Transportation	$1,655	$2,096	$2,264	$2,579	$3,067	$3,586	16.7%

Source: Dataquest (July 1995 Estimates)

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Market
Analysis



Semiconductors Application Markets Europe

Market Analysis

Final 1994 European Market Share Ranking by Application

Abstract: *It was a particularly strong year in 1994 for companies with microprocessor and DRAM memory products, these products excelling in a year when the market was driven by personal computer production. Cellular telephone handsets have also emerged in the communications segment, and discrete devices from the automotive and industrial market segments are expected to be another growth area in the future. Highlighting these and other trends, this report analyses vendor market share results in 1994 in the six semiconductor application segments.*

Executive Summary

Dataquest estimates that the overall semiconductor market growth in 1994 over 1993 was 34.8 percent. Strongest growths were seen in the segments of electronic data processing (EDP) at 52.3 percent, and communications (40.5 percent). The transportation (automotive) segment also showed significant growth (31.8 percent), albeit slightly below market average (see Table 1). The military/aerospace (0 percent), industrial (3.2 percent) and consumer (18.7 percent) segments all grew below the market average. Personal computers continued to drive market growth in data processing, while cellular telephones emerged as a market growth driver in the communications segment. The EDP segment continues to drive the European semiconductor market (see Figure 1) with an unending increase in market share (43 percent) of the total market in 1994 (compared with 38 percent in 1993).

Survey Results

PCs, Mobile Communications and Automotive Electronics Drive Industry Growth

Figure 1 shows an overview of the historical semiconductor market trends by end-use application markets from 1988 to 1994. Over the historical period, the EDP market segment has maintained its lead by growing market share. The last three years have witnessed dramatic growth in the EDP, communications and transportation market segments.

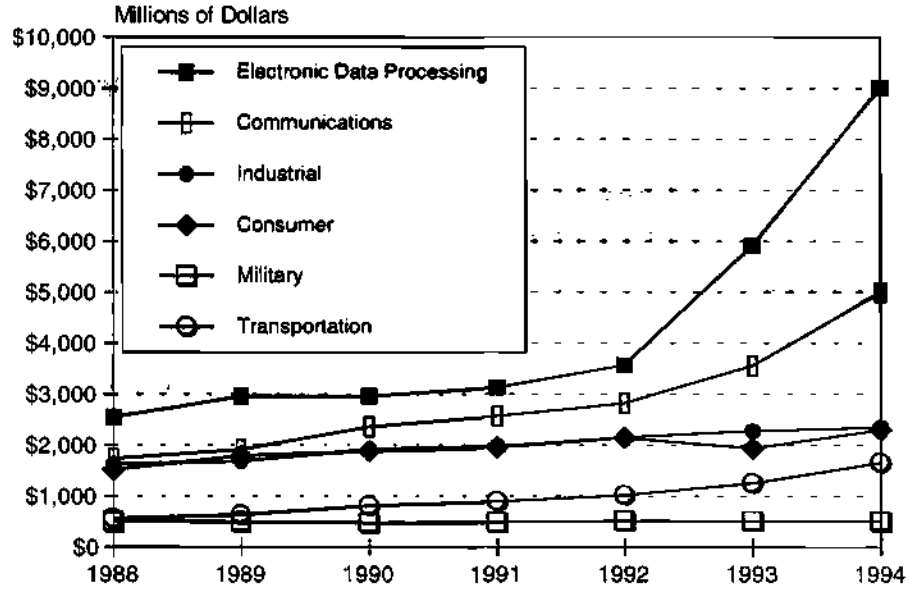
The European semiconductor market is now very dependent on the EDP and communications market segments. PCs and cellular telephones have been the two single engines of growth in each of these markets that have influenced,

Table 1
1993 and 1994 European Semiconductor Market by End-Use Application Market Segment
(Millions of Dollars)

End-Use Market Segment	1993 (these span) Revenue	1993 (these span) Percent of Total	1994 Revenue	1994 Percent of Total
Electronic Data Processing	5,915	38.3	9,010	43.3
Communications	3,559	23.0	5,000	24.0
Industrial	2,278	14.7	2,350	11.3
Consumer	1,938	12.5	2,300	11.0
Military/Civil Aerospace	504	3.3	504	2.4
Transportation	1,256	8.1	1,655	7.9
Total	$15,450	100.0	20,819	100.0

Source: Dataquest (July 1995 Estimates)

Figure 1
European Semiconductor Market by End-Use Application Market Segment



Source: Dataquest (July 1995 Estimates)

most significantly, the spectacular growths seen during 1993 and 1994. Transportation is mostly automotive applications, and this too has demonstrated very buoyant growth, albeit at a lower rate than EDP and communications. The importance of transportation electronics is evident in the consistency of steady growth that this segment has shown historically.

All three market segments (EDP, communications and transportation) have consistently grown faster than the semiconductor market as a whole. Overall, the strong growths in these three combined market segments contributed 22 percent compound annual growth rate (CAGR) between 1988 and 1994. As a result, companies with a strong presence in all three market segments have made it into the top 10 overall semiconductor vendor ranking shown in Table 2.

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Overall European Semiconductor Vendor Ranking (Top 20)

Table 2 shows the top 20 European semiconductor vendor ranking for 1994. The top 20 semiconductor vendors now account for 80 percent of the European semiconductor market as a whole. Following the strong market growth in 1994, the electronic data processing segment continues to drive the semiconductor vendor ranking. Overall, 9 out of the top 10 players also rank among the top 10 semiconductor vendors in the EDP segment. Companies supplying MOS memory and MOS microcomponent products to the EDP segment dominated the vendor rankings.

Having displaced Philips from number-one position in 1992, Intel continued its lead in the European semiconductor vendor ranking for the third consecutive year, largely as a result of very strong growth in the EDP and communications markets during 1994. Among the top 10 companies, Philips, NEC and Toshiba dropped in the overall 1994 rankings one place to fourth, eighth and ninth respectively, while Siemens rose one place into third position (displacing Philips). Samsung moved up two positions displacing NEC and Toshiba.

Six companies among the top 20 semiconductor vendors grew above the market average of 34.8 percent; these were Samsung, NEC, Hitachi, Fujitsu, Mitsubishi, Goldstar and Hyundai. All of these companies benefited from the strong growth in the DRAM marketplace, which grew by 84 percent in 1994. Goldstar showed the strongest growth in 1994 at 183.6 percent. Goldstar's growth comes largely from the strong market demand in the EDP segment where the company grew its semiconductor business in Europe by an estimated 79 percent.

The following sections detail semiconductor vendor rankings in each of the six application market segments.

EDP Market Share Ranking (Top 10)

The EDP market (worth $9 billion) has emerged as the largest single semiconductor application market, expanding its importance to account for 43 percent of the total European market in 1994 (from 38 percent in 1993 and 30 percent in 1992). During 1994, the top 5 vendors in this market segment accounted for 50 percent of the total EDP market, while the top 10 vendors accounted for 69 percent (see Table 3). Due to the sheer size of the European EDP market segment, 9 of these vendors rank in the overall European semiconductor top 10 ranking.

Dataquest research shows that the computer systems segment of the EDP market increased its semiconductor consumption to 36 percent of the total semiconductor market in 1994, from 30 percent in 1993. The survey shows that Intel (the most dominant player) now controls 27 percent of the overall EDP market segment with nearly all of its product portfolio being the 80x86 processor. The next significant player in this segment is Samsung, which accounts for 8 percent of the EDP market (approximately one-third of Intel's size). The remaining suppliers have sales of between $200 million and $500 million. Most importantly, 9 vendors out of the top 10 EDP players now rank in the top 10 overall European semiconductor vendor rankings.

Only one company, IBM, emerged as a player in this market segment, displacing AMD from the top 10 rankings. AMD's business in Europe showed overall growth of 34 percent, but in the microprocessor (MPU) market, Intel started to shift the PC processor market away from the 486 platform to the Pentium, thus eroding some of AMD's potential during 1994.

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Table 2
Top 20 European Semiconductor Market Share Rankings
Total Semiconductor Including Hybrids
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Intel	2,056	2,605	26.7%	2,605	12.5%	12.5%
2	2	Motorola	1,260	1,539	22.1%	4,144	7.4%	19.9%
4	3	Siemens	1,032	1,380	33.7%	5,524	6.6%	26.5%
3	4	Philips	1,104	1,269	14.9%	6,793	6.1%	32.6%
5	5	SGS-Thomson	977	1,236	26.5%	8,029	5.9%	38.6%
6	6	Texas Instruments	871	1,121	28.7%	9,150	5.4%	44.0%
9	7	Samsung	510	1,007	97.5%	10,157	4.8%	48.8%
7	8	NEC	605	969	60.2%	11,126	4.7%	53.4%
8	9	Toshiba	577	772	33.8%	11,898	3.7%	57.1%
13	10	IBM	409	705	72.4%	12,603	3.4%	60.5%
12	11	Hitachi	425	657	54.6%	13,260	3.2%	63.7%
11	12	AMD	452	606	34.1%	13,866	2.9%	66.6%
10	13	National Semi.	454	501	10.4%	14,367	2.4%	69.0%
16	14	Fujitsu	267	494	85.0%	14,861	2.4%	71.4%
15	15	Mitsubishi	270	392	45.2%	15,253	1.9%	73.3%
24	16	Goldstar	134	380	183.6%	15,633	1.8%	75.1%
14	17	TEMIC	340	348	2.4%	15,981	1.7%	76.8%
25	18	Hyundai	134	337	151.5%	16,318	1.6%	78.4%
17	19	AT&T	205	241	17.6%	16,559	1.2%	79.5%
18	20	Analog Devices	182	196	7.7%	16,755	0.9%	80.5%
		Total European Market	$15,450	$20,819	34.8%			

Source: Dataquest (July 1995 Estimates)

PC production increased from 10.9 million units in 1993 to 13 million units in 1994 giving an annual unit growth rate of 19.3 percent. Dataquest research indicates that during 1994, strong growth in the home PC markets, and specifically for multimedia PC systems, combined with component shortages and high average selling prices (ASPs) contributed to tremendous growth in this market segment. Peripherals for multimedia applications such as graphics chipsets, CD-ROM drives and random access memory (RAM) upgrades also helped to further stimulate an already buoyant market. In other areas, dedicated computer systems such as personal organizers, calculators, handheld peripheral systems and cash registers/transaction systems also showed a healthy 40 percent increase in semiconductor consumption.

Of the top 10 vendors, 4 were North American, 3 were Japanese, 2 were European, and 1 was South Korean.

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Table 3
Top 10 European Semiconductor Market Share Rankings Electronic Data Processing Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Intel	1,892	2,414	27.6%	2,414	26.8%	26.8%
2	2	Samsung	381	735	92.9%	3,149	8.2%	35.0%
4	3	NEC	333	510	53.2%	3,659	5.7%	40.6%
3	4	Texas Instruments	340	455	33.8%	4,114	5.0%	45.7%
13	5	IBM	135	423	213.3%	4,537	4.7%	50.4%
5	6	Siemens	290	374	29.0%	4,911	4.2%	54.5%
7	7	Hitachi	257	365	42.0%	5,276	4.1%	58.6%
8	8	Toshiba	243	338	39.1%	5,614	3.8%	62.3%
6	9	Motorola	265	312	17.7%	5,926	3.5%	65.8%
9	10	Philips	232	282	21.6%	6,208	3.1%	68.9%
		Total European EDP Market	$5,915	$9,010	52.3%			

Source: Dataquest (July 1995 Estimates)

Communications Market Share Ranking (Top 10)

The communications market segment finished as the second-largest growth after EDP, growing at 40.5 percent to reach $5 billion. Increasing its share of the overall market to 24 percent in 1994 from 23 percent in 1993, this segment continues to be the second-biggest European semiconductor application market. Strong market growth in this segment has come from cellular telephony. Digital personal communication systems, specifically GSM, has heralded an ever-increasing demand for flash memory products and digital signal processors (DSPs).

The top 5 vendors account for nearly 40 percent of the communications segment semiconductor market (see Table 4), while the top 10 companies account for about 60 percent. AT&T, IBM and National Semiconductor are the only companies in the top 10 communications market share ranking that do not feature in the top 10 ranking for the European semiconductor market as a whole (see Table 2).

Motorola grew its lead share of the European communications market segment by nearly 60 percent, maintaining its foothold on the number-one position with sales of $684 million; its market share in this segment is now 13.7 percent. Siemens displaced SGS-Thomson from the number-two position. NEC made a new entry to the 1994 top 10 rankings with a swift move up 4 positions displacing Toshiba, IBM and National Semiconductor. AMD dropped off the list from tenth position to number 11 (not shown in the ranking tables).

Of the top 10 vendors, 5 were North American, 3 were European and 2 were Japanese.

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Table 4
Top 10 European Semiconductor Market Share Rankings—Communications Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Motorola	428	684	59.8%	684	13.7%	13.7%
3	2	Siemens	252	384	52.4%	1,068	7.7%	21.4%
2	3	SGS-Thomson	300	376	25.3%	1,444	7.5%	28.9%
4	4	Philips	221	246	11.3%	1,690	4.9%	33.8%
5	5	Texas Instruments	200	245	22.5%	1,935	4.9%	38.7%
6	6	AT&T	197	231	17.3%	2,166	4.6%	43.3%
11	7	NEC	121	204	68.6%	2,370	4.1%	47.4%
9	8	Toshiba	139	177	27.3%	2,547	3.5%	50.9%
7	9	IBM	151	176	16.6%	2,723	3.5%	54.5%
8	10	National Semi.	140	165	17.9%	2,888	3.3%	57.8%
		Total European Communications Market	$3,559	$5,000	40.5%			

Source: Dataquest (July 1995 Estimates)

Industrial Market Share Ranking (Top 10)

The industrial segment lost market share of the overall semiconductor market, declining from 14.7 percent in 1993 to 11.3 percent in 1994. However, the size of the industrial semiconductor market itself grew 3.2 percent from $2.27 billion to $2.35 billion. After the military and civil aerospace segment, this represents the slowest growth rate in all the end-application market segments we surveyed.

Among the top 10 overall semiconductor company rankings (shown in Table 2), only five companies rank among the top 10 industrial segment semiconductor ranking (see Table 5).

The fragmented nature of the market for semiconductors in industrial application manifests itself in the fact that the top 5 vendors account for 43 percent of the market, while the top 10 vendors only accounted for less than 65 percent of the overall industrial semiconductor market. This also makes vendor market share rather volatile, as no single company has strong control of the market. Several changes occurred in the top 10 rankings during 1994. Texas Instruments toppled SGS-Thomson from the number-one position. New entrants in the top 10 industrial semiconductor market segment rankings are Samsung and Fujitsu.

Of the top 10 vendors, 4 were North American, 3 were European, 2 were Japanese, and 1 was South Korean.

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Table 5
Top 10 European Semiconductor Market Share Rankings—Industrial Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
2	1	Texas Instruments	226	285	26.1%	285	12.1%	12.1%
1	2	SGS-Thomson	237	259	9.3%	544	11.0%	23.1%
4	3	Siemens	184	230	25.0%	774	9.8%	32.9%
7	4	Analog Devices	87	122	40.2%	896	5.2%	38.1%
5	5	National Semi.	95	110	15.8%	1,006	4.7%	42.8%
6	6	Philips	88	101	14.8%	1,107	4.3%	47.1%
12	7	Samsung	63	101	60.3%	1,208	4.3%	51.4%
14	8	Fujitsu	53	97	83.0%	1,305	4.1%	55.5%
13	9	NEC	61	93	52.5%	1,398	4.0%	59.5%
9	10	Toshiba	69	91	31.9%	1,489	3.9%	63.4%
		Total European Industrial Market	$2,278	$2,350	3.2%			

Source: Dataquest (July 1995 Estimates)

Consumer Market Share Ranking (Top 10)

Survey results indicate a 19 percent growth in the consumer semiconductor market segment, reaching $2.3 billion during 1994 (from $1.9 billion in 1993). In terms of market size importance, the consumer segment now ranks as the fourth-largest application market with an 11 percent market share. Nearly 70 percent of the European consumer total available market (TAM) in Europe is accounted for by video equipment production (televisions, camcorders, VCRs and set-top boxes).

Table 6 shows the vendor market share ranking for the consumer segment. Philips maintains its market share lead and remains at least double the size of its nearest competitors: SGS-Thomson and Siemens. However, SGS-Thomson gained a very rapid ascent, narrowing the gap between Philips' number-one position from a 130 percent lead in 1993 (ahead of the second-ranked company, Motorola, in that year) to a 104 percent lead in 1994 (ahead of SGS-Thomson). Both SGS-Thomson and Siemens displaced Motorola from second position, relegating the latter to number 4 (see Table 6). Six companies in the top 10 consumer rankings feature in the top 10 overall semiconductor market rankings.

Strong growth in satellite set-top box production was generally observed during 1994, although this represented a rather negligible contribution to growth in the semiconductor market as a whole. Overall improvements in the TV business was also noted during the year as digital TV features such as NiCAM, on-screen displays, Surround Sound and Fastext (teletext). All of these contributed to the positive growth indicated by our research.

Of the top 10 vendors, 4 were European, 3 were Japanese, and 3 were North American.

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Table 6
Top 10 European Semiconductor Market Share Rankings—Consumer Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Philips	464	519	11.9%	519	22.6%	22.6%
3	2	SGS-Thomson	199	254	27.6%	773	11.0%	33.6%
4	3	Siemens	155	190	22.6%	963	8.3%	41.9%
2	4	Motorola	202	173	-14.4%	1,136	7.5%	49.4%
5	5	Toshiba	104	133	27.9%	1,269	5.8%	55.2%
9	6	NEC	60	74	23.3%	1,343	3.2%	58.4%
11	7	Fujitsu	40	71	77.5%	1,414	3.1%	61.5%
8	8	TEMIC	68	69	1.5%	1,483	3.0%	64.5%
7	9	ITT	69	62	-10.1%	1,545	2.7%	67.2%
19	10	Samsung	16	50	212.5%	1,595	2.2%	69.3%
		Total European Consumer Market	$1,938	$2,300	18.6%			

Source: Dataquest (July 1995 Estimates)

Military and Civil Aerospace Market Share Ranking (Top 10)

Although the military market continues to be in decline, an apparent slight growth in the civil aerospace business has allowed this market to remain flat in 1994.

Key changes in the ranking (Table 7) were the fall of AMD, TEMIC and Harris, while SGS-Thomson and Cypress also dropped out of the top 10 market rankings in 1994. Three companies gained rapidly in the ranking—LSI Logic, Motorola and TCS. Motorola and Texas Instruments were the only companies in the military/aerospace ranking to feature among the top 10 ranked vendors for the semiconductor market as a whole (see Table 2).

No Japanese or Rest of World company showed any revenue for this market segment. Of the top 10 vendors, 7 were North American and 3 were European.

Transportation Market Share Ranking (Top 10)

Transportation semiconductor consumption grew 31.8 percent to reach $1.6 billion in 1994 (from $1.26 billion in 1993). This growth is slightly below the market average of 34.8 percent, largely because of the phenomenal growth recorded by the EDP segment. The transportation semiconductor business now has a market share of 7.95 percent (slightly down from 8.1 percent in 1993) of the overall European semiconductor market.

Engine management systems, antilock braking systems (ABS) and electronic ignition systems have all contributed to strong historical growth in the transportation semiconductor market. Emerging developments in advanced driver information systems using RDS-TMC radios, navigation systems, car security systems and Global Positioning by Satellite technology will drive future growth in this market segment.

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Table 7
Top 10 European Semiconductor Market Share Rankings—Military and Civil Aerospace Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum Sum ($)	1994 Market Share (%)	1994 Cum Sum (%)
1	1	Texas Instruments	52	63	21.2%	63	12.5%	12.5%
3	2	TCS	48	58	20.8%	121	11.5%	24.0%
2	3	AMD	50	55	10.0%	176	10.9%	34.9%
4	4	GEC Plessey	45	26	-42.2%	202	5.2%	40.1%
5	5	Analog Devices	25	24	-4.0%	226	4.8%	44.8%
9	6	Motorola	13	22	69.2%	248	4.4%	49.2%
8	7	SGS-Thomson	13	18	38.5%	266	3.6%	52.8%
6	8	TEMIC	17	17	0.0%	283	3.4%	56.2%
7	9	Harris	15	17	13.3%	300	3.4%	59.5%
12	10	LSI Logic	12	13	8.3%	313	2.6%	62.1%
		Total European Military/Civil Aerospace Market	$504	$504	0.0%			

Source: Dataquest (July 1995 Estimates)

Table 8
Top 10 European Semiconductor Market Share Rankings—Transportation Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
2	1	Motorola	151	232	53.6%	232	14.0%	14.0%
1	2	Siemens	151	192	27.2%	424	11.6%	25.6%
4	3	SGS-Thomson	80	125	56.3%	549	7.6%	33.2%
3	4	Philips	88	102	15.9%	651	6.2%	39.3%
6	5	National	54	65	20.4%	716	3.9%	43.3%
5	6	TEMIC	54	56	3.7%	772	3.4%	46.6%
7	7	Intel	41	50	22.0%	822	3.0%	49.7%
9	8	NEC	30	46	53.3%	868	2.8%	52.4%
10	9	Texas Instruments	26	33	26.9%	901	2.0%	54.4%
12	10	Harris	21	32	52.4%	933	1.9%	56.4%
		Total European Transportation Market	$1,256	$1,655	31.8%			

Source: Dataquest (July 1995 Estimates)

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Although unit growth rose sharply, price pressures and the continuing effect of the "Lopez factor" (a term associated with the low-cost procurement strategy adopted by I. Lopez, the ex–General Motors purchasing director poached by VolksWagen) in the automotive industry continued to play down revenue growth. However, it must be noted that despite the difficult trading conditions observed across Europe, the penetration of electronics into cars has continued to rise. Legislation and competitive product differentiation using electronics helped the transportation segment to continue its growth. Airbags and ABS aside, safety and security applications emerged as one of the areas of fastest growth in the automotive electronics market segment.

The key change in the transportation segment was Motorola displacing Siemens from the number-one position with a growth of 53.6 percent during 1994. Other changes in the rankings include SGS-Thomson moving into number-three slot, displacing Philips; and National Semiconductor moving up one place, displacing TEMIC. NEC moved up a position to eighth place displacing ITT, which dropped out of the top 10 ranking. These changes reflect the product market trends outlined in the earlier paragraph, as companies with strong design wins grew their business and new entrants gained solid foundations.

Of the top 10 vendors, 5 were North American, 4 were European and 1 was Japanese. Samsung is the only South Korean vendor that reported European sales, for the first time, in this segment.

Dataquest Perspective

It was a particularly strong year in 1994 for companies with microprocessor and DRAM memory products. These products excelled in a year when the market was driven by personal computer production. Vendors faced capacity problems—especially with DRAM—with higher ASPs. The result was a very strong dollar growth for the second consecutive year. No other products showed contributions to overall semiconductor market growth as significant as DRAMs and MPUs.

The European semiconductor market in 1994 continued to be driven mainly by local production of PC systems. Cellular telephone handsets have also emerged, and we anticipate strong growth for companies supplying flash memory products for this application market. Dataquest forecasts that the EDP, communications and transportation (automotive) segments will demonstrate stronger than average semiconductor market growth during 1995. We also expect to see strong demand for discrete devices from the automotive and industrial market segments.

Overall, Dataquest believes that the strong growth trends noted for microprocessor and memory components, primarily for personal computer applications, will continue through 1995. The net result will be strong growth and consolidation of market positioning for vendor companies with products for the high-growth end-application markets of EDP and communications.

By Mike Williams

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Market Analysis



Semiconductors Application Markets Europe

Market Analysis

Final 1994 European Market Share Ranking by Application

Abstract: *It was a particularly strong year in 1994 for companies with microprocessor and DRAM memory products, these products excelling in a year when the market was driven by personal computer production. Cellular telephone handsets have also emerged in the communications segment, and discrete devices from the automotive and industrial market segments are expected to be another growth area in the future. Highlighting these and other trends, this report analyses vendor market share results in 1994 in the six semiconductor application segments.*

Executive Summary

Dataquest estimates that the overall semiconductor market growth in 1994 over 1993 was 34.8 percent. Strongest growths were seen in the segments of electronic data processing (EDP) at 52.3 percent, and communications (40.5 percent). The transportation (automotive) segment also showed significant growth (31.8 percent), albeit slightly below market average (see Table 1). The military/aerospace (0 percent), industrial (3.2 percent) and consumer (18.7 percent) segments all grew below the market average. Personal computers continued to drive market growth in data processing, while cellular telephones emerged as a market growth driver in the communications segment. The EDP segment continues to drive the European semiconductor market (see Figure 1) with an unending increase in market share (43 percent) of the total market in 1994 (compared with 38 percent in 1993).

Survey Results

PCs, Mobile Communications and Automotive Electronics Drive Industry Growth

Figure 1 shows an overview of the historical semiconductor market trends by end-use application markets from 1988 to 1994. Over the historical period, the EDP market segment has maintained its lead by growing market share. The last three years have witnessed dramatic growth in the EDP, communications and transportation market segments.

The European semiconductor market is now very dependent on the EDP and communications market segments. PCs and cellular telephones have been the two single engines of growth in each of these markets that have influenced,

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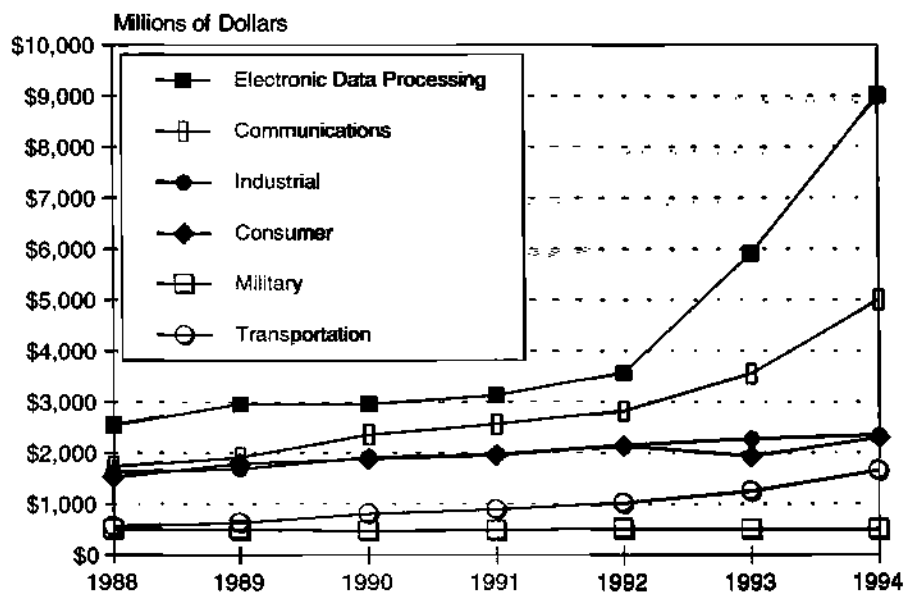
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Table 1
1993 and 1994 European Semiconductor Market by End-Use Application Market Segment
(Millions of Dollars)

	1993 (these span)		1994	
End-Use Market Segment	Revenue	Percent of Total	Revenue	Percent of Total
Electronic Data Processing	5,915	38.3	9,010	43.3
Communications	3,559	23.0	5,000	24.0
Industrial	2,278	14.7	2,350	11.3
Consumer	1,938	12.5	2,300	11.0
Military/Civil Aerospace	504	3.3	504	2.4
Transportation	1,256	8.1	1,655	7.9
Total	$15,450	100.0	20,819	100.0

Source: Dataquest (July 1995 Estimates)

Figure 1
European Semiconductor Market by End-Use Application Market Segment



Source: Dataquest (July 1995 Estimates)

most significantly, the spectacular growths seen during 1993 and 1994. Transportation is mostly automotive applications, and this too has demonstrated very buoyant growth, albeit at a lower rate than EDP and communications. The importance of transportation electronics is evident in the consistency of steady growth that this segment has shown historically.

All three market segments (EDP, communications and transportation) have consistently grown faster than the semiconductor market as a whole. Overall, the strong growths in these three combined market segments contributed 22 percent compound annual growth rate (CAGR) between 1988 and 1994. As a result, companies with a strong presence in all three market segments have made it into the top 10 overall semiconductor vendor ranking shown in Table 2.

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Overall European Semiconductor Vendor Ranking (Top 20)

Table 2 shows the top 20 European semiconductor vendor ranking for 1994. The top 20 semiconductor vendors now account for 80 percent of the European semiconductor market as a whole. Following the strong market growth in 1994, the electronic data processing segment continues to drive the semiconductor vendor ranking. Overall, 9 out of the top 10 players also rank among the top 10 semiconductor vendors in the EDP segment. Companies supplying MOS memory and MOS microcomponent products to the EDP segment dominated the vendor rankings.

Having displaced Philips from number-one position in 1992, Intel continued its lead in the European semiconductor vendor ranking for the third consecutive year, largely as a result of very strong growth in the EDP and communications markets during 1994. Among the top 10 companies, Philips, NEC and Toshiba dropped in the overall 1994 rankings one place to fourth, eighth and ninth respectively, while Siemens rose one place into third position (displacing Philips). Samsung moved up two positions displacing NEC and Toshiba.

Six companies among the top 20 semiconductor vendors grew above the market average of 34.8 percent; these were Samsung, NEC, Hitachi, Fujitsu, Mitsubishi, Goldstar and Hyundai. All of these companies benefited from the strong growth in the DRAM marketplace, which grew by 84 percent in 1994. Goldstar showed the strongest growth in 1994 at 183.6 percent. Goldstar's growth comes largely from the strong market demand in the EDP segment where the company grew its semiconductor business in Europe by an estimated 79 percent.

The following sections detail semiconductor vendor rankings in each of the six application market segments.

EDP Market Share Ranking (Top 10)

The EDP market (worth $9 billion) has emerged as the largest single semiconductor application market, expanding its importance to account for 43 percent of the total European market in 1994 (from 38 percent in 1993 and 30 percent in 1992). During 1994, the top 5 vendors in this market segment accounted for 50 percent of the total EDP market, while the top 10 vendors accounted for 69 percent (see Table 3). Due to the sheer size of the European EDP market segment, 9 of these vendors rank in the overall European semiconductor top 10 ranking.

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Only one company, IBM, emerged as a player in this market segment, displacing AMD from the top 10 rankings. AMD's business in Europe showed overall growth of 34 percent, but in the microprocessor (MPU) market, Intel started to shift the PC processor market away from the 486 platform to the Pentium, thus eroding some of AMD's potential during 1994.

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9	7	Samsung	510	1,007	97.5%	10,157	4.8%	48.8%
7	8	NEC	605	969	60.2%	11,126	4.7%	53.4%
8	9	Toshiba	577	772	33.8%	11,898	3.7%	57.1%
13	10	IBM	409	705	72.4%	12,603	3.4%	60.5%
12	11	Hitachi	425	657	54.6%	13,260	3.2%	63.7%
11	12	AMD	452	606	34.1%	13,866	2.9%	66.6%
10	13	National Semi.	454	501	10.4%	14,367	2.4%	69.0%
16	14	Fujitsu	267	494	85.0%	14,861	2.4%	71.4%
15	15	Mitsubishi	270	392	45.2%	15,253	1.9%	73.3%
24	16	Goldstar	134	380	183.6%	15,633	1.8%	75.1%
14	17	TEMIC	340	348	2.4%	15,981	1.7%	76.8%
25	18	Hyundai	134	337	151.5%	16,318	1.6%	78.4%
17	19	AT&T	205	241	17.6%	16,559	1.2%	79.5%
18	20	Analog Devices	182	196	7.7%	16,755	0.9%	80.5%
		Total European Market	$15,450	$20,819	34.8%			

Source: Dataquest (July 1995 Estimates)

PC production increased from 10.9 million units in 1993 to 13 million units in 1994 giving an annual unit growth rate of 19.3 percent. Dataquest research indicates that during 1994, strong growth in the home PC markets, and specifically for multimedia PC systems, combined with component shortages and high average selling prices (ASPs) contributed to tremendous growth in this market segment. Peripherals for multimedia applications such as graphics chipsets, CD-ROM drives and random access memory (RAM) upgrades also helped to further stimulate an already buoyant market. In other areas, dedicated computer systems such as personal organizers, calculators, handheld peripheral systems and cash registers/transaction systems also showed a healthy 40 percent increase in semiconductor consumption.

Of the top 10 vendors, 4 were North American, 3 were Japanese, 2 were European, and 1 was South Korean.

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Table 3
Top 10 European Semiconductor Market Share Rankings Electronic Data Processing Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Intel	1,892	2,414	27.6%	2,414	26.8%	26.8%
2	2	Samsung	381	735	92.9%	3,149	8.2%	35.0%
4	3	NEC	333	510	53.2%	3,659	5.7%	40.6%
3	4	Texas Instruments	340	455	33.8%	4,114	5.0%	45.7%
13	5	IBM	135	423	213.3%	4,537	4.7%	50.4%
5	6	Siemens	290	374	29.0%	4,911	4.2%	54.5%
7	7	Hitachi	257	365	42.0%	5,276	4.1%	58.6%
8	8	Toshiba	243	338	39.1%	5,614	3.8%	62.3%
6	9	Motorola	265	312	17.7%	5,926	3.5%	65.8%
9	10	Philips	232	282	21.6%	6,208	3.1%	68.9%
		Total European EDP Market	$5,915	$9,010	52.3%			

Source: Dataquest (July 1995 Estimates)

Communications Market Share Ranking (Top 10)

The communications market segment finished as the second-largest growth after EDP, growing at 40.5 percent to reach $5 billion. Increasing its share of the overall market to 24 percent in 1994 from 23 percent in 1993, this segment continues to be the second-biggest European semiconductor application market. Strong market growth in this segment has come from cellular telephony. Digital personal communication systems, specifically GSM, has heralded an ever-increasing demand for flash memory products and digital signal processors (DSPs).

The top 5 vendors account for nearly 40 percent of the communications segment semiconductor market (see Table 4), while the top 10 companies account for about 60 percent. AT&T, IBM and National Semiconductor are the only companies in the top 10 communications market share ranking that do not feature in the top 10 ranking for the European semiconductor market as a whole (see Table 2).

Motorola grew its lead share of the European communications market segment by nearly 60 percent, maintaining its foothold on the number-one position with sales of $684 million; its market share in this segment is now 13.7 percent. Siemens displaced SGS-Thomson from the number-two position. NEC made a new entry to the 1994 top 10 rankings with a swift move up 4 positions displacing Toshiba, IBM and National Semiconductor. AMD dropped off the list from tenth position to number 11 (not shown in the ranking tables).

Of the top 10 vendors, 5 were North American, 3 were European and 2 were Japanese.

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Table 4
Top 10 European Semiconductor Market Share Rankings—Communications Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Motorola	428	684	59.8%	684	13.7%	13.7%
3	2	Siemens	252	384	52.4%	1,068	7.7%	21.4%
2	3	SGS-Thomson	300	376	25.3%	1,444	7.5%	28.9%
4	4	Philips	221	246	11.3%	1,690	4.9%	33.8%
5	5	Texas Instruments	200	245	22.5%	1,935	4.9%	38.7%
6	6	AT&T	197	231	17.3%	2,166	4.6%	43.3%
11	7	NEC	121	204	68.6%	2,370	4.1%	47.4%
9	8	Toshiba	139	177	27.3%	2,547	3.5%	50.9%
7	9	IBM	151	176	16.6%	2,723	3.5%	54.5%
8	10	National Semi.	140	165	17.9%	2,888	3.3%	57.8%
		Total European Communications Market	$3,559	$5,000	40.5%			

Source: Dataquest (July 1995 Estimates)

Industrial Market Share Ranking (Top 10)

The industrial segment lost market share of the overall semiconductor market, declining from 14.7 percent in 1993 to 11.3 percent in 1994. However, the size of the industrial semiconductor market itself grew 3.2 percent from $2.27 billion to $2.35 billion. After the military and civil aerospace segment, this represents the slowest growth rate in all the end-application market segments we surveyed.

Among the top 10 overall semiconductor company rankings (shown in Table 2), only five companies rank among the top 10 industrial segment semiconductor ranking (see Table 5).

The fragmented nature of the market for semiconductors in industrial application manifests itself in the fact that the top 5 vendors account for 43 percent of the market, while the top 10 vendors only accounted for less than 65 percent of the overall industrial semiconductor market. This also makes vendor market share rather volatile, as no single company has strong control of the market. Several changes occurred in the top 10 rankings during 1994. Texas Instruments toppled SGS-Thomson from the number-one position. New entrants in the top 10 industrial semiconductor market segment rankings are Samsung and Fujitsu.

Of the top 10 vendors, 4 were North American, 3 were European, 2 were Japanese, and 1 was South Korean.

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Table 5
Top 10 European Semiconductor Market Share Rankings—Industrial Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
2	1	Texas Instruments	226	285	26.1%	285	12.1%	12.1%
1	2	SGS-Thomson	237	259	9.3%	544	11.0%	23.1%
4	3	Siemens	184	230	25.0%	774	9.8%	32.9%
7	4	Analog Devices	87	122	40.2%	896	5.2%	38.1%
5	5	National Semi.	95	110	15.8%	1,006	4.7%	42.8%
6	6	Philips	88	101	14.8%	1,107	4.3%	47.1%
12	7	Samsung	63	101	60.3%	1,208	4.3%	51.4%
14	8	Fujitsu	53	97	83.0%	1,305	4.1%	55.5%
13	9	NEC	61	93	52.5%	1,398	4.0%	59.5%
9	10	Toshiba	69	91	31.9%	1,489	3.9%	63.4%
		Total European Industrial Market	$2,278	$2,350	3.2%			

Source: Dataquest (July 1995 Estimates)

Consumer Market Share Ranking (Top 10)

Survey results indicate a 19 percent growth in the consumer semiconductor market segment, reaching $2.3 billion during 1994 (from $1.9 billion in 1993). In terms of market size importance, the consumer segment now ranks as the fourth-largest application market with an 11 percent market share. Nearly 70 percent of the European consumer total available market (TAM) in Europe is accounted for by video equipment production (televisions, camcorders, VCRs and set-top boxes).

Table 6 shows the vendor market share ranking for the consumer segment. Philips maintains its market share lead and remains at least double the size of its nearest competitors: SGS-Thomson and Siemens. However, SGS-Thomson gained a very rapid ascent, narrowing the gap between Philips' number-one position from a 130 percent lead in 1993 (ahead of the second-ranked company, Motorola, in that year) to a 104 percent lead in 1994 (ahead of SGS-Thomson). Both SGS-Thomson and Siemens displaced Motorola from second position, relegating the latter to number 4 (see Table 6). Six companies in the top 10 consumer rankings feature in the top 10 overall semiconductor market rankings.

Strong growth in satellite set-top box production was generally observed during 1994, although this represented a rather negligible contribution to growth in the semiconductor market as a whole. Overall improvements in the TV business was also noted during the year as digital TV features such as NiCAM, on-screen displays, Surround Sound and Fastext (teletext). All of these contributed to the positive growth indicated by our research.

Of the top 10 vendors, 4 were European, 3 were Japanese, and 3 were North American.

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Table 6
Top 10 European Semiconductor Market Share Rankings—Consumer Segment (Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
1	1	Philips	464	519	11.9%	519	22.6%	22.6%
3	2	SGS-Thomson	199	254	27.6%	773	11.0%	33.6%
4	3	Siemens	155	190	22.6%	963	8.3%	41.9%
2	4	Motorola	202	173	-14.4%	1,136	7.5%	49.4%
5	5	Toshiba	104	133	27.9%	1,269	5.8%	55.2%
9	6	NEC	60	74	23.3%	1,343	3.2%	58.4%
11	7	Fujitsu	40	71	77.5%	1,414	3.1%	61.5%
8	8	TEMIC	68	69	1.5%	1,483	3.0%	64.5%
7	9	ITT	69	62	-10.1%	1,545	2.7%	67.2%
19	10	Samsung	16	50	212.5%	1,595	2.2%	69.3%
		Total European Consumer Market	$1,938	$2,300	18.6%			

Source: Dataquest (July 1995 Estimates)

Military and Civil Aerospace Market Share Ranking (Top 10)

Although the military market continues to be in decline, an apparent slight growth in the civil aerospace business has allowed this market to remain flat in 1994.

Key changes in the ranking (Table 7) were the fall of AMD, TEMIC and Harris, while SGS-Thomson and Cypress also dropped out of the top 10 market rankings in 1994. Three companies gained rapidly in the ranking—LSI Logic, Motorola and TCS. Motorola and Texas Instruments were the only companies in the military/aerospace ranking to feature among the top 10 ranked vendors for the semiconductor market as a whole (see Table 2).

No Japanese or Rest of World company showed any revenue for this market segment. Of the top 10 vendors, 7 were North American and 3 were European.

Transportation Market Share Ranking (Top 10)

Transportation semiconductor consumption grew 31.8 percent to reach $1.6 billion in 1994 (from $1.26 billion in 1993). This growth is slightly below the market average of 34.8 percent, largely because of the phenomenal growth recorded by the EDP segment. The transportation semiconductor business now has a market share of 7.95 percent (slightly down from 8.1 percent in 1993) of the overall European semiconductor market.

Engine management systems, antilock braking systems (ABS) and electronic ignition systems have all contributed to strong historical growth in the transportation semiconductor market. Emerging developments in advanced driver information systems using RDS-TMC radios, navigation systems, car security systems and Global Positioning by Satellite technology will drive future growth in this market segment.

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Table 7
Top 10 European Semiconductor Market Share Rankings—Military and Civil Aerospace Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum Sum ($)	1994 Market Share (%)	1994 Cum Sum (%)
1	1	Texas Instruments	52	63	21.2%	63	12.5%	12.5%
3	2	TCS	48	58	20.8%	121	11.5%	24.0%
2	3	AMD	50	55	10.0%	176	10.9%	34.9%
4	4	GEC Plessey	45	26	-42.2%	202	5.2%	40.1%
5	5	Analog Devices	25	24	-4.0%	226	4.8%	44.8%
9	6	Motorola	13	22	69.2%	248	4.4%	49.2%
8	7	SGS-Thomson	13	18	38.5%	266	3.6%	52.8%
6	8	TEMIC	17	17	0.0%	283	3.4%	56.2%
7	9	Harris	15	17	13.3%	300	3.4%	59.5%
12	10	LSI Logic	12	13	8.3%	313	2.6%	62.1%
		Total European Military/Civil Aerospace Market	$504	$504	0.0%			

Source: Dataquest (July 1995 Estimates)

Table 8
Top 10 European Semiconductor Market Share Rankings—Transportation Segment
(Millions of Dollars)

1993 Rank	1994 Rank	Company	1993 Revenue	1994 Revenue	1994 AGR	1994 Cum. Sum ($)	1994 Market Share (%)	1994 Cum. Sum (%)
2	1	Motorola	151	232	53.6%	232	14.0%	14.0%
1	2	Siemens	151	192	27.2%	424	11.6%	25.6%
4	3	SGS-Thomson	80	125	56.3%	549	7.6%	33.2%
3	4	Philips	88	102	15.9%	651	6.2%	39.3%
6	5	National	54	65	20.4%	716	3.9%	43.3%
5	6	TEMIC	54	56	3.7%	772	3.4%	46.6%
7	7	Intel	41	50	22.0%	822	3.0%	49.7%
9	8	NEC	30	46	53.3%	868	2.8%	52.4%
10	9	Texas Instruments	26	33	26.9%	901	2.0%	54.4%
12	10	Harris	21	32	52.4%	933	1.9%	56.4%
		Total European Transportation Market	$1,256	$1,655	31.8%			

Source: Dataquest (July 1995 Estimates)

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Although unit growth rose sharply, price pressures and the continuing effect of the "Lopez factor" (a term associated with the low-cost procurement strategy adopted by I. Lopez, the ex–General Motors purchasing director poached by VolksWagen) in the automotive industry continued to play down revenue growth. However, it must be noted that despite the difficult trading conditions observed across Europe, the penetration of electronics into cars has continued to rise. Legislation and competitive product differentiation using electronics helped the transportation segment to continue its growth. Airbags and ABS aside, safety and security applications emerged as one of the areas of fastest growth in the automotive electronics market segment.

The key change in the transportation segment was Motorola displacing Siemens from the number-one position with a growth of 53.6 percent during 1994. Other changes in the rankings include SGS-Thomson moving into number-three slot, displacing Philips; and National Semiconductor moving up one place, displacing TEMIC. NEC moved up a position to eighth place displacing ITT, which dropped out of the top 10 ranking. These changes reflect the product market trends outlined in the earlier paragraph, as companies with strong design wins grew their business and new entrants gained solid foundations.

Of the top 10 vendors, 5 were North American, 4 were European and 1 was Japanese. Samsung is the only South Korean vendor that reported European sales, for the first time, in this segment.

Dataquest Perspective

It was a particularly strong year in 1994 for companies with microprocessor and DRAM memory products. These products excelled in a year when the market was driven by personal computer production. Vendors faced capacity problems—especially with DRAM—with higher ASPs. The result was a very strong dollar growth for the second consecutive year. No other products showed contributions to overall semiconductor market growth as significant as DRAMs and MPUs.

The European semiconductor market in 1994 continued to be driven mainly by local production of PC systems. Cellular telephone handsets have also emerged, and we anticipate strong growth for companies supplying flash memory products for this application market. Dataquest forecasts that the EDP, communications and transportation (automotive) segments will demonstrate stronger than average semiconductor market growth during 1995. We also expect to see strong demand for discrete devices from the automotive and industrial market segments.

Overall, Dataquest believes that the strong growth trends noted for microprocessor and memory components, primarily for personal computer applications, will continue through 1995. The net result will be strong growth and consolidation of market positioning for vendor companies with products for the high-growth end-application markets of EDP and communications.

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Market Analysis



Semiconductor Application Markets Europe

Market Forecast

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Abstract: *As an update to our report* European Electronic Equipment Production Forecast *published in April 1995, this year Dataquest is publishing two forecasts—one in the summer and one in the winter—for semiconductor applications resulting from that production forecast. In this present document, the first of the updates, we examine the underlying applications that are driving the growth of the semiconductor market.*

European Semiconductor Applications Market Forecast by Product—First Half 1995

Executive Summary

- The European semiconductor market grew from $15,486 million in 1993 to $20,819 in 1994, a growth of 34 percent, and we forecast the market will grow to $42,607 million by 1999.
- The PC continues its relentless growth, driving the overall semiconductor market and in particular contributing to the growth in both MOS memory and MOS microcomponents.
- Communications is the star performer among the applications segments in terms of growth, overtaking the electronic data processing (EDP) and automotive (transportation) segments. The main contributor to this growth is the mobile/radio communications subsegment. This has provided a useful contribution to both MOS memory and microcomponents.
- Industrial will lose its third-place ranking to consumer by the end of the forecast period and will also be seriously challenged by automotive.

Introduction

Dataquest published the 1995 report *European Electronic Equipment Production Forecast* (SAMM-EU-MS-9501) in April this year. This report forecasts the European semiconductor market that results from that production in greater detail than has previously been published, including a forecast for the total semiconductor market by application subsegment and a semiconductor product forecast by each of the six application segments. Dataquest is publishing two

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semiconductor application forecasts in 1995, one in the summer and one in the winter, and this present document is the former of these. Here, we examine the underlying applications that are driving the current and forecast growth of the market.

Applications Growth Trends

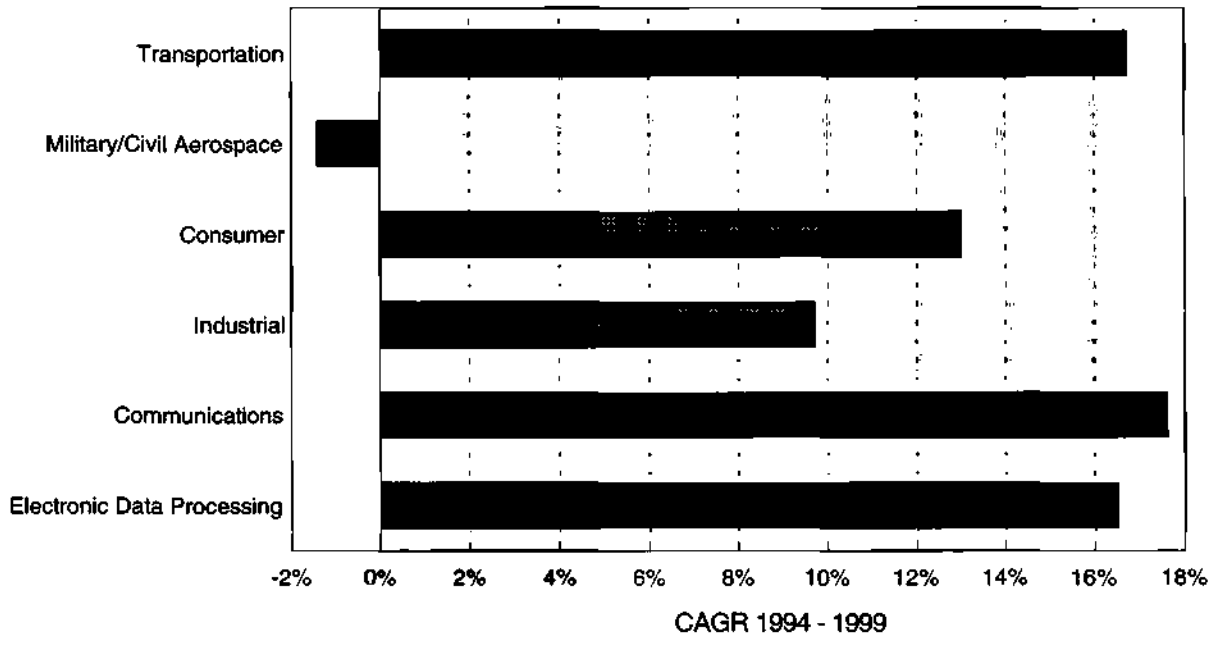
Figure 1 shows Dataquest's forecast of growth rate by application between 1994 and 1999. We now expect the communications segment to grow at the fastest rate over the next five years. The automotive and EDP segments now rank second and third respectively by growth rate.

The EDP segment continues to dominate the European semiconductor market, with the PC as the main driver. The computer semiconductor market is dominated by the PC, and is expected to grow from $7.5 billion in 1994 to $16.8 billion in 1999. The growth in the EDP segment is also given a significant boost from the dedicated systems subsegment. This subsegment is dominated by chip and smart cards.

Historically (1989 to 1994), the data storage subsegment had a growth rate higher than the overall EDP segment, as shown in Table 1. This was due to the phenomenal rise in demand from PCs for small rigid disk drives (RDDs). Major disk drive producers in Europe were Conner, IKB and IBM. However, in the forecast period we expect this growth to be reversed, with Conner closing down one of its facilities and the underlying demand for large disk drives (5.25-inch and 8-inch) for mainframes and midrange computers reducing.

Also historically, there was tremendous growth in the computer segment—28 percent compound annual growth rate (CAGR) from 1989 to 1994. This growth is all attributable to the PC, which provided most of the growth from 1992 to 1994. During this period semiconductor demand in this area alone jumped from $2.8 billion in 1992 to $7.5 billion in 1994.

Figure 1
European Semiconductor Growth Rate by Application, 1994-1999



Source: Dataquest (June 1995 Estimates)

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Communications shows the most impressive growth of all segments, growing at a CAGR of 17.6 percent between 1994 and 1999. The driver for this growth is the continued spectacular growth in the mobile/radio communications equipment segment shown in Table 2. The mobile subsegment had previously shown spectacular growth at 50 percent CAGR. This was due mainly to the tremendous growth in European production of cellular handsets and base stations. Most of this growth was from 1992 to 1994, and we do not expect this growth rate to be sustained during the forecast period, reverting to a more modest 21.6 percent CAGR.

The industrial segment is now starting to show signs of growth, though still well below the market average of 15.4 percent CAGR. Industrial has been ranked as the third-largest segment after EDP and communications, but will be overtaken by consumer electronics by the end of the forecast period. The security and energy management systems subsegment is growing ahead of the overall segment growth. Robot systems are also showing strong growth, but are less important as this is the smallest of all the subsegments at $60 million in 1994.

Consumer electronics is entering a period of growth. The main subsegments driving this growth are video and domestic appliances. The introduction of ever more digital technology and the major developments in cable and satellite set-top boxes will push growth to 14 percent over the forecast period. Domestic appliances will also show growth of 14 percent, in part due to the long-awaited adoption of semiconductors in this subsegment.

Military and civil aerospace will continue to shrink, showing an overall decline of 1.3 percent over the forecast period. The decline in this sector would have been more severe except for the good performance from the European civil aerospace industry. We expect modest growth in the worldwide civil aerospace sector but, also, European companies will capture a larger share.

The automotive segment for many years has shown very healthy growth rates. We expect this to continue with 16.7 percent growth forecast over the period 1994 to 1999. The automotive segment has shown above-average growth for several years, but it is accepted that high growth is more easily achieved from a segment which is small in value. By the end of this forecast period the transportation sector will be substantial, very close to the size of the industrial segment. We expect that by the year 2000 automotive will overtake industrial, making it the fourth-largest segment.

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Table 1
European Semiconductor Market by Application—Total Market, History
(Millions of Dollars, Ex-Factory Revenues)

Segment	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Total Semiconductor	**$9,498**	**$10,415**	**$11,014**	**$12,217**	**$15,450**	**$20,819**	**17.0%**
Electronic Data Processing	$2,965	$2,963	$3,136	$3,572	$5,915	$9,010	24.9%
Computers	2,181	2,256	2,425	2,760	4,658	7,501	28.0%
Data Storage	73	99	115	159	222	269	29.7%
Input/Output Devices	464	395	379	397	541	551	3.5%
Dedicated Systems	246	213	217	256	494	689	22.9%
Communications	$1,915	$2,362	$2,567	$2,823	$3,559	$5,000	21.2%
Premise Telecoms Equipment	603	683	746	780	845	1,015	11.0%
Public Telecoms Equipment	664	826	883	832	860	1,005	8.6%
Mobile/Radio Communications Equipment	326	418	510	818	1,492	2,545	50.9%
Other Communications	266	346	350	319	264	325	4.1%
Broadcast and Studio	56	89	79	74	98	109	14.4%
Industrial	$1,685	$1,917	$1,979	$2,152	$2,278	$2,350	6.9%
Security/Energy Management Systems	182	182	197	228	249	278	8.7%
Manufacturing and Instrumentation Systems	981	1,182	1,232	1,319	1,414	1,429	7.8%
Robot Systems	45	45	48	53	56	61	6.3%
Medical Equipment	246	298	297	336	345	365	8.2%
Other Industrial	231	211	206	216	214	218	-1.1%
Consumer	$1,795	$1,883	$1,951	$2,137	$1,938	$2,300	5.1%
Audio	328	359	381	445	326	372	2.6%
Video	1,209	1,215	1,249	1,283	1,257	1,532	4.8%
Personal Electronics	140	171	166	217	184	209	8.4%
Appliances	118	138	155	193	171	187	9.6%
Other Consumer	-	-	-	-	-	-	-
Military and Civil Aerospace	$498	$478	$488	$515	$504	$504	0.2%
Transportation	$640	$812	$893	$1,018	$1,256	$1,655	20.9%

Source: Dataquest (June 1995 Estimates)

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Table 2
European Semiconductor Market by Application—Total Market, Forecast
(Millions of Dollars, Ex-Factory Revenues)

Segment	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Total Semiconductor	**$20,819**	**$26,088**	**$28,932**	**$32,860**	**$37,671**	**$42,607**	**15.4%**
Electronic Data Processing	$9,010	$12,025	$13,347	$15,042	$17,143	$19,351	16.5%
Computers	7,501	10,394	11,470	13,110	14,665	16,751	17.4%
Data Storage	269	251	245	178	163	149	-11.2%
Input/Output Devices	551	621	627	613	644	716	5.4%
Dedicated Systems	689	759	1,005	1,141	1,671	1,735	20.3%
Communications	$5,000	$6,347	$7,359	$8,564	$9,991	$11,245	17.6%
Premise Telecoms Equipment	1,015	1,257	1,420	1,610	1,829	2,001	14.5%
Public Telecoms Equipment	1,005	1,210	1,324	1,452	1,589	1,669	10.7%
Mobile/Radio Communications Equipment	2,545	3,347	4,017	4,830	5,817	6,756	21.6%
Other Communications	325	400	449	505	570	618	13.7%
Broadcast and Studio	109	133	149	166	186	201	13.0%
Industrial	$2,350	$2,589	$2,736	$3,066	$3,431	$3,725	9.7%
Security/Energy Management Systems	278	326	365	433	510	573	15.6%
Manufacturing and Instrumentation Systems	1,429	1,553	1,633	1,828	2,051	2,242	9.4%
Robot Systems	61	69	73	82	92	100	10.6%
Medical Equipment	365	405	420	451	477	487	6.0%
Other Industrial	218	236	244	271	301	324	8.2%
Consumer	$2,300	$2,541	$2,783	$3,163	$3,571	$4,229	13.0%
Audio	372	399	414	478	555	601	10.1%
Video	1,532	1,722	1,928	2,181	2,455	2,971	14.2%
Personal Electronics	209	218	223	249	270	300	7.5%
Appliances	187	202	218	255	291	356	13.8%
Other Consumer	-	-	-	-	-	-	-
Military and Civil Aerospace	$504	$490	$443	$448	$468	$471	-1.4%
Transportation	$1,655	$2,096	$2,264	$2,579	$3,067	$3,586	16.7%

Source: Dataquest (June 1995 Estimates)

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Semiconductor Product Growth Trends

EDP

The bipolar digital market continues to decline sharply in EDP, its primary market, as shown in Tables 3 and 4 (tables placed at the end of the text). The decline in the market for, and production of, mainframe and midrange computers is the major cause. The PC's insatiable demand for memory and microcomponents continues to drive these product markets. Growth in the memory market is compounded by three factors: unit production growth, the increase in system memory per PC, and the current high prices for memory caused by shortages. We expect analog and mixed signal products to grow well in EDP, fuelled by demand for multimedia in the PC. Multimedia will require analog interfaces for I/O in the PC, such as modems, sound cards, speech recognition and voice mail.

The dramatic rise in the markets for chip cards and smart cards is also assisting the growth of the MOS memory and MOS microcomponent lines.

Communications

Communications has been one of the application areas driving the MOS memory and microcomponent product markets, as Tables 5 and 6 show. The increasing use of memory, in particular SRAM and flash memory, in the mobile subsegment contributed to an historical 25.8 percent CAGR. The use of digital signal processors (DSPs) in cellular and high-performance microcontrollers in cellular and digital cordless telephones will help to provide the 19.2 percent CAGR in MOS microcomponent. The communications segment has also become Europe's biggest market for MOS logic.

The analog and discretes markets have also been given a healthy boost by the mobile communications sector, particularly radiofrequency devices. This subsegment is helping communications to become the second-biggest market for analog components, closing in on the consumer market's dominance of analog.

Industrial

Generally, industrial electronics interfaces with the physical world, measuring parameters such as temperature, pressure and so on. These interfaces will always drive the need for analog, discrete and optoelectronic devices.

Industrial equipment is showing the electronics industry trend towards digital technology. Tables 7 and 8 show the growing use of MOS memory and microcomponents in the industrial application segment. The discretes market, though, has benefited from the increasing demand for high-value components such as IGBTs and thyristors.

Consumer

Historically, the consumer sector has always been a major market for discretes and analog, as shown in Table 9. The imminent introduction of a whole range of digital technologies to the consumer sector will help drive demand for all components in the MOS digital segment, especially MOS memory. Table 10 shows the expected 28.3 percent growth in MOS memory, most of which will be from DRAMs. This may present a problem to consumer electronics OEMs, as DRAMs are already in shortage. The growth in digital video products, which require MPEG I and II and support logic, will be the major source of growth in MOS logic.

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Military and Civil Aerospace

This segment is in overall decline, as shown in Tables 11 and 12. Just two segments are showing modest growth—MOS memory and MOS microcomponents. The worst-affected segment is bipolar digital, which will see an annual decline of 28 percent, as this technology is no longer designed-in and MOS alternatives are found.

Automotive

The expected boom in automotive electronics over the next five years will drive a 16.7 percent CAGR for semiconductors, as shown in Table 13. Dataquest expects the average semiconductor content of a car produced in Europe to rise from $100 now, to $200 by 1999. The use of digital solutions for engine management and antilock braking systems (ABS) has provided a significant market for MOS microcomponents, as shown in Table 14. The future drivers will be the increasingly complex and sophisticated driver information and safety and security systems. MOS microcomponents and MOS logic will grow sharply—the important contributors being navigation systems, airbags, keyless entry and digital audio broadcast (DAB) receivers.

Dataquest Perspective

The European semiconductor market is on a roll at the moment. There have been two years of outstanding growth—26.4 percent in 1993/1992 and 34.8 percent in 1994/1993. The trend is set to continue in 1995, with a forecast minimum growth rate of 25.3 percent for 1995/1994. This growth is the sum of a number of new applications that have come in one after the other. The PC provided the boost in 1993, contributing $3.4 billion to the total available market (TAM) and $6.2 billion in 1994. In 1994, GSM handsets were made in volume for the first time. GSM handsets and base stations provided an estimated $1.5 billion to the 1994 TAM; production of GSM handsets is expected to more than double in 1995, and by 1999 is expected to contribute $2.6 billion to the TAM.

Other applications are forecast to add to this wave—set-top boxes in 1996/1997, and automotive electronics in 1997/1998. This wave of new applications is riding on top of a steady growth in semiconductor demand from all application segments. Vendors that have products to meet the needs of these new wave of applications will benefit most from the growth of the European semiconductor market.

By David Moorhouse

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Table 3
European Semiconductor Market by Application—Electronic Data Processing Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Electronic Data Processing Equipment	**$31,776**	**$37,469**	**$36,860**	**$34,899**	**$37,160**	**$39,981**	**4.7%**
Total Semiconductor	2,965	2,963	3,136	3,572	5,915	9,009	24.9%
Total IC	2,827	2,791	2,963	3,412	5,696	8,731	25.3%
Bipolar Digital	333	299	257	219	262	251	-5.5%
MOS Digital	2,304	2,214	2,420	2,919	5,077	7,979	28.2%
MOS Memory	1,538	1,308	1,359	1,659	2,587	4,428	23.6%
MOS Microcomponent	503	642	745	939	2,136	3,075	43.6%
MOS Logic	264	264	317	321	354	476	12.6%
Analog (mono + hybrid)	190	279	285	274	357	501	21.4%
Total Discrete	114	144	140	132	159	174	8.8%
Total Optoelectronic	23	28	33	28	60	104	34.7%

Source: Dataquest (June 1995 Estimates)

Table 4
European Semiconductor Market by Application—Electronic Data Processing Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Electronic Data Processing Equipment	**$39,981**	**$43,475**	**$45,875**	**$48,286**	**$52,940**	**$56,715**	**7.2%**
Total Semiconductor	9,009	12,022	13,348	15,041	17,139	19,355	16.5%
Total IC	8,731	11,618	12,905	14,607	16,694	18,903	16.7%
Bipolar Digital	251	218	174	131	114	89	-18.6%
MOS Digital	7,979	10,753	11,998	13,718	15,680	17,844	17.5%
MOS Memory	4,428	6,284	6,910	8,166	9,238	10,405	18.6%
MOS Microcomponent	3,075	3,885	4,448	4,900	5,704	6,607	16.5%
MOS Logic	476	584	640	652	738	831	11.8%
Analog (mono + hybrid)	501	648	734	758	899	970	14.1%
Total Discrete	174	287	326	318	328	328	13.5%
Total Optoelectronic	104	117	116	115	116	123	3.5%

Source: Dataquest (June 1995 Estimates)

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Table 5
European Semiconductor Market by Application—Communications Equipment, History
(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Communications Equipment	**$25,030**	**$28,698**	**$31,087**	**$32,899**	**$34,886**	**$37,325**	**8.3%**
Total Semiconductor	1,915	2,362	2,567	2,823	3,559	5,001	21.2%
Total IC	1,486	1,780	1,960	2,230	3,102	4,307	23.7%
Bipolar Digital	140	138	121	110	43	37	-23.3%
MOS Digital	1,003	1,093	1,266	1,535	2,270	3,211	26.2%
MOS Memory	389	362	383	498	735	1,224	25.8%
MOS Microcomponent	192	268	318	426	637	817	33.6%
MOS Logic	422	463	566	611	897	1,169	22.6%
Analog (mono + hybrid)	343	549	573	585	789	1,059	25.3%
Total Discrete	329	453	449	451	371	541	10.5%
Total Optoelectronic	100	129	158	142	86	153	8.8%

Source: Dataquest (June 1995 Estimates)

Table 6
European Semiconductor Market by Application—Communications Equipment, Forecast
(Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Communications Equipment	**$37,325**	**$40,377**	**$43,877**	**$46,738**	**$49,405**	**$52,089**	**6.9%**
Total Semiconductor	5,001	6,351	7,358	8,564	9,995	11,241	17.6%
Total IC	4,307	5,484	6,344	7,462	8,751	9,937	18.2%
Bipolar Digital	37	28	21	16	13	12	-20.6%
MOS Digital	3,211	4,126	4,785	5,745	6,687	7,675	19.0%
MOS Memory	1,224	1,716	1,979	2,546	2,963	3,388	22.6%
MOS Microcomponent	817	985	1,174	1,420	1,696	1,969	19.2%
MOS Logic	1,169	1,425	1,632	1,779	2,029	2,318	14.7%
Analog (mono + hybrid)	1,059	1,330	1,539	1,700	2,050	2,250	16.3%
Total Discrete	541	677	811	877	986	1,023	13.6%
Total Optoelectronic	153	189	203	225	259	281	13.0%

Source: Dataquest (June 1995 Estimates)

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Table 7
European Semiconductor Market by Application—Industrial Equipment, History
(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Industrial Equipment	**$21,244**	**$26,078**	**$26,196**	**$27,491**	**$26,295**	**$27,217**	**5.1%**
Total Semiconductor	1,685	1,917	1,979	2,152	2,278	2,350	6.9%
Total IC	1,046	1,152	1,214	1,402	1,502	1,535	8.0%
Bipolar Digital	106	92	78	70	31	21	-27.7%
MOS Digital	649	651	724	911	1,073	1,112	11.4%
MOS Memory	247	203	207	269	343	390	9.5%
MOS Microcomponent	226	277	317	425	431	432	13.9%
MOS Logic	177	171	201	217	298	290	10.4%
Analog (mono + hybrid)	290	409	412	420	398	402	6.7%
Total Discrete	510	619	592	595	709	731	7.4%
Total Optoelectronic	129	146	173	156	67	84	-8.2%

Source: Dataquest (June 1995 Estimates)

Table 8
European Semiconductor Market by Application— Industrial Equipment, Forecast
(Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Industrial Equipment	**$27,217**	**$28,525**	**$30,196**	**$32,202**	**$34,539**	**$37,359**	**6.5%**
Total Semiconductor	2,350	2,589	2,736	3,066	3,431	3,725	9.7%
Total IC	1,535	1,710	1,802	2,090	2,363	2,638	11.4%
Bipolar Digital	21	15	10	8	5	4	-28.6%
MOS Digital	1,112	1,247	1,302	1,548	1,744	1,968	12.1%
MOS Memory	390	472	451	581	662	732	13.4%
MOS Microcomponent	432	458	519	618	706	814	13.5%
MOS Logic	290	317	332	349	376	422	7.8%
Analog (mono + hybrid)	402	448	490	534	613	666	10.6%
Total Discrete	731	786	845	881	960	971	5.9%
Total Optoelectronic	84	93	89	95	108	115	6.5%

Source: Dataquest (June 1995 Estimates)

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Table 9
European Semiconductor Market by Application—Consumer Equipment, History
(Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Consumer Equipment	**$18,964**	**$19,606**	**$20,410**	**$19,450**	**$20,415**	**$21,389**	**2.4%**
Total Semiconductor	1,795	1,883	1,951	2,137	1,938	2,300	5.1%
Total IC	1,353	1,421	1,499	1,682	1,545	1,805	5.9%
Bipolar Digital	14	11	9	8	8	6	-15.6%
MOS Digital	659	579	656	807	438	519	-4.7%
MOS Memory	146	104	105	139	81	113	-4.9%
MOS Microcomponent	197	211	240	327	242	280	7.2%
MOS Logic	316	265	311	341	115	125	-16.9%
Analog (mono + hybrid)	680	832	834	866	1,099	1,280	13.5%
Total Discrete	389	409	390	398	274	321	-3.8%
Total Optoelectronic	54	53	62	57	119	175	26.7%

Source: Dataquest (June 1995 Estimates)

Table 10
European Semiconductor Market by Application— Consumer Equipment, Forecast
(Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Consumer Equipment	**$21,389**	**$22,595**	**$23,949**	**$25,305**	**$26,753**	**$28,217**	**5.7%**
Total Semiconductor	2,300	2,541	2,783	3,163	3,571	4,229	13.0%
Total IC	1,805	2,013	2,219	2,552	2,918	3,497	14.1%
Bipolar Digital	6	5	3	2	2	2	-22.8%
MOS Digital	519	593	695	856	984	1,208	18.4%
MOS Memory	113	160	220	284	323	395	28.3%
MOS Microcomponent	280	300	329	397	451	557	14.7%
MOS Logic	125	133	146	175	209	257	15.4%
Analog (mono + hybrid)	1,280	1,415	1,521	1,694	1,932	2,287	12.3%
Total Discrete	321	341	375	403	430	474	8.1%
Total Optoelectronic	175	186	189	207	223	258	8.1%

Source: Dataquest (June 1995 Estimates)

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Table 11
European Semiconductor Market by Application—Military/Civil Aerospace Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Military/Civil Aerospace Equipment	**$21,749**	**$20,976**	**$21,171**	**$21,055**	**$21,447**	**$20,851**	**-0.8%**
Total Semiconductor	498	478	488	515	504	504	0.2%
Total IC	346	326	339	377	454	449	5.3%
Bipolar Digital	29	21	17	15	35	21	-6.2%
MOS Digital	225	195	214	257	309	319	7.2%
MOS Memory	64	44	44	54	133	161	20.3%
MOS Microcomponent	95	98	109	140	81	72	-5.3%
MOS Logic	66	54	62	63	96	86	5.4%
Analog (mono + hybrid)	93	110	108	105	110	109	3.4%
Total Discrete	119	121	113	108	35	36	-21.2%
Total Optoelectronic	32	31	36	30	15	19	-10.5%

Source: Dataquest (June 1995 Estimates)

Table 12
European Semiconductor Market by Application—Military/Civil Aerospace Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Military/Civil Aerospace Equipment	**$20,851**	**$20,628**	**$20,489**	**$20,275**	**$20,075**	**$19,719**	**-1.1%**
Total Semiconductor	504	490	443	448	468	471	-1.3%
Total IC	449	438	395	402	421	428	-1.0%
Bipolar Digital	21	13	10	7	6	4	-28.0%
MOS Digital	319	318	294	312	328	336	1.0%
MOS Memory	161	174	160	181	191	191	3.6%
MOS Microcomponent	72	68	65	69	75	78	1.5%
MOS Logic	86	77	69	61	62	66	-5.0%
Analog (mono + hybrid)	109	106	90	84	88	89	-4.2%
Total Discrete	36	34	33	31	32	28	-5.2%
Total Optoelectronic	19	18	15	15	15	15	-4.1%

Source: Dataquest (June 1995 Estimates)

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Table 13
European Semiconductor Market by Application—Transportation (Automotive) Equipment, History (Millions of Dollars, Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Automotive Equipment	**$5,191**	**$6,262**	**$6,818**	**$7,809**	**$8,558**	**$9,953**	**13.9%**
Total Semiconductor	640	812	893	1,018	1,256	1,655	20.9%
Total IC	512	645	726	856	1,009	1,309	20.6%
Bipolar Digital	5	5	4	4	12	10	14.1%
MOS Digital	411	492	571	702	818	1,075	21.2%
MOS Memory	34	30	31	40	162	256	49.7%
MOS Microcomponent	229	306	354	466	504	631	22.5%
MOS Logic	148	155	186	196	153	188	5.0%
Analog (mono + hybrid)	96	148	151	151	179	223	18.3%
Total Discrete	112	148	144	141	221	304	22.1%
Total Optoelectronic	16	19	23	20	26	43	22.1%

Source: Dataquest (June 1995 Estimates)

Table 14
European Semiconductor Market by Application—Transportation (Automotive) Equipment, Forecast (Millions of Dollars, Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Automotive Equipment	**$9,953**	**$11,231**	**$12,606**	**$14,075**	**$15,763**	**$17,538**	**12.0%**
Total Semiconductor	1,655	2,095	2,264	2,579	3,067	3,586	16.7%
Total IC	1,309	1,643	1,747	2,026	2,430	2,892	17.2%
Bipolar Digital	10	9	4	3	2	2	-25.6%
MOS Digital	1,075	1,355	1,442	1,693	2,039	2,438	17.8%
MOS Memory	256	366	387	441	500	562	17.0%
MOS Microcomponent	631	756	810	952	1,174	1,441	18.0%
MOS Logic	188	232	245	300	364	435	18.2%
Analog (mono + hybrid)	223	279	301	330	389	451	15.1%
Total Discrete	304	391	456	488	562	609	14.9%
Total Optoelectronic	43	61	61	65	75	86	15.1%

Source: Dataquest (June 1995 Estimates)

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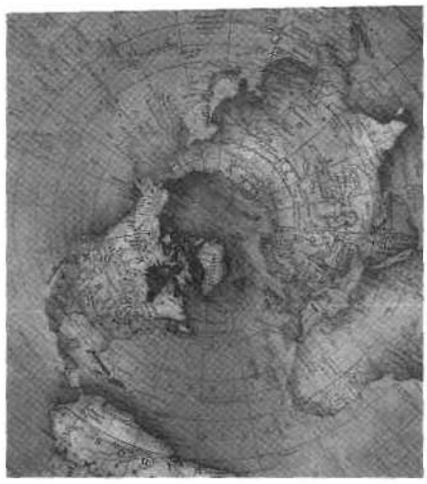
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European Electronic Equipment Production Forecast

Market Statistics
1995

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European Electronic Equipment Production Forecast



Market Statistics

1995

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European Electronic Equipment Production Forecast

Introduction

Electronic equipment production is an important determinant of semiconductor market activity because semiconductor demand is derived, in part, from the underlying demand for the systems that use semiconductors. Therefore, the forecast of expected electronics systems production is an essential component to assessing future electronic component market activity.

This report presents detailed information on Dataquest's view of the European electronic equipment production. It contains tables detailing the spring 1995 electronics equipment production forecast. European production is estimated for the years 1989 to 1999. Production tables contain both historical data and forecasts. In most tables, historical data begins with 1989 and ends with 1994, while forecast data provide estimates for 1995 through 1999. Tables detail the type of production data by application market and unit of measure.

Changes in Definitions

Ex-factory revenues are used throughout this report rather than *end-user revenues*. Ex-factory revenues measure the value of equipment as they are shipped out of a factory. End-user revenues take into account retailing costs such as distribution costs, wholesale overhead costs, storage costs, and other additional costs that are not associated with the production side of equipment costing. Ex-factory revenues therefore provide a meaningful estimation of equipment I/O ratios as a more accurate indication of semiconductor content value of equipment built in Europe.

Equipment definition and segmentation has also been changed in the electronic data processing (EDP), communications and transportation segments. The details of these changes are outlined in the Definitions section of the report.

Segmentation and Methodology

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along lines of segmentation that are logical, and appropriate to the industry in question.

Dataquest defines the electronic equipment industry as the group of competing companies primarily engaged in manufacturing electronic goods. For the purposes of this report, important products of the electronics industry include data processing equipment, communications equipment, selected types of industrial equipment, consumer electronics, selected types of military and civil aerospace and defense-oriented electronics, and automotive electronics.

For forecasting purposes, Dataquest segments the electronics industry into six broad semiconductor application markets, desegregated into narrower electronic system groups, as follows:

- Electronic Data Processing
  - Computers
  - Data Storage
  - Input/Output Devices
  - Dedicated Systems

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- Communications
  - Premise Telecoms Equipment
  - Public Telecoms Equipment
  - Mobile/Radio Communications Equipment
  - Other Communications Equipment
  - Broadcast and Studio Equipment
- Industrial
  - Security and Energy Management Systems
  - Manufacturing and Instrumentation Systems
  - Robot Systems
  - Medical Equipment
  - Other Industrial Equipment
- Consumer
  - Audio
  - Video
  - Personal Electronics
  - Appliances
- Military and Civil Aerospace
- Transportation

For detailed definitions of the above, please see the end of this section.

Forecast Assumptions and Changes to Previously Published Forecasts

This year we have separated the forecast assumptions and changes to market forecast from this document. In June 1995, the Semiconductor Application Markets Europe group will publish a Market Trends report which will be an explanatory document for these estimates. This Market Trends document will also cover in more detail the economic assumptions, market conditions and production trends in each application segment.

Also, we have separated the semiconductor forecast by application from this document. A more detailed and comprehensive forecast will be provided twice this year in June and November. In each of these forecast perspectives, more detail will be provided including an application forecast by product (MOS memory, MOS microcomponents, discrete and so on).

Exchange Rates

Dataquest uses an average annual exchange rate for each European country for converting revenue to US dollar values. When forecasting electronic equipment production, it is important to maintain consistency and continuity, thus we maintain exchange rates at constant 1994 calendar year. This prevents any inconsistencies in the conversion of growth projections and currency fluctuations. The 1994 exchange rate estimate uses actual average monthly exchange rates from January through December (these data are gathered and supplied by the Dun & Bradstreet Corporation). The annual rate is estimated as the arithmetic mean of the 12 monthly rates. Exchange rates are provided in Table 1-1 for your reference. Exchange rates for historical years are available on request.

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Table 1
1994 Exchange Rates

	Foreign Currency per US Dollar	US Dollar per Foreign Currency
Austria (Schilling)	11.40	0.08784
Belgium (Franc)	33.36	0.03003
Denmark (Krone)	6.35	0.15772
ECU	0.84	1.18691
Finland (Markka)	5.21	0.19278
France (Franc)	5.54	0.18090
Germany (Mark)	1.62	0.61828
Greece (Drachma)	242.06	0.00413
Ireland (Punt)	0.67	1.50115
Italy (Lira)	1,609.34	0.00062
Netherlands (Gulden)	1.82	0.55137
Norway (Krone)	7.04	0.14218
Portugal (Escudo)	165.63	0.00605
Spain (Peseta)	133.48	0.00750
Sweden (Krona)	7.70	0.13004
Switzerland (Franc)	1.37	0.73356
United Kingdom (Pound)	0.65	1.53068

Source: Dun & Bradstreet, Dataquest (April 1995)

Definitions

This section lists the definitions used by Dataquest to present the data in this report. Complete definitions for all terms associated with Dataquest's segmentation of the high-technology marketplace can be found in the Dataquest *Semiconductor Market Definitions* book.

Electronic systems groups are comprised of the following specific electronic equipment types.

Electronic Data Processing

- **Computer Systems:** Includes supercomputers, mainframe computers, midrange computers, workstations, personal computers (including personal digital assistants or PDAs).
- **Data Storage Devices:** Includes fixed/rigid disk drives, flexible/removable disk drives, optical disk drives, tape drives (streamers), and solid-state storage devices (including PCMCIA memory cards).
- **Input/Output Devices** (includes previous categories Terminals and Input/Output devices): Includes alphanumeric terminals, graphics terminals, monitors, printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, mice, keyboards, digitizers, and other input/output devices.
- **Dedicated Systems:** Includes electronic copiers, electronic calculators and personal organizers, smart cards (IC cards), dictating/transcribing equipment, electronic typewriters and dedicated word processors, banking systems and funds transfer systems and terminals, point-of-sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.

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Communications

- **Premise Telecoms Equipment** (Sometimes referred to as "customer premise equipment"): Includes:
  - *Image and text communications* such as facsimile and facsimile cards, and video teleconferencing.
  - *Data communications equipment*: This year this section has been redefined to reflect the segmentation which appears in the industry. The equipment is segmented by speed categories rather than function. Included are modems and modem cards, 64 Kbit/s access equipment, 2Mbit/s and below access equipment, backbone equipment, ISDN access equipment, network interface cards (LAN cards) and LAN interconnect equipment.
  - *Premise switching equipment* such as PBX telephone equipment, and key telephone systems, interactive voice response systems, call accounting and automatic call distributors (ACDs).
  - *Desktop terminal equipment* such as telephone sets/pay telephones and cordless telephones, and teleprinters.
- **Public Telecoms Equipment:** Includes transmission equipment such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment and central office switching equipment.
- **Mobile/Radio Communications Equipment:** Includes cellular telephones including microcellular telephones (for example DCS-1800, GSM, PHP), mobile radios and mobile radio base station equipment; pagers and accompanying base station equipment; portable radio receivers and transmitters; radio checkout equipment; and other RF communications equipment.
- **Other Communications:** Includes airborne, marine, and ground systems sold as complete packages that include transceivers, power amplifiers, antennae, repeaters, transmitters, checkout (testing), monitoring, evaluation and other equipment including terminal and broadcast equipment.
- **Broadcast and Studio Equipment:** Includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV equipment, closed circuit TV equipment, and other equipment such as studio and theatre equipment.

Industrial

- **Energy/Security Management Systems:** Includes alarm systems, such as intrusion detection and fire detection systems and energy management systems.
- **Manufacturing and Instrumentation Systems:** Includes semiconductor production equipment, controllers and actuators, sensor systems, management systems, semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and wave-form analysers, nuclear instruments, and other test and measuring equipment.
- **Robots:** Includes automated material handling, robot systems, robot-aided laser equipment, and robotic systems.
- **Medical Equipment:** Includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analysers, patient monitoring equipment, and other diagnostic and therapeutic equipment.
- **Other Industrial Equipment:** Includes power supplies, traffic control equipment, industrial and scientific research equipment, other industrial electronic equipment such as vending machines, laser systems, and teaching machines and aids.

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Consumer

- **Audio Equipment:** Includes compact disc players, radio combinations, stereo hi-fi components, amplifiers, preamplifiers, tuners, cassette decks, graphics equalizers, turntables, speakers, equipment used in studio broadcast, home environments (equipment that interpret frequencies corresponding to audible sound waves), and musical instruments.
- **Video Equipment:** Includes video cameras and camcorders, videocassette recorders/videotape recorders, and color, monochrome and LCD televisions, and cable set-top and satellite set-top equipment (decoders).
- **Personal Electronics:** Includes electronic game systems and cartridges, electronic toys, cameras, watches and clocks
- **Appliances:** Includes air conditioners, microwave ovens, washers and dryers, refrigerators/freezers, dishwashers, and ranges and ovens.

Military and Civil Aerospace

- Includes *military electronics* such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, military computer systems, simulation systems, and military electronics not elsewhere classified; and *civil aerospace electronics* such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

Transportation (Automotive)

Transportation electronics includes:

- **In-car entertainment** systems such as AM/FM radio, cassette, compact disk players, and radio cassette combination systems; vehicle controls such as steering control, 2WD/4WD control, suspension control and traction control, active suspension, collision avoidance systems, collision warning systems, and cruise control.
- **Body controls** (chassis) such as multiplex systems, lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls, and other body controls including aerodynamic aid control and power window/roof controls.
- **Driver information** systems such as dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, signal and warning lights, and trip computer.
- **Powertrain** systems such as engine management systems, ignition control, fuel injection systems, and transmission control.
- **Safety and convenience** systems such as climate control systems, airbag control systems, automatic/interval wiper, keyless entry and door locks, security systems, memory seats, memory steering, memory mirrors, automatic seat belt systems, and antilock braking systems.

Regional Definitions

- **Europe:** Western Europe includes Benelux (Belgium, Netherlands, Luxembourg), France, Italy, Germany (including former East Germany), Scandinavia (Denmark, Finland, Norway, Sweden, and Iceland), United Kingdom and Eire (Ireland), and Rest of Western Europe (Austria, Gibraltar, Greece, Liechtenstein, Malta, Monaco, Portugal, San Marino, Spain, Switzerland, Turkey, Andorra and Vatican City, Central and Eastern Europe).
  - *Central and Eastern Europe:* includes Albania, Bulgaria, Czech Republic, Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Republics of former Yugoslavia, Ukraine, Belarus, Georgia, Russian Federation, Moldova, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, Turkmenistan.

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Line Item Definitions

The objective of analysing electronic systems production is to estimate its important implications for semiconductor consumption.

The value of production is estimated as ex-factory revenue. Dataquest defines factory revenue as the money exchange value of the commodity transaction between the original equipment manufacturer and the point of entry into distribution. In the case of a direct sale that involves no distribution—as is the case with military systems—factory revenue is equal to the final user cost, net of sales taxes. For the purposes of this report Dataquest defines ex-factory revenue as the derived production revenue from the factory value.

Data Sources

The historical information presented in the production data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. From time to time, we conduct production surveys for specific types of electronic equipment and the data gathered are also incorporated into the database. Our other sources include the following:

- Dataquest's estimates of systems manufacturers' end-user revenue
- Trade association data
- Various European Union and government agency statistics
- Japanese government and trade association (MITI, MOF, and EIAJ) intelligence
- Estimates presented by knowledgeable and reliable industry spokespersons
- Published product literature and prices
- Other Dataquest research groups (including Computer Systems and Peripherals, Telecommunications and Document Management).

Unlike in Japan and the United States where government bodies supply regular production statistics, Europe-wide statistic programs are in their infancy; we believe that the estimates presented here are the most reliable and meaningful generally as they apply to the components manufacturers.

Forecast Methodology

Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. Dataquest follows a three-step process to forecast electronic equipment production. Firstly, current and expected future worldwide and European macroeconomic conditions are assessed and forecast. Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies—the Group of Seven (G7) Countries. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from other Dataquest industry sources (as identified earlier), Dataquest estimates the overall business climates in which the electronic systems market will operate.

Secondly, Dataquest analyses and forecasts the significant long-range trend and outlook in the various electronic system research groups (within Dataquest). This establishes a five-year trend growth path for electronic system production.

The final step in the forecast process is to reconcile expected fluctuations about market trends so that the two do not inexplicably diverge. Dataquest anticipates that in the absence of shocks to the market, market fluctuations converge toward a long-term trend.

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Because the time series data contained in this document comprise, in general, annual observations, and are sparse in terms of the number of observations, the data generally do not satisfy the requirements of quantitative empirical techniques such as econometric or statistical time series models. Therefore, in most cases, we have used judgmental models (that is, intuitive judgements, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

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European Overview

Table 2
Segment Overview, European Electronic Equipment Production (in Millions of US Dollars) History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1989-1994 CAGR
Total Equipment	**$123,954**	**$139,089**	**$142,540**	**$143,603**	**$148,761**	**$156,716**	**4.8%**
Electronic Data Processing	$31,776	$37,469	$36,859	$34,899	$37,160	$39,982	4.7%
Computers	$24,767	$30,430	$28,719	$26,658	$27,323	$29,401	3.5%
Data Storage	$668	$908	$1,298	$1,418	$1,673	$2,040	25.0%
Input/Ouput Devices	$4,105	$3,879	$4,385	$4,185	$4,877	$4,564	2.1%
Dedicated Systems	$2,236	$2,252	$2,458	$2,639	$3,287	$3,976	12.2%
Communications	$25,030	$28,698	$31,087	$32,899	$34,886	$37,325	8.3%
Premise Telecoms Equipment	$4,616	$4,943	$5,317	$5,612	$5,798	$6,495	7.1%
Public Telecoms Equipment	$12,587	$14,305	$15,375	$15,186	$15,197	$15,174	3.8%
Mobile/Radio Communications Equipment	$2,286	$2,566	$2,996	$4,793	$7,819	$9,485	32.9%
Other Communications	$4,757	$5,949	$6,510	$6,422	$5,103	$5,337	2.3%
Broadcast and Studio	$784	$935	$890	$885	$970	$834	1.3%
Industrial	$21,244	$26,078	$26,196	$27,491	$26,295	$27,217	5.1%
Security/Energy Management Systems	$2,587	$2,566	$2,594	$2,668	$2,600	$2,730	1.1%
Manufacturing and Instrumentation Systems	$11,704	$15,698	$15,716	$16,448	$15,553	$15,964	6.4%
Robot Systems	$665	$689	$733	$790	$819	$871	5.5%
Medical Equipment	$2,941	$3,700	$3,692	$4,025	$3,941	$4,169	7.2%
Other Industrial	$3,347	$3,425	$3,461	$3,560	$3,382	$3,483	0.8%
Consumer	$18,964	$19,606	$20,410	$19,450	$20,415	$21,389	2.4%
Audio	$1,394	$1,543	$1,463	$1,352	$1,299	$1,517	1.7%
Video	$4,679	$4,905	$5,648	$5,108	$5,465	$6,000	5.1%
Personal Electronics	$944	$1,148	$1,109	$1,161	$1,207	$1,380	7.9%
Appliances	$11,948	$12,010	$12,190	$11,829	$12,445	$12,492	0.9%
Other Consumer Equipment	-	-	-	-	-	-	-
Military and Civil Aerospace	$21,749	$20,976	$21,171	$21,055	$21,447	$20,851	-0.8%
Transportation	$5,191	$6,262	$6,818	$7,809	$8,558	$9,953	13.9%

Source: Dataquest (April 1995 Estimates)

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Table 3
Segment Overview, European Electronic Equipment Production (in Millions of US Dollars) Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Total Equipment	**$156,716**	**$166,831**	**$176,992**	**$186,880**	**$199,476**	**$211,637**	**6.2%**
Electronic Data Processing	$39,982	$43,475	$45,875	$48,285	$52,940	$56,715	7.2%
Computers	$29,401	$32,789	$34,773	$37,125	$40,478	$44,066	8.4%
Data Storage	$2,040	$1,797	$1,841	$1,357	$1,252	$1,086	-11.8%
Input/Ouput Devices	$4,564	$4,894	$5,003	$5,516	$6,317	$6,847	8.4%
Dedicated Systems	$3,976	$3,995	$4,259	$4,288	$4,893	$4,715	3.5%
Communications	$37,325	$40,377	$43,877	$46,738	$49,405	$52,089	6.9%
Premise Telecoms Equipment	$6,495	$7,290	$7,889	$8,613	$9,447	$9,756	8.5%
Public Telecoms Equipment	$15,174	$15,168	$15,186	$15,190	$15,365	$15,534	0.5%
Mobile/Radio Communications Equipment	$9,485	$11,405	$13,883	$15,349	$16,135	$17,754	13.4%
Other Communications	$5,337	$5,665	$5,988	$6,615	$7,459	$8,021	8.5%
Broadcast and Studio	$834	$849	$932	$971	$998	$1,024	4.2%
Industrial	$27,217	$28,525	$30,196	$32,202	$34,539	$37,359	6.5%
Security/Energy Management Systems	$2,730	$2,921	$3,184	$3,534	$3,923	$4,355	9.8%
Manufacturing and Instrumentation Systems	$15,964	$16,602	$17,432	$18,478	$19,772	$21,354	6.0%
Robot Systems	$871	$938	$1,014	$1,105	$1,215	$1,349	9.1%
Medical Equipment	$4,169	$4,440	$4,726	$4,976	$5,192	$5,465	5.6%
Other Industrial	$3,483	$3,623	$3,840	$4,109	$4,438	$4,837	6.8%
Consumer	$21,389	$22,595	$23,949	$25,305	$26,753	$28,217	5.7%
Audio	$1,517	$1,659	$1,766	$1,937	$2,091	$2,225	8.0%
Video	$6,000	$6,692	$7,543	$8,238	$9,026	$9,907	10.6%
Personal Electronics	$1,380	$1,462	$1,551	$1,658	$1,752	$1,848	6.0%
Appliances	$12,492	$12,782	$13,089	$13,471	$13,884	$14,237	2.6%
Other Consumer Equipment	-	-	-	-	-	-	-
Military and Civil Aerospace	$20,851	$20,628	$20,489	$20,275	$20,075	$19,719	-1.1%
Transportation	$9,953	$11,231	$12,606	$14,075	$15,763	$17,538	12.0%

Source: Dataquest (April 1995 Estimates)

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Electronic Data Processing

Table 4
Segment Detail, European Electronic Data Processing Equipment Production (in Millions of US Dollars)
History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Electronic Data Processing	**$31,776**	**$37,469**	**$36,859**	**$34,899**	**$37,160**	**$39,982**	**4.7%**
Computer Systems	$24,767	$30,430	$28,719	$26,658	$27,323	$29,401	3.5%
Supercomputers	$0	$0	$0	$0	$0	$0	NA
Mainframes	$9,948	$10,537	$11,259	$8,305	$7,191	$6,684	-7.6%
Midrange Computers	$9,943	$9,240	$9,279	$6,685	$6,103	$6,002	-9.6%
Superminicomputers	$6,946	$6,419	$6,627	$4,739	$4,339	$4,316	-9.1%
Minicomputers	$1,713	$1,653	$1,595	$1,192	$1,090	$1,024	-9.8%
Microcomputers	$1,284	$1,168	$1,057	$754	$674	$662	-12.4%
Workstations	$258	$510	$993	$1,833	$1,755	$1,965	50.1%
Personal Computers	$4,618	$10,143	$7,188	$9,835	$12,274	$14,750	26.1%
Data Storage	$668	$908	$1,298	$1,418	$1,673	$2,040	25.0%
Rigid Disk Drives	$575	$793	$1,166	$1,265	$1,492	$1,823	26.0%
Flexible/Removable Media	$12	$9	$0	$0	$0	$0	-100.0%
Optical Disk Drives	$2	$5	$6	$13	$25	$44	87.7%
Tape Drives	$79	$100	$126	$140	$156	$173	16.9%
Input/Ouput Devices	$4,105	$3,879	$4,385	$4,185	$4,877	$4,564	2.1%
Displays	$1,636	$1,359	$1,307	$935	$985	$991	-9.5%
Serial Printers	$896	$639	$1,176	$1,016	$1,270	$872	-0.5%
Line Printers	$371	$534	$487	$391	$415	$337	-1.9%
Page Printers	$343	$536	$512	$579	$706	$750	16.9%
Input Devices	$858	$810	$901	$1,261	$1,497	$1,611	13.4%
Other Output Devices	$2	$2	$2	$3	$3	$4	19.6%
Dedicated Systems	$2,236	$2,252	$2,458	$2,639	$3,287	$3,976	12.2%
Office Equipment	$1,992	$1,996	$2,145	$2,248	$2,592	$3,056	8.9%
Copiers and Duplicators	$1,718	$1,739	$1,887	$1,983	$2,328	$2,824	10.5%
Electronic Calculators	$60	$67	$54	$53	$47	$41	-7.3%
Dictating, Transcribing	$31	$32	$36	$39	$36	$29	-1.3%
Electronic Typewriters	$183	$158	$168	$173	$181	$162	-2.4%
Cash Registers	$154	$152	$183	$195	$188	$162	1.0%
Smart Cards (IC Cards)	$90	$104	$130	$196	$507	$758	53.1%

NA = not applicable
Source: Dataquest (April 1995 Estimates)

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Table 5
Segment Detail, European Electronic Data Processing Equipment Production (in Millions of US Dollars)
Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Electronic Data Processing	**$39,982**	**$43,475**	**$45,875**	**$48,285**	**$52,940**	**$56,715**	**7.2%**
Computer Systems	$29,401	$32,789	$34,773	$37,125	$40,478	$44,066	8.4%
Supercomputers	$0	$0	$0	$0	$0	$0	NA
Mainframes	$6,684	$6,238	$5,734	$5,178	$4,634	$4,212	-8.8%
Midrange Computers	$6,002	$5,986	$5,784	$5,428	$5,074	$4,803	-4.4%
Superminicomputers	$4,316	$4,368	$4,210	$3,863	$3,525	$3,254	-5.5%
Minicomputers	$1,024	$998	$984	$975	$967	$963	-1.2%
Microcomputers	$662	$620	$590	$590	$582	$586	-2.4%
Workstations	$1,965	$2,105	$2,320	$2,759	$3,270	$3,972	15.1%
Personal Computers	$14,750	$18,460	$20,935	$23,760	$27,500	$31,080	16.1%
Data Storage	$2,040	$1,797	$1,841	$1,357	$1,252	$1,086	-11.8%
Rigid Disk Drives	$1,823	$1,565	$1,603	$1,127	$1,031	$871	-13.7%
Flexible/Removable Media	$0	$0	$0	$0	$0	$0	NA
Optical Disk Drives	$44	$43	$39	$36	$29	$27	-9.3%
Tape Drives	$173	$189	$198	$194	$192	$188	1.7%
Input/Ouput Devices	$4,564	$4,894	$5,003	$5,516	$6,317	$6,847	8.4%
Displays	$991	$1,048	$1,023	$987	$939	$880	-2.3%
Serial Printers	$872	$987	$990	$1,216	$1,669	$2,122	19.5%
Line Printers	$337	$352	$437	$574	$816	$820	19.4%
Page Printers	$750	$832	$908	$961	$1,007	$1,025	6.5%
Input Devices	$1,611	$1,671	$1,640	$1,773	$1,880	$1,993	4.4%
Other Output Devices	$4	$4	$5	$5	$6	$6	10.8%
Dedicated Systems	$3,976	$3,995	$4,259	$4,288	$4,893	$4,715	3.5%
Office Equipment	$3,056	$2,802	$2,578	$2,383	$2,164	$1,973	-8.4%
Copiers and Duplicators	$2,824	$2,596	$2,392	$2,201	$2,018	$1,843	-8.2%
Electronic Calculators	$41	$27	$23	$20	$16	$13	-21.1%
Dictating, Transcribing	$29	$23	$17	$14	$11	$9	-21.6%
Electronic Typewriters	$162	$156	$146	$149	$118	$109	-7.6%
Cash Registers	$162	$133	$110	$86	$73	$61	-17.7%
Smart Cards (IC Cards)	$758	$1,061	$1,571	$1,819	$2,656	$2,681	28.7%

NA = not applicable
Source: Dataquest (April 1995 Estimates)

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Communications

Table 6
Segment Detail, European Communications Equipment Production (in Millions of US Dollars)
History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Communications	**$25,030**	**$28,698**	**$31,087**	**$32,899**	**$34,886**	**$37,325**	**8.3%**
Premise Telecoms Equipment	$4,616	$4,943	$5,317	$5,612	$5,798	$6,495	7.1%
Image and Text Communications Equipment	$1,230	$1,330	$1,273	$1,098	$899	$895	-6.2%
Facsimile	$346	$348	$342	$334	$288	$313	-2.0%
Video Teleconferencing	$6	$6	$11	$15	$23	$54	57.3%
Telex	$116	$95	$80	$66	$55	$47	-16.4%
Videotex	$704	$807	$758	$586	$424	$364	-12.4%
CCTV	$58	$73	$83	$96	$107	$117	15.0%
Data Communications Equipment	$999	$1,068	$1,285	$1,565	$1,754	$2,256	17.7%
Modems	$426	$379	$362	$391	$290	$323	-5.4%
64-Kbit/s Access Equipment	$130	$100	$93	$83	$68	$58	-14.8%
2-Mbit/s Access Equipment	$14	$16	$15	$13	$11	$13	-1.1%
Backbone Equipment	$171	$186	$245	$283	$279	$305	12.3%
ISDN Access Equipment	$0	$16	$51	$94	$135	$191	NA
Network Interface Cards	$248	$347	$479	$633	$853	$1,200	37.1%
LAN Interconnect	$10	$24	$40	$67	$118	$165	74.8%
Premise Switching Equipment	$1,449	$1,553	$1,703	$1,842	$1,913	$2,062	7.3%
PBX/Key Telephone Systems	$1,411	$1,501	$1,617	$1,721	$1,732	$1,786	4.8%
Call Processing Equipment	$38	$52	$86	$120	$182	$276	48.4%
Voice Messaging	$7	$9	$17	$23	$42	$57	54.2%
Call Accounting	$10	$17	$29	$49	$88	$140	68.5%
Automatic Call Distributors	$22	$27	$40	$48	$52	$79	29.7%
Desktop Terminal Equipment	$937	$992	$1,056	$1,108	$1,232	$1,281	6.5%
Telephones	$922	$973	$1,031	$1,077	$1,195	$1,239	6.1%
Standard Telephones	$812	$829	$851	$825	$830	$781	-0.8%
Cordless Telephones	$110	$144	$181	$247	$353	$445	32.3%
Video Telephones	$0	$0	$0	$6	$11	$12	NA
Answering Machines	$15	$20	$25	$31	$37	$43	23.7%
Public Telecoms Equipment	$12,587	$14,305	$15,375	$15,186	$15,197	$15,174	3.8%
Transmission Equipment	$5,215	$5,790	$5,627	$5,784	$6,534	$7,033	6.2%
Central Office Switching	$7,283	$8,434	$9,628	$9,281	$8,552	$8,032	2.0%
Public Packet Data Switching	$90	$81	$119	$121	$111	$109	3.9%

(Continued)

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Table 6 (Continued)
Segment Detail, European Communications Equipment Production (in Millions of US Dollars)
History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Mobile/Radio Communications Equipment	$2,286	$2,566	$2,996	$4,793	$7,819	$9,485	32.9%
Cellular Telephones	$456	$547	$656	$991	$1,911	$2,917	44.9%
Analog Cellular	$456	$547	$576	$556	$702	$834	12.8%
Digital Cellular	$0	$0	$80	$435	$1,209	$2,083	NA
Mobile Communications Equipment	$1,830	$2,019	$2,340	$3,803	$5,908	$6,567	29.1%
Mobile Radio Base Stations	$1,164	$1,293	$1,496	$2,527	$3,978	$4,343	30.1%
Pagers and Base Stations	$85	$90	$101	$114	$126	$150	12.0%
Other Mobile Radio	$580	$637	$743	$1,162	$1,804	$2,075	29.0%
Other Communications	$4,757	$5,949	$6,510	$6,422	$5,103	$5,337	2.3%
Broadcast and Studio	$784	$935	$890	$885	$970	$834	1.3%

NA = not applicable
Source: Dataquest (April 1995 Estimates)

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Table 7
Segment Detail, European Communications Equipment Production (in Millions of US Dollars)
Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Communications	**$37,325**	**$40,377**	**$43,877**	**$46,738**	**$49,405**	**$52,089**	**6.9%**
Premise Telecoms Equipment	$6,495	$7,290	$7,889	$8,613	$9,447	$9,756	8.5%
Image and Text Communications Equipment	$895	$901	$857	$929	$1,177	$1,248	6.9%
Facsimile	$313	$316	$303	$304	$285	$261	-3.5%
Video Teleconferencing	$54	$92	$137	$211	$462	$591	61.4%
Telex	$47	$40	$34	$30	$27	$12	-24.1%
Videotex	$364	$330	$254	$250	$267	$242	-7.8%
CCTV	$117	$124	$129	$133	$136	$142	3.8%
Data Communications Equipment	$2,256	$2,812	$3,184	$3,584	$3,892	$3,875	11.4%
Modems	$323	$306	$283	$271	$263	$258	-4.4%
64-Kbit/s Access Equipment	$58	$51	$43	$35	$30	$26	-14.8%
2-Mbit/s Access Equipment	$13	$16	$13	$11	$9	$7	-12.0%
Backbone Equipment	$305	$335	$351	$369	$405	$405	5.8%
ISDN Access Equipment	$191	$257	$329	$404	$485	$501	21.3%
Network Interface Cards	$1,200	$1,642	$1,920	$2,211	$2,382	$2,316	14.1%
LAN Interconnect	$165	$205	$244	$283	$319	$363	17.0%
Premise Switching Equipment	$2,062	$2,223	$2,396	$2,582	$2,777	$2,959	7.5%
PBX/Key Telephone Systems	$1,786	$1,860	$1,947	$2,047	$2,148	$2,243	4.7%
Call Processing Equipment	$276	$363	$449	$536	$629	$717	21.0%
Voice Messaging	$57	$80	$108	$143	$185	$199	28.2%
Call Accounting	$140	$151	$163	$175	$187	$194	6.8%
Automatic Call Distributors	$79	$133	$178	$217	$256	$324	32.6%
Desktop Terminal Equipment	$1,281	$1,355	$1,451	$1,517	$1,602	$1,674	5.5%
Telephones	$1,239	$1,304	$1,388	$1,440	$1,510	$1,572	4.9%
Standard Telephones	$781	$728	$715	$695	$700	$705	-2.0%
Cordless Telephones	$445	$553	$630	$708	$783	$841	13.6%
Video Telephones	$12	$23	$43	$37	$27	$25	15.9%
Answering Machines	$43	$51	$64	$77	$92	$102	19.0%
Public Telecoms Equipment	$15,174	$15,168	$15,186	$15,190	$15,365	$15,534	0.5%
Transmission Equipment	$7,033	$7,202	$7,351	$7,517	$7,760	$7,975	2.5%
Central Office Switching	$8,032	$7,868	$7,743	$7,591	$7,525	$7,488	-1.4%
Public Packet Data Switching	$109	$98	$92	$82	$80	$71	-8.2%

(continued)

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Table 7 (Continued)
Segment Detail, European Communications Equipment Production (in Millions of US Dollars)
Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Mobile/Radio Communications Equipment	$9,485	$11,405	$13,883	$15,349	$16,135	$17,754	13.4%
Cellular Telephones	$2,917	$3,640	$4,640	$5,437	$6,056	$7,411	20.5%
Analog Cellular	$834	$394	$309	$260	$181	$131	-31.0%
Digital Cellular	$2,083	$3,246	$4,331	$5,178	$5,875	$7,280	28.4%
Mobile Communications Equipment	$6,567	$7,766	$9,243	$9,912	$10,079	$10,343	9.5%
Mobile Radio Base Stations	$4,343	$5,227	$6,313	$6,839	$7,002	$7,130	10.4%
Pagers and Base Stations	$150	$185	$243	$305	$388	$505	27.5%
Other Mobile Radio	$2,075	$2,353	$2,687	$2,768	$2,689	$2,708	5.5%
Other Communications	$5,337	$5,665	$5,988	$6,615	$7,459	$8,021	8.5%
Broadcast and Studio	$834	$849	$932	$971	$998	$1,024	4.2%

Source: Dataquest (April 1995 Estimates)

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Industrial

Table 8
Segment Detail, European Industrial Equipment Production (in Millions of US Dollars) History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Industrial	**$21,244**	**$26,078**	**$26,196**	**$27,491**	**$26,295**	**$27,217**	**5.1%**
Security/Energy Management Systems	$2,587	$2,566	$2,594	$2,668	$2,600	$2,730	1.1%
Manufacturing and Instrumentation Systems	$11,704	$15,698	$15,716	$16,448	$15,553	$15,964	6.4%
Robot Systems	$665	$689	$733	$790	$819	$871	5.5%
Medical Equipment	$2,941	$3,700	$3,692	$4,025	$3,941	$4,169	7.2%
Other Industrial	$3,347	$3,425	$3,461	$3,560	$3,382	$3,483	0.8%

Source: Dataquest (April 1995 Estimates)

Table 9
Segment Detail, European Industrial Equipment Production (in Millions of US Dollars) Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Industrial	**$27,217**	**$28,525**	**$30,196**	**$32,202**	**$34,539**	**$37,359**	**6.5%**
Security/Energy Management Systems	$2,730	$2,921	$3,184	$3,534	$3,923	$4,355	9.8%
Manufacturing and Instrumentation Systems	$15,964	$16,602	$17,432	$18,478	$19,772	$21,354	6.0%
Robot Systems	$871	$938	$1,014	$1,105	$1,215	$1,349	9.1%
Medical Equipment	$4,169	$4,440	$4,726	$4,976	$5,192	$5,465	5.6%
Other Industrial	$3,483	$3,623	$3,840	$4,109	$4,438	$4,837	6.8%

Source: Dataquest (April 1995 Estimates)

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Consumer

Table 10
Segment Detail, European Consumer Equipment Production (in Millions of US Dollars) History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Consumer	**$18,964**	**$19,606**	**$20,410**	**$19,450**	**$20,415**	**$21,389**	**2.4%**
Audio	$1,394	$1,543	$1,463	$1,352	$1,299	$1,517	1.7%
Compact Disc Players	$670	$775	$725	$669	$708	$837	4.5%
Digital Compact Cassette Players	$0	$0	$0	$6	$19	$30	NA
Radio Combinations	$417	$428	$437	$402	$321	$370	-2.3%
Stereo Hi-Fi Components	$256	$275	$240	$217	$196	$222	-2.8%
Musical Instruments	$51	$66	$61	$59	$55	$58	2.9%
Video	$4,679	$4,905	$5,648	$5,108	$5,465	$6,000	5.1%
Video Cameras/Camcorders	$294	$374	$404	$372	$366	$482	10.4%
VCRs	$1,058	$1,084	$1,224	$968	$1,090	$1,223	2.9%
Color Televisions	$3,033	$3,051	$3,498	$3,111	$3,187	$3,304	1.7%
Black and White Televisions	$22	$22	$16	$19	$16	$16	-5.8%
Set Top Boxes	$271	$374	$505	$638	$805	$974	29.2%
Satellite Set-Top Boxes	$174	$277	$400	$527	$683	$842	37.1%
CATV Set-Top Boxes	$97	$97	$106	$111	$122	$132	6.4%
Personal Electronics	$944	$1,148	$1,109	$1,161	$1,207	$1,380	7.9%
Watches	$825	$1,025	$972	$1,006	$1,041	$1,195	7.7%
Clocks	$119	$123	$137	$154	$166	$185	9.2%
Appliances	$11,948	$12,010	$12,190	$11,829	$12,445	$12,492	0.9%
Air Conditioners	$324	$339	$398	$473	$536	$626	14.1%
Microwave Ovens	$1,246	$1,582	$1,701	$1,787	$1,551	$1,540	4.3%
Washers and Dryers	$3,143	$3,042	$3,069	$2,910	$3,168	$3,021	-0.8%
Refrigerators/Freezers	$3,872	$3,566	$3,457	$3,217	$3,388	$3,394	-2.6%
Dishwashers	$921	$986	$1,056	$1,178	$1,393	$1,660	12.5%
Ranges and Ovens	$2,442	$2,495	$2,508	$2,263	$2,409	$2,251	-1.6%

NA = not applicable
Source: Dataquest (April 1995 Estimates)

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Table 11
Segment Detail, European Consumer Equipment Production (in Millions of US Dollars) Forecast (Ex-Factory Revenues)

	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
Consumer	**$21,389**	**$22,595**	**$23,949**	**$25,305**	**$26,753**	**$28,217**	**5.7%**
Audio	$1,517	$1,659	$1,766	$1,937	$2,091	$2,225	8.0%
Compact Disc Players	$837	$910	$936	$1,002	$1,056	$1,108	5.8%
Digital Compact Cassette Players	$30	$68	$135	$180	$250	$318	60.3%
Radio Combinations	$370	$358	$366	$393	$394	$408	2.0%
Stereo Hi-Fi Components	$222	$256	$261	$291	$316	$314	7.2%
Musical Instruments	$58	$67	$69	$72	$75	$77	5.8%
Video	$6,000	$6,692	$7,543	$8,238	$9,026	$9,907	10.6%
Video Cameras/Camcorders	$482	$636	$764	$864	$983	$1,090	17.7%
VCRs	$1,223	$1,378	$1,488	$1,664	$1,744	$1,957	9.9%
Color Televisions	$3,304	$3,475	$3,859	$3,991	$4,293	$4,599	6.8%
Black and White Televisions	$16	$15	$14	$13	$12	$11	-7.5%
Set-Top Boxes	$974	$1,188	$1,418	$1,706	$1,993	$2,250	18.2%
Satellite Set-Top Boxes	$842	$1,035	$1,240	$1,458	$1,663	$1,802	16.4%
CATV Set-Top Boxes	$132	$153	$178	$248	$330	$449	27.7%
Personal Electronics	$1,380	$1,462	$1,551	$1,658	$1,752	$1,848	6.0%
Watches	$1,195	$1,260	$1,333	$1,420	$1,495	$1,569	5.6%
Clocks	$185	$201	$218	$239	$257	$279	8.6%
Appliances	$12,492	$12,782	$13,089	$13,471	$13,884	$14,237	2.6%
Air Conditioners	$626	$645	$705	$766	$832	$893	7.4%
Microwave Ovens	$1,540	$1,572	$1,603	$1,633	$1,662	$1,690	1.9%
Washers and Dryers	$3,021	$3,165	$3,227	$3,275	$3,322	$3,339	2.0%
Refrigerators/Freezers	$3,394	$3,395	$3,403	$3,424	$3,455	$3,478	0.5%
Dishwashers	$1,660	$1,747	$1,857	$2,072	$2,274	$2,464	8.2%
Ranges and Ovens	$2,251	$2,258	$2,293	$2,302	$2,339	$2,373	1.1%

Source: Dataquest (April 1995 Estimates)

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Military and Civil Aerospace

Table 12
Segment Detail, European Military and Civil Aerospace Equipment Production (in Millions of US Dollars)
History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Military and Civil Aerospace	**$21,749**	**$20,976**	**$21,171**	**$21,055**	**$21,447**	**$20,851**	**-0.8%**
Military Electronic Equipment Systems	$19,524	$18,498	$18,181	$17,867	$17,381	$16,924	-2.8%
Radar and Sonar	$3,685	$3,456	$3,422	$3,319	$3,153	$2,996	-4.1%
Missiles and Weapons	$3,097	$2,878	$2,745	$2,685	$2,551	$2,423	-4.8%
Space-Related Electronics	$899	$890	$873	$873	$882	$891	-0.2%
Communications and Navigation	$2,917	$2,736	$2,702	$2,702	$2,716	$2,729	-1.3%
Electronic Warfare	$2,575	$2,395	$2,406	$2,395	$2,347	$2,300	-2.2%
Aircraft Systems	$2,137	$2,077	$2,045	$1,922	$1,845	$1,772	-3.7%
Military Computer Systems	$694	$728	$756	$794	$833	$875	4.7%
Military Simulation Systems	$301	$321	$340	$357	$375	$394	5.5%
Other Military Equipment	$3,219	$3,017	$2,892	$2,820	$2,679	$2,545	-4.6%
Civil Aerospace Electronic Equipment Systems	$3,293	$3,613	$3,877	$4,140	$4,175	$3,926	3.6%
Radar	$910	$991	$1,096	$1,151	$1,174	$1,198	5.6%
Space-Related Electronics	$983	$1,083	$1,142	$1,246	$1,346	$1,453	8.1%
Communications and Navigation	$338	$370	$385	$401	$378	$282	-3.5%
Flight Systems	$970	$1,067	$1,142	$1,223	$1,154	$861	-2.3%
Simulation Systems	$92	$102	$112	$119	$123	$132	7.5%

Source: Dataquest (April 1995 Estimates)

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Table 13
Segment Detail, European Military and Civil Aerospace Equipment Production (in Millions of US Dollars)
Forecast (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Military and Civil Aerospace	**$20,851**	**$20,628**	**$20,489**	**$20,275**	**$20,075**	**$19,719**	**-1.1%**
Military Electronic Equipment Systems	$16,924	$16,495	$16,093	$15,717	$15,366	$14,871	-2.6%
Radar and Sonar	$2,996	$2,846	$2,704	$2,568	$2,440	$2,300	-5.1%
Missiles and Weapons	$2,423	$2,302	$2,187	$2,078	$1,974	$1,800	-5.8%
Space-Related Electronics	$891	$899	$908	$918	$927	$905	0.3%
Communications and Navigation	$2,729	$2,743	$2,756	$2,770	$2,784	$2,798	0.5%
Electronic Warfare	$2,300	$2,254	$2,209	$2,165	$2,122	$2,079	-2.0%
Aircraft Systems	$1,772	$1,701	$1,633	$1,567	$1,505	$1,400	-4.6%
Military Computer Systems	$875	$919	$965	$1,013	$1,064	$1,117	5.0%
Military Simulation Systems	$394	$413	$434	$456	$478	$502	5.0%
Other Military Equipment	$2,545	$2,418	$2,297	$2,182	$2,073	$1,969	-5.0%
Civil Aerospace Electronic Equipment Systems	$3,926	$4,133	$4,396	$4,558	$4,710	$4,849	4.3%
Radar	$1,198	$1,221	$1,246	$1,271	$1,296	$1,322	2.0%
Space-Related Electronics	$1,453	$1,570	$1,679	$1,780	$1,869	$1,944	6.0%
Communications and Navigation	$282	$297	$326	$333	$339	$346	4.2%
Flight Systems	$861	$904	$995	$1,015	$1,035	$1,056	4.2%
Simulation Systems	$132	$141	$150	$160	$170	$181	6.5%

Source: Dataquest (April 1995 Estimates)

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Transportation

Table 14
Segment Detail, European Transportation Equipment Production (in Millions of US Dollars)
History (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Transportation	**$5,191**	**$6,262**	**$6,818**	**$7,809**	**$8,558**	**$9,953**	**13.9%**
In-Car Entertainment Systems	$447	$525	$541	$602	$648	$686	8.9%
Body Control and Vehicle Control Electronics	$734	$979	$1,042	$1,154	$1,258	$1,297	12.1%
Driver Information Systems	$717	$851	$918	$1,037	$1,105	$1,404	14.4%
Powertrain Systems	$2,145	$2,538	$2,755	$3,157	$3,360	$3,558	10.6%
Safety and Convenience Systems	$1,148	$1,369	$1,561	$1,860	$2,187	$3,008	21.2%

Source: Dataquest (April 1995 Estimates)

Table 15
Segment Detail, European Transportation Equipment Production (in Millions of US Dollars)
Forecast (Ex-Factory Revenues)

	1989	1990	1991	1992	1993	1994	1994-1999 CAGR
Transportation	**$9,953**	**$11,231**	**$12,606**	**$14,075**	**$15,763**	**$17,538**	**12.0%**
In-Car Entertainment Systems	$686	$772	$847	$926	$1,026	$1,135	10.6%
Body Control and Vehicle Control Electronics	$1,297	$1,383	$1,433	$1,490	$1,654	$1,778	6.5%
Driver Information Systems	$1,404	$1,646	$1,859	$2,050	$2,242	$2,465	11.9%
Powertrain Systems	$3,558	$3,807	$4,132	$4,446	$4,700	$4,935	6.8%
Safety and Convenience Systems	$3,008	$3,623	$4,335	$5,163	$6,142	$7,225	19.2%

Source: Dataquest (April 1995 Estimates)

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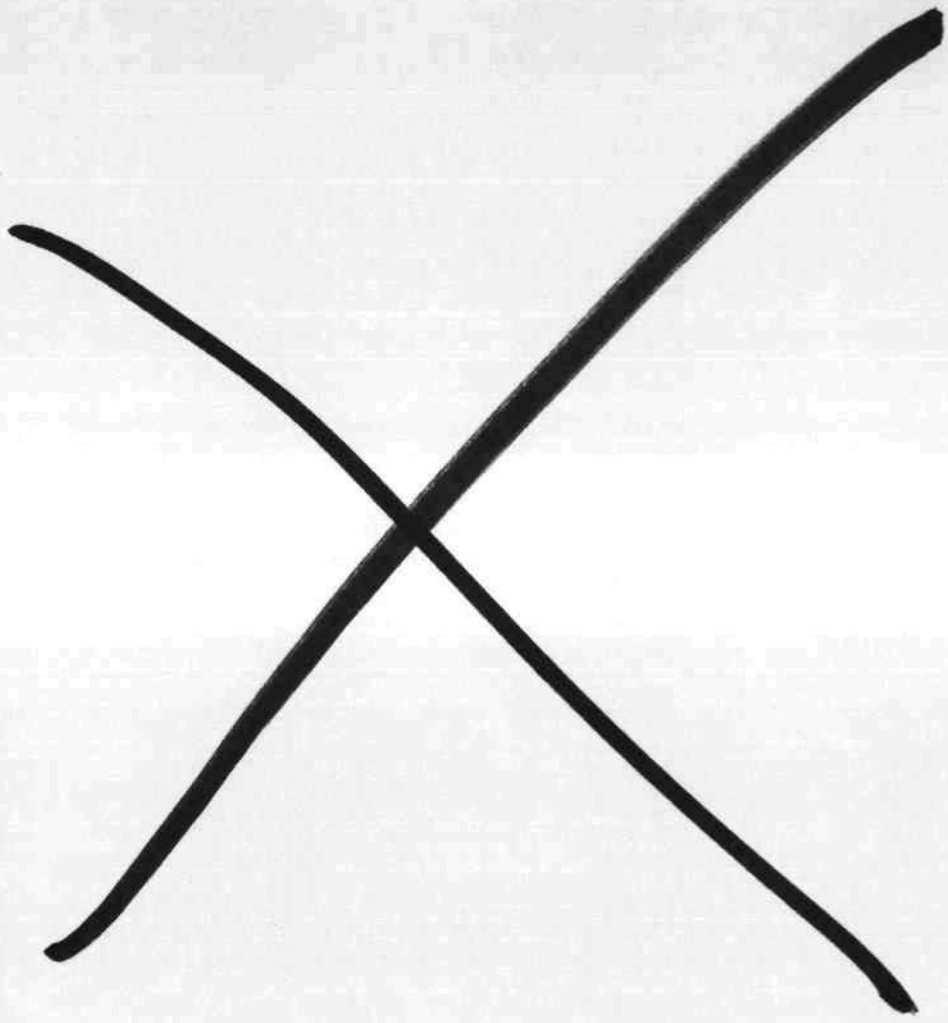
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Perspectives



Semiconductor Application Markets Europe

Conference Briefing

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Digital Cordless Telephones—CT2 or DECT

Abstract: *Dataquest's fourteenth annual semiconductor industry conference was held in Paris on May 18. This presentation was given by David Moorhouse, Senior Industry Analyst for Dataquest's European Semiconductor Group. In this Perspective we provide the speech in full, accompanied by the slide presentation, for the benefit of those clients who could not attend the conference.*

Introduction

I am constantly asked by clients for forecasts about cellular and cordless telephones; this is a reflection of the importance of these products to the European telecoms market. Many component companies see them as offering future opportunities in the communications sector. Here, I will present Dataquest's forecasts for the digital cordless telephone market and the opportunity for component vendors.

Slide 1—Digital Cordless Telephony Technology Status

There are two competing standards in Europe for digital cordless telephony (DCT)—CT2 and DECT. DECT, the Digital European Cordless Telecommunications standard, has been an approved Europe-wide standard for three to four years.

All European countries agreed to free up the frequency spectrum around 1.8 GHz for the use of DECT. CT2 currently has status as an interim ETSI standard. However, CT2 still cannot be used in certain European countries, which have not released the required frequency band. CT2 has the benefit of an earlier product development and introduction than DECT. CT2 has also benefited from an early decision to develop what is called a Common Air Interface. This allows handsets from different manufacturers to work on the same system.

After an abortive start, DECT has gone down a similar route to CT2 with a new additional requirement in the DECT standard. This new requirement—the Generic Access Profile (GAP)—is a minimum set of functions and features that all DECT handsets must have. This will enable, for instance, a Siemens handset to operate with a Philips DECT base station.

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Applications

Slide 2—DCT Applications

Analog cordless telephones dominate the European cordless market—primarily to the consumer or home market. There is also a limited market for advanced analog cordless in the business/office environment. The primary reasons why cordless telephones have had limited success in the business environment are concerns over privacy, often poor speech quality, and a limited number of allowable users per office.

Although the costs for digital cordless are higher than for analog cordless, the inherent business advantages will justify the additional expense. The unique benefits of digital cordless—privacy, high user densities and high-quality speech—will enable it to provide solutions for the business environment. These digital cordless technologies, CT2 and DECT, have enabled two completely new applications: telepoint; and the use of digital cordless for the final connection to the public telephone system, the local loop.

In the next four slides these applications are explained in further detail.

Slide 3—DCT in the Office Environment

This diagram shows that cordless handsets link to the strategically placed base stations in the office—in theory, a single base station can handle up to 120 users. If you move away from your desk, your phone goes with you and so do your calls.

Of all the areas where digital cordless will provide a solution, the office environment is the most interesting. The use of cordless telephones in the office environment is very low—less than 1 percent at the moment—and most of this is analog cordless in Germany, Switzerland and Austria.

We expect the biggest market for digital cordless to be in the office environment, because of the cost-justifiable benefits which cordless can provide: reaching the person to be called, even if he or she is away from the desk—the so-called corridor cruiser. The reason for the expected success is the way digital cordless will be sold to the business community via the major PBX manufacturers.

Every major PBX manufacturer selling in Europe has a digital cordless handset available or in development. Companies like Northern Telecom are having DECT handsets designed and manufactured for them by Nokia.

These digital cordless solutions are usually implemented as an add-on box to an existing PBX. With the very large installed base of each of the telecoms companies' PBX customers, it only requires relatively low numbers to convert to cordless to generate demand for high volumes of cordless phones.

Slide 4—DCT in the Home Environment

Some vendors have hopes of the home or consumer market for digital cordless being the biggest opportunity; it is certainly by far and away the biggest market for analog cordless. The consumer is known to be primarily interested in cost. However, it is believed that the extra benefits provided by digital cordless will convert buyers from analog to digital even though the cost is inevitably higher.

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Slide 1

DCT Technology Status

- Two Competing Standards CT2 and DECT
- DECT full ETSI standard
- CT2 Interim ETSI standard

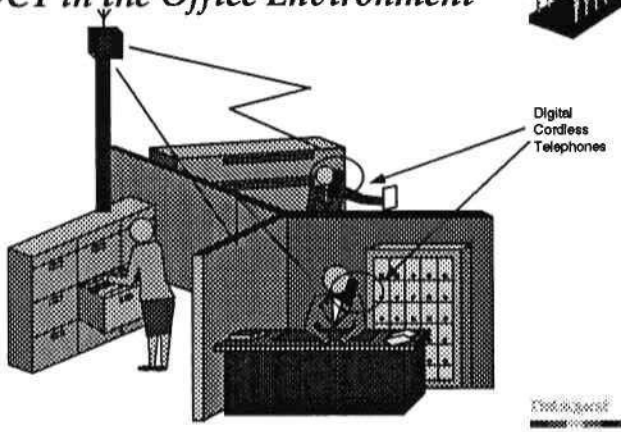
Slide 2

DCT Applications

- Business / Office
- Home / Consumer
- Telepoint
- Local Loop

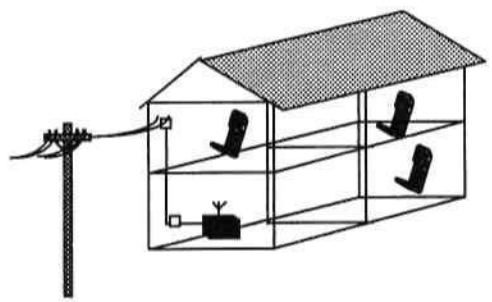
Slide 3

DCT in the Office Environment



Slide 4

DCT in the Home Environment



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This slide shows a home where the owner has one handset and one base station, but further cordless handsets could be added later—the maximum would normally be 12, but a more normal number would be 3 or 4. The advantage here is that although there may be more than one handset, there is only base station.

In this environment CT2 has an advantage over DECT in the near term as it is cheaper. The reason that CT2 is cheaper than DECT at the moment is the much higher volumes of production to currently serve the needs of telepoint applications in Europe and Asia, and the initial digital cordless PBX offerings.

Fundamentally, DECT should be cheaper than CT2. The semiconductor content is higher for DECT, but the overall component cost is lower as fewer expensive filters and passive components are required.

It is expected that DECT will make its first inroads in the consumer market where CT2 is prohibited and where expensive analog cordless is used—the CT1+ standards in Germany, Switzerland and Austria.

Slide 5—DCT in the Telepoint Environment

The concept of telepoint allows the use of small, lightweight handsets to be used in public areas away from the home or office. Initial systems allowed only outgoing calls when near a public base station. Later, systems included radio pagers in the handset to provide some form of two-way system.

If this conference were being held two or three years ago, this application would be receiving a great deal of attention. Now the story is different. The telepoint concept, although not dead, has been dramatically overtaken by the success of cellular. Telepoint was pushed as a poor man's cellular, but with cellular handsets being virtually given away in some country markets, telepoint has no opportunity. Actually, of course, the total cost of ownership for telepoint is lower than for cellular, but this is to be expected as telepoint is a lesser service.

Although the only real successes so far in Europe for telepoint are in the Netherlands and France, these telepoint systems are small when compared with those that have been implemented in Asian countries such as Singapore and Hong Kong.

Overall, we do not expect significant new European telepoint projects to occur in the near future.

Slide 6—DCT in the Wireless Local Loop

This slide shows one of the latest application areas for digital cordless. It shows the use of cordless technology as the last connection of the local loop. This application is becoming important because of the interest from Central and Eastern Europe. These countries are trying to bring their telecommunications in line with the rest of Europe as fast and as economically as possible.

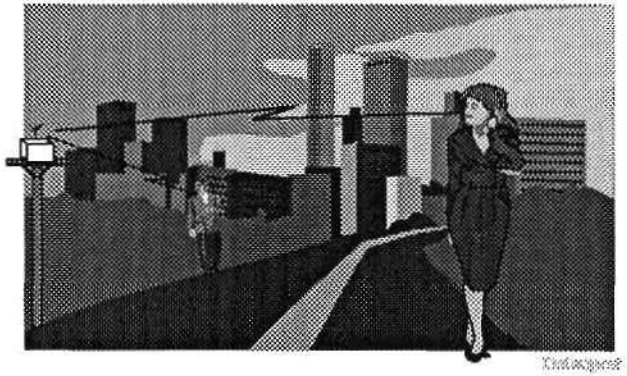
The most expensive part of the local loop is the wire connection into the home. By using wireless technology, the last leg of the local loop can be implemented at less cost and more quickly. A variant of this technology can be applied to rural areas using directional aerial technology with distances of 2 to 3 km possible. There have been a number of trials conducted using DECT, funded by the European Commission.

Digital cordless will always be a specialist solution to the radio local loop market, with the majority of solutions being provided by analog or digital cellular and wide area radio.

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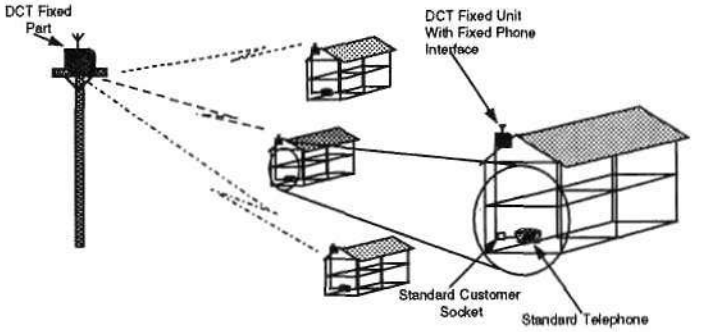
Slide 5

DCT in the Telepoint Environment



Slide 6

DCT in the Wireless Local Loop



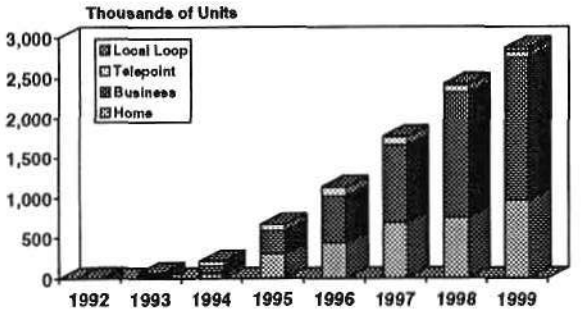
Slide 7

What's Driving DCT at the Moment

- **PBX in Europe**
- **Telepoint in Europe**
- **Telepoint in Asia**

Slide 8

DCT Shipments by Market



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Slide 7—What's Driving DCT at the Moment

So to summarize there are three areas that are driving the digital cordless market in its early years:

- The use of digital cordless in the office is driven by Europe's PBX companies.
- It is also driven by telepoint in Europe, although this will come under pressure from cellular in the future because of the excellent marketing of the cellular concept and product.
- Telepoint in the Asian markets is already going well and we should expect this market to grow, although Asian telepoint is primarily a market for CT2 handsets.

I would now like to move on and look at the overall market and our forecasts.

The Market in Europe

Slide 8—DCT Shipments by Market Segment

So, with all the market opportunities and these major companies wanting a stake in the future market, how much will they be fighting over?

We expect the European market to be 2.8 million handsets by 1999. We can see in 1995 that a significant portion of sales are to the residential market, but we forecast the business market to become more and more significant in later years. Telepoint and the local loop applications will always be a minor part of the market. In fact, towards the end of the forecast period we expect telepoint to suffer as cellular's relentless growth takes over some of this opportunity.

Slide 9—Analog versus Digital Shipments

Let us for a moment put digital cordless in context. This graph shows the relative markets for analog cordless and digital cordless in Europe. There is a large and growing market for the convenience of cordless telephones; as a region, Europe is far behind the United States in adopting this consumer communications product.

As I indicated earlier, a significant portion of the digital cordless shipments will be to the business market, but it is the vast *potential* of home users that is the really big market opportunity. Still, digital cordless must undergo rapid price reductions to make any serious impact on this market.

Slide 10—DCT Handset Producers

This slide lists the major digital cordless handset manufacturers. We should expect to see some more CT2 handset producers from Asia appear soon, for two reasons: the market that exists for telepoint in Asia; and the likelihood that CT2 will initially be a lower-cost solution for consumer/home digital cordless. The use of CT2 for the French telepoint system Bi Bop accounts for the two French handset manufacturers, Sagem and Dassault.

The larger number of DECT handset manufacturers is because all the major European PBX manufacturers have developed handsets for their own systems. Both Siemens and Philips are also offering versions of DECT systems for use in the home.

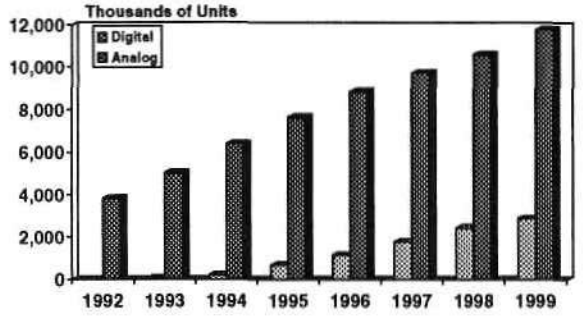
We expect other known telephone handset manufacturers to enter the market, such as Dancall. I also expect we will see some additional DECT players from Asia in the near future.

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Slide 9

Analog vs Digital Shipments



Slide 10

DCT Handset Producers

CT2

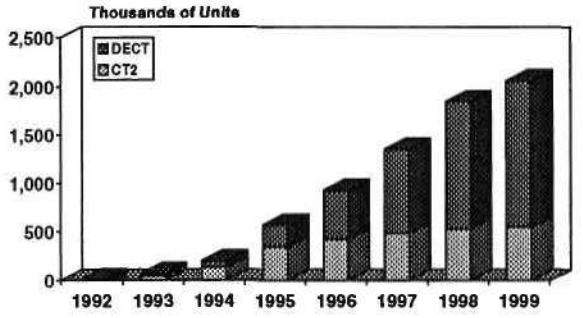
- Sony
- Motorola
- AT&T (Shaye)
- Dassault
- Sagem
- Kenwood

DECT

- Alcatel
- Philips
- Siemens
- Ascom
- Hagenuk
- Ericsson
- Panasonic
- Nokia - soon
- DeTeWe - soon

Slide 11

DCT European Production



Slide 12

DCT Semiconductor Vendors

- AMD
- VLSI
- Motorola
- Philips
- Siemens
- Sierra
- National Semiconductor
- Sony
- Hewlett-Packard
- GPS
- AT&T
- Oki

Slide 11—DCT European Production

There are promising signs that digital cordless telephones for the European market will continue to be produced in Europe. As we look forward to the end of the forecast period, the production becomes dominated by DECT. This is a function of three factors:

- The erosion of the competitive cost advantage of CT2.
- Asian players have a bigger stake in CT2 production than DECT.
- The major market for digital cordless is in the business/office environment; this business is dominated by the European PBX manufacturers.

Implications for Semiconductors

Slide 12—DCT Semiconductor Vendors

In the final analysis, the market size for digital cordless will also be determined by the semiconductor industry. If the right low-cost solutions can be provided by the industry, volumes will grow; if not, it will be marginalized and digital cordless will remain a niche solution to people's communication needs.

The semiconductor industry responded well two or three years ago with a flurry of activity—sold on the promise of DECT. In 1993 and 1994 it seemed that from the semiconductor industry's point of view, DECT would be the clear winner, with VLSI, Philips Semiconductors and Siemens all introducing highly advanced chipsets. The situation is now different: AMD has offered an advanced chipset for the CT2 standard along with Motorola's own in-house solution; VLSI and Sierra followed suit.

A number of vendors now offer core logic that can be used for CT2, DECT or the Japanese PHP standard. I believe the main reason for this was vendors backing both horses after the success of CT2 in the Asian telepoint markets.

The radiofrequency devices have probably seen the greatest amount of development activity, as these still represent a sizable portion of the semiconductor bill of materials.

Slide 13—CT2 and DECT Handset Semiconductor Content

As I have suggested earlier, the CT2 semiconductor solution is forecast to be lower than the DECT solution throughout the forecast period. CT2 semiconductor pricing will now remain competitive because of the developments of a number of companies such as Motorola, VLSI and Sierra.

The DECT standard still affords some advantages over CT2; as the passive component cost should be lower, there will be little difference in the total cost of the bill of materials between the two. Of all the factors that affect the competitiveness of one standard over the other, it is volume that is the most significant. DECT is forecast to be a higher volume, but not really enough that it would affect component selling prices that much. DECT has an ace up its sleeve—there are strong indications that a DECT lookalike will be chosen for the US cordless market. This could add millions of units to the forecast market potential of DECT chipset vendors.

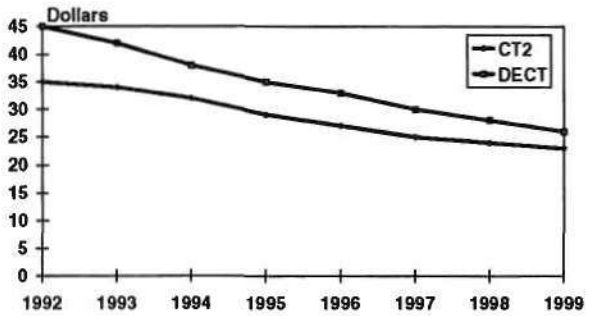
Slide 14—DCT Handset Semiconductor Market

This slide shows our expectations for the semiconductor market for digital cordless in Europe, using our forecasts for semiconductor component price trends and the handset production forecast. This slide is not completely fair because it only shows data for handsets—not for the opportunity for base

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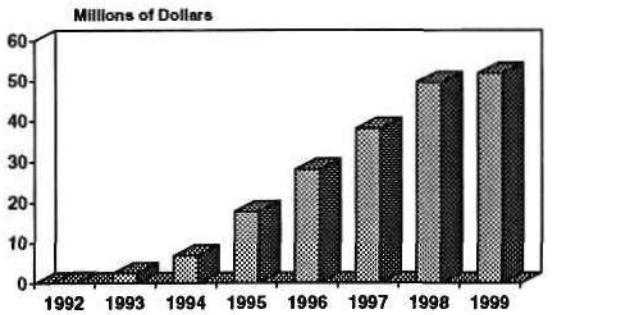
Slide 13

CT2 and DECT Handset Semiconductor Content



Slide 14

DCT Handset Semiconductor Market



Slide 15

DECT in the Future

- **Dual-mode phones DECT/GSM, DECT/DCS1800**
- **Opportunities in the US with new Digital Cordless Standard, protocol same as DECT**

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stations. There would be base station opportunities in all the applications we have shown, but it is not one base station per handset. For instance, in the business application it may be as high as 12 handsets to one base station. As an example, if there were one base station for every handset, the market in 1999 would be double that shown here—just over $100 million.

Conclusion

Slide 15—DECT in the Future

To summarize, the initial markets will be for the business/office environment and the telepoint opportunities in Europe and Asia. The use of digital cordless in the home environment will take some time to grow—unless there are some aggressive price reductions.

The particular use of DECT as a wireless local loop solution will grow steadily throughout the forecast period, but the overall opportunity is small—hundreds of thousands of units at best, not millions of units.

So where else has DECT to go? Defined within the standard is the capability for data transport. There are DECT configurations being used as wireless local area networks (WLANs). Although the market for WLANs is beginning to emerge, DECT-based WLANs have serious competition from US-dominated dedicated spread spectrum and frequency hopping solutions. We should therefore expect the DECT-based WLAN market to be very much a European opportunity.

One development that could have a major positive impact on the market for DECT is the development of the so-called personal communication networks (PCNs). The ultimate solution for PCN is single handset for all occasions—at home, at work and mobile. Of course, cellular telephones work in all of these three environments ... sometimes ... but would not be a cost-effective solution in terms of call charges.

The telecoms industry expects the ultimate solution to be multimode phones—for instance, GSM and DECT or DCS-1800 and DECT, or perhaps even all three. This is happening already with Ericsson supplying a batch of dual-mode GSM/DECT handsets for trials in Sweden.

This may be the real killer application that DECT needs. Dataquest will watch this opportunity and report any developments back to you—perhaps at next year's conference.

By David Moorhouse

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Perspectives



Semiconductor Application Markets Europe

Research Brief

Final 1994 European PC Production

Abstract: *Dataquest's Semiconductor Application Markets Europe service has finished collecting data from its annual survey of PC production in Europe. In this Research Brief we present these results.*

Summary

Dataquest's Semiconductor Application Markets Europe service has finished collecting data from its annual survey of personal computer (PC) production in Europe. In this Research Brief we present these results; and for the first time include information on PC production in Eastern Europe—this includes production in the following states:

- Czech Republic
- Hungary
- Poland
- Albania
- Bulgaria
- Croatia
- Macedonia
- Romania
- Slovakia
- Slovenia
- Baltic States
- Russian Federation
- Others, CIS

European PC Market Overview

PC unit shipments in 1994 for Western Europe reached 11.7 million units, a growth of 13.9 percent over the previous year. In dollar terms the market saw a growth of 31.9 percent to $27 billion compared with a market contraction of 8.8 percent the previous year. Shipments in Central and Eastern Europe reached 1.5 million, giving a combined Eastern/Western European shipments total of 13.2 million units.

The German market strengthened its position as the largest in Western Europe with a growth rate of 18.7 percent, taking its share of Europe to 23.9 percent—this growth was on the back of the phenomenal success of assemblers like Escom and Vobis.

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Publication Date: May 5, 1995
Filing: Perspectives

It was in 1994 that Compaq became the largest PC vendor worldwide and in Western Europe, where it showed a 39 percent growth on the previous year. IBM's European sales contracted 5.6 percent year on year. AST Research, Digital Equipment, Escom, Hewlett-Packard and Vobis—all of which are among the top 10 vendors—showed growth rates of more than 50 percent. Apple's unit sales remained almost unchanged in what was a year of transition for the company, while Olivetti experienced a 4.2 percent decline.

Analysis of European PC Production

Effective European PC unit production (this includes Central and Eastern Europe)—that is, where at least memory and/or microprocessors were purchased in Europe—in 1994 showed a 19.3 percent growth to 13 million units (10.9 million in 1993). Western European PC production reached 12.2 million (10.2 million in 1993), a 19.6 percent growth over the previous year.

PC production once again showed growth above that of the market. During 1994 we saw two major plants start production in Europe—AST Research and Gateway 2000, both located in Ireland—and there were also a number of expansions announced, such as Compaq adding board assembly. This extra production capacity helped production grow faster than sales.

Europe's production of PCs is used not only to satisfy local demand but also to supply a number of other regions such as the Middle East and Africa. Several companies even supply to other regions further afield, such as Apricot's production for Japan.

Production by Company

Table 1 shows Dataquest's estimates of effective European PC production ranked by company. These manufacturers account for more than 75 percent of production.

Although in 1994 Compaq became the largest PC vendor in Europe, in terms of manufacturing IBM remains number one in Europe with estimated production of 1.5 million units. Compaq follows with production of 1.35 million units.

The Eastern European production of 800,000 units includes those of Western companies such as IBM and Escom which assemble PCs in Central and Eastern Europe, as well as local assemblers like Albacomp, Vist and Optimus (more detailed information on each of the players' operations, and the local markets, is available in a new series of reports published by Dataquest's Central and Eastern European Markets service).

Production by Microprocessor

Table 2 shows PC production by processor for 1993 and 1994. During 1994 the big gain came from the 486DX2, which accounted for 20 percent in the first quarter of 1994 and reached 41 percent in the fourth quarter 1994; most of this gain was at the expense of 486SX and 486DX processors. During 1995 the Pentium will become the dominant processor, and will remain so until 1998 when it will be surpassed by the P6. Although the P6 is expected to start shipping around the third quarter of 1995, this will have no impact on Pentium shipments until 1997. By then, it should be just over half the size of Pentium shipments. Table 3 gives a full list of PC production by microprocessor type for each manufacturer.

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Table 1
Final 1994 Effective European PC Production Ranking
(Thousands of Units)

Rank	Manufacturer	Desktop	Notebook and Subnotebook	Total	Percentage of Production	Cum. Percentage
1	IBM	1,312.5	187.5	1,500.0	11.5%	11.5%
2	Compaq	1,244.5	105.5	1,350.0	10.4%	21.9%
3	Apple	660.0	90.0	750.0	5.8%	27.7%
4	Olivetti	600.0	60.0	660.0	5.1%	32.8%
5	Dell	550.0	-	550.0	4.2%	37.0%
6	Vobis	500.0	50.0	550.0	4.2%	41.2%
7	Hewlett-Packard	500.0	-	500.0	3.8%	45.1%
8	Escom	416.5	8.5	425.0	3.3%	48.3%
9	Siemens Nixdorf	355.0	45.0	400.0	3.1%	51.4%
10	Digital	350.0	-	350.0	2.7%	54.1%
11	Bull (ZDS)	270.0	50.0	320.0	2.5%	56.6%
12	ICL (Nokia Data)	280.0	-	280.0	2.2%	58.7%
13	Packard Bell	247.0	3.0	250.0	1.9%	60.7%
14	Psion	-	230.0	230.0	1.8%	62.4%
15	Actebis	193.2	16.8	210.0	1.6%	64.0%
16	AST Research	200.0	-	200.0	1.5%	65.6%
17	Peacock Computers	165.0	10.0	175.0	1.3%	66.9%
18	Tulip Computers	175.0	-	175.0	1.3%	68.3%
19	AT&T (GIS)	170.0	-	170.0	1.3%	69.6%
20	Acer	116.0	29.0	145.0	1.1%	70.7%
21	Toshiba	-	95.0	95.0	0.7%	71.4%
22	Elonex	87.0	-	87.0	0.7%	72.1%
23	PC Warehouse	66.0	7.0	73.0	0.6%	72.7%
24	Olidata	72.0	-	72.0	0.6%	73.2%
25	Apricot	70.0	-	70.0	0.5%	73.7%
26	Aquarius Systems	68.6	1.4	70.0	0.5%	74.3%
27	Gateway 2000	70.0	-	70.0	0.5%	74.8%
28	Unisys	60.0	-	60.0	0.5%	75.3%
29	Acorn	57.0	-	57.0	0.4%	75.7%
	Others	3,089.6	66.4	3,156.0	24.3%	100.0%
	Total Units	11,944.9	1,055.0	13,000.0		
	Split by Format	91.9%	8.1%	100.0%		

Source: Dataquest (May 1995 Estimates)

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Table 2
European PC Production by Microprocessor, 1993 and 1994
(Thousands of Units)

Microprocessor	Units 1993	Percent 1993	Units 1994	Percent 1994
386 or below	2,258	20.7%	392	3.0%
486SX	3,940	36.2%	4,996	38.4%
486DX/DX2/DX4	3,748	34.4%	6,101	46.9%
Pentium	25	0.2%	704	5.4%
68XXX	855	7.8%	559	4.3%
PowerPC	-	0.0%	191	1.5%
Others	74	0.7%	57	0.4%
Total Units	10,900	100.0%	13,000	100.0%

Source: Dataquest (May 1995 Estimates)

Table 3
Final 1994 Effective European PC Production by Microprocessor
(Thousands of Units)

Rank	Manufacturer	386 or Below	486SX/SL	486DX/ DX2/DX3	Pentium	68XXX	PowerPC	Other	Total
1	IBM	1.7	865.9	614.3	18.2	-	-	-	1,500.0
2	Compaq	15.4	560.8	698.9	74.9	-	-	-	1,350.0
3	Apple	-	-	-	-	558.9	191.1	-	750.0
4	Olivetti	7.2	366.8	257.4	18.6	-	-	-	660.0
5	Dell	-	174.1	297.9	78.0	-	-	-	550.0
6	Vobis	8.7	93.2	388.6	59.5	-	-	-	550.0
7	Hewlett-Packard	1.1	220.1	254.7	24.1	-	-	-	500.0
8	Escom	5.3	66.7	272.2	80.8	-	-	-	425.0
9	Siemens Nixdorf	1.0	147.8	218.9	32.3	-	-	-	400.0
10	Digital	2.7	132.5	195.4	19.5	-	-	-	350.0
11	Bull (ZDS)	2.0	189.3	121.4	7.3	-	-	-	320.0
12	ICL (Nokia Data)	1.5	143.4	123.2	12.0	-	-	-	280.0
13	Packard Bell	0.4	127.9	109.5	12.3	-	-	-	250.0
14	Psion	230.0	-	-	-	-	-	-	230.0
15	Actebis	4.8	20.3	166.0	18.9	-	-	-	210.0
16	AST Research	0.1	88.3	102.0	9.7	-	-	-	200.0
17	Peacock Computers	-	26.8	133.7	14.5	-	-	-	175.0
18	Tulip Computers	0.6	104.6	68.3	1.5	-	-	-	175.0
19	AT&T (GIS)	-	57.8	103.7	8.5	-	-	-	170.0
20	Acer	0.6	51.3	88.7	4.4	-	-	-	145.0
21	Toshiba	3.8	54.2	36.1	1.0	-	-	-	95.0
22	Elonex	-	29.6	49.6	7.8	-	-	-	87.0
23	PC Warehouse	-	29.9	35.8	7.3	-	-	-	73.0
24	Olidata	1.4	18.7	41.0	10.8	-	-	-	72.0
25	Apricot	-	30.8	32.9	6.3	-	-	-	70.0

(continued)

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Table 3 (Continued)
Final 1994 Effective European PC Production by Microprocessor
(Thousands of Units)

Rank	Manufacturer	386 or Less	486SX/SL	486DX/ DX2/DX3	Pentium	68XXX	PowerPC	Other	Total
26	Aquarius Systems	0.1	13.0	52.5	4.4	-	-	-	70.0
27	Gateway 2000	-	20.2	35.3	14.5	-	-	-	70.0
28	Unisys	-	19.2	36.0	4.8	-	-	-	60.0
29	Acorn	-	-	-	-	-	-	57.0	57.0
	Others	94.0	1,342.6	1,567.2	152.2	-	-	-	3,156.0
	Total Units	392.3	4,996.0	6,101.0	703.8	558.9	191.1	57.0	13,000.0
	Split by Format	3.0%	38.4%	46.9%	5.4%	4.3%	1.5%	0.4%	100.0%

Source: Dataquest (May 1995 Estimates)

Table 4
European PC Production by Country
(Thousands of Units)

Region of Manufacture	1992 Units	1992 Percent	1993 Units	1993 Percent	1994 Units	1994 Percent
Benelux	192	3.7%	535	4.9%	520	4.0%
France	443	8.4%	924	8.5%	1,430	11.0%
Italy	552	10.5%	868	8.0%	934	7.2%
Nordic	191	3.6%	457	4.2%	483	3.7%
United Kingdom	2,270	43.1%	3,778	34.7%	4,448	34.2%
Ireland	944	17.9%	1,378	12.6%	1,627	12.5%
Germany	453	8.6%	2,035	18.7%	2,461	18.9%
Rest of W. Europe	216	4.1%	225	2.1%	297	2.3%
Ć, & E. Europe	NA	NA	700	6.4%	800	6.2%
Total Units	5,262	100%	10,900	100.0%	13,000	100.0%

NA = not applicable
Source: Dataquest (May 1995 Estimates)

Production and Design by Country

Once again, the UK and Ireland region dominates other parts of Europe in terms of PC production. This is illustrated in Table 4, which shows PC production for Europe; the numbers for 1993 have been adjusted to include Central and Eastern Europe, while 1992 numbers remain unadjusted. The United Kingdom and Ireland have the benefit of a large contract equipment manufacturing (CEM) base, such as SCI, Avex, D2D and so on. Dataquest will publish a full report on this subject later in the year.

Table 5 lists the major European PC manufacturing locations. The table also gives some indication as to the type of work carried out at each location, as follows:

- **Full stuffing** of the motherboard means where all semiconductors are loaded onto a printed circuit board (PCB), while **part stuffing** of the motherboard refers to when some components (usually memory or microprocessors) are loaded onto a PCB.

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- **Subcontract assembly** applies to the manufacture of partially stuffed PC motherboards that are contracted to an outside company within Europe.
- **Screwdriver assembly** involves the assembly of PCs from brought-in subassembled components; companies involved in only this type of manufacture are not shown in the table.
- The design location of the PC motherboard is also indicated in the last column. **OEM** means that the motherboard comes in from the Far East and is sourced from one of the numerous motherboard manufacturers.

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Table 5
European PC Manufacturing by Location and Activity

Company	City	Country	Full Stuffing	Part Stuffing	Sub-contract	Screw-driver	PCB Design Location
Acer	Ahrensburg	Germany		✔		✔	Lungtan, Taiwan and San Jose, USA
Acer	Eindhoven	Netherlands		✔		✔	Lungtan, Taiwan and San Jose, USA
Acorn	Cambridge	England			✔		Cambridge, England
Actebis	Soest	Germany		✔			OEM
Amstrad	Brentwood	England			✔		Brentwood, England
Apple	Cork	Ireland	✔				Cupertino, USA
Apricot	Glenrothes	Scotland	✔	✔		✔	Birmingham, England and OEM
Aquarius Systems	Bad Homburg	Germany		✔			Aquarius, Taiwan
AST Europe	Limerick	Ireland		✔			Irvine, USA
Compaq	Erskine	Scotland	✔	✔	✔		Houston, USA
Computer Elektronik Dresden	Dresden	Germany		✔	✔		OEM
Dell	Limerick	Ireland		✔			Austin, USA
Digital	Ayr	Scotland	✔	✔			Taiwan and USA
Elonex	London	England		✔			Oakleigh Systems, USA
Elonex (Cordata)	Cumbernauld	Scotland	✔	✔			Oakleigh Systems, USA
Escom	Brno	Czech Republic					OEM
Escom	Swarzedz	Poland		✔			OEM
Escom	Nieuw-Vennep	Netherlands		✔			OEM
Escom (European Monitors)	Irvin	Scotland		✔			OEM
Gateway 2000	Dublin	Ireland		✔			North Sioux City, USA
Hewlett-Packard	Ile d'Abeau (Lyon)	France		✔	✔		Grenoble, France
IBM	Kvant	Russia		✔			Raleigh, USA
IBM	Greenock	Scotland	✔	✔	✔		Raleigh, USA
ICL (Nokia Data)	Ashton-Under-Lyne	England		✔			Kidsgrove, England
ICL (Nokia Data)	Helsinki	Finland	✔	✔			Linkoping, Sweden
ICL (Nokia Data)	Kidsgrove	England	✔				Kidsgrove, England
Intel	Leixlip	Ireland	✔	✔			Oregon, USA
AT&T (NCR)	Augsburg	Germany		✔			USA

(continued)

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Table 5 (Continued)
European PC Manufacturing by Location and Activity

Company	City	Country	Full Stuffing	Part Stuffing	Sub-contract	Screw-driver	PCB Design Location
Olidata	Cesena	Italy		✔			OEM
Olivetti	Marcianise	Italy	✔				Ivrea, Italy
Olivetti	Scarmagno	Italy	✔				Ivrea, Italy
Packard Bell	Wijchen	Netherlands		✔			N/A
Packard Bell	Angers	France	✔				N/A
PC Warehouse	Val-de-Reuil	France		✔			Taiwan
Peacock Computers	Wunnenberg-Haaren	Germany		✔	✔		Wunnenberg, Germany and OEM
Psion	London	England	✔	✔			London, England
Siemens Nixdorf	Augsburg	Germany	✔			✔	Augsburg, Germany and OEM
Siemens Nixdorf	Haubourdin	France	✔				Augsburg, Germany and OEM
Toshiba	Regensberg	Germany	✔				Japan
Tulip Computers	Hertogenbosch	Netherlands	✔	✔			Hertogenbosch, Netherlands
Unisys	Barentin	France		✔			San Jose, USA
Vobis	Aachen	Germany		✔		✔	OEM
Vobis	Würselen	Germany		✔			OEM
Vobis	Siegen	Germany		✔			OEM
Vobis	Eupen	Belgium		✔			OEM
Vobis	Vienna	Austria		✔			OEM
ZDS	Angers	France	✔				Bull/ZDS/Chatsworth, USA

N/A = not available
Source: Dataquest (May 1995)

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Dataquest Perspective

The Wind Blows East

At present, Central and Eastern European production of PCs is relatively small, and nearly all production consists of final assembly, with DRAM and processor being added. Currently, there are a few non–Central and Eastern European companies manufacturing in the region, most notably IBM in Kvant, Russia and Escom in Brno, Czech Republic. However, the majority of PC production is made up from local players in the individual countries.

The forecast of PC production to the year 2000 assumes that a number of major vendors will move some or even all of their manufacturing into Central and Eastern Europe. However, this may well be an optimistic forecast, for there are a multitude of obstacles in setting up and running an operation in Central and Eastern Europe.

Many issues are important here, but perhaps the most important in the short term is tariffs, although this problem might be solved for the those countries that join the European Union. At the moment, each country sets its own tariffs, so even if a company is manufacturing in one country in the region, it may well still have to pay tariffs to export to a neighboring Central or Eastern European country, or import taxes may be lower on parts rather than assembled products. Also, indirect tariffs may be used to encourage local production, like safety standards—finished goods coming into the country having to apply for a safety certificate, while locally assembled goods are exempt.

Although the growth of production in Central and Eastern Europe is difficult to forecast at this stage—depending so much on major manufacturers moving production into the region—overall, European production should not be affected because if assembly does not take place in Central and Eastern Europe, then it will be in Western Europe.

Outlook for 1995 and Beyond

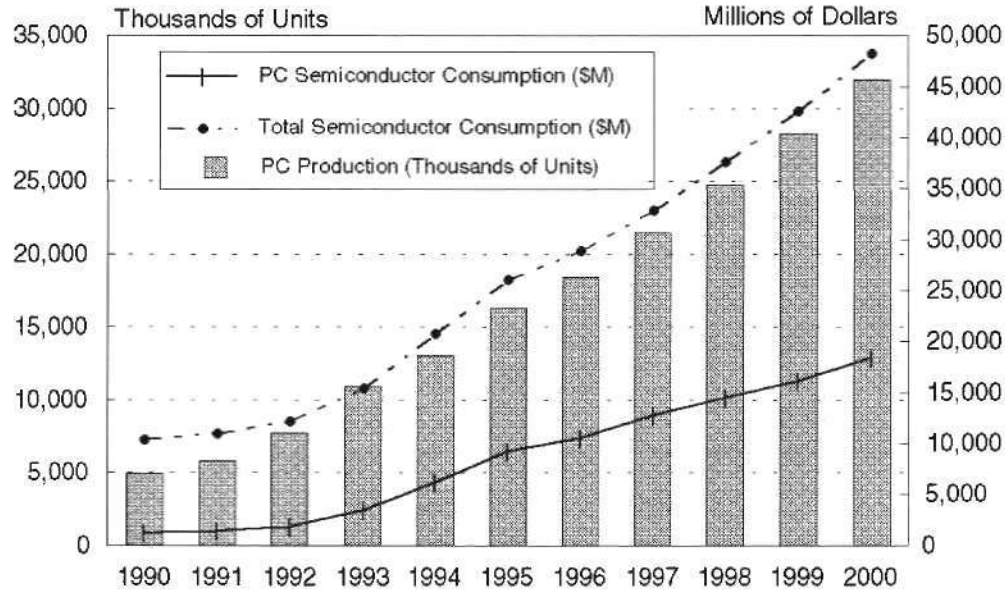
Dataquest estimates that in 1995 European PC production will rise to 16.3 million units, a 25 percent increase over 1994. We expect IBM to remain the largest PC manufacturer in Europe with forecast production of 1.75 million units, while Compaq will close the gap. Dataquest's quarterly rolling forecast of PC production by major manufacturers is available in our new service ***PC Watch***, which includes monthly newsletters on PC production events and quarterly PC shipment information.

In terms of semiconductor consumption, PC production accounted for approximately 29 percent of the 1994 European market, or just over $6.1 billion of the total market of $20.8 billion, as shown in Figure 1. This reflects the increased importance of PC production to the semiconductor industry, which was due to the move towards 486DX- and Pentium-based machines and average memory content of machines showing a sharp increase as well as increased DRAM cost. Although this is not shown in Figure 1, if you add PC peripherals such disk drives, printers, monitors, LAN cards and so on, and their semiconductor consumption, then the percentage by which the semiconductor industry is reliant on the PC is taken to even higher levels.

Figure 1 shows that by the year 2000 PC production in Europe will reach 32 million units, a compound annual growth rate (CAGR) of 16.2 percent between 1994 and 2000. Dataquest's outlook for the total European semiconductor market shows a CAGR of 15 percent between 1994 and 2000, while semiconductor consumption of PC market will grow at 20.1 percent CAGR to a value of $18.4 billion—accounting for about 38 percent of the total semiconductor market. In summary, the assumption behind Figure 1 are as follows.

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Figure 1
European Semiconductor Consumption and PC Semiconductor Consumption



Source: Dataquest (May 1995 Estimates)

PC Unit Production

The European production numbers for PCs include production for Central and Eastern Europe from 1993 onwards. Europe will continue manufacturing to supply its own demand, while a number of companies will ship products outside the European region. Full notebook production will occur only with a small number of companies, while the majority will carry out final assembly only with boards from the Far East. With nearly all local vendors now manufacturing in Europe, growth rates for production will be more in line with shipment growth.

Type of PC Production

The type of production—full stuffing or part stuffing—obviously has an effect on semiconductor consumption; therefore our forecast takes this into account. Currently, slightly over 40 percent of motherboards are produced in Europe, but this level is likely to rise as companies invest in surface mount technology—as Compaq has over the last year.

Semiconductor Content

The trend in production follows the forecast of shipments by processor. As we have seen with the Pentium, Intel has introduced and ramped up production faster than seen before, and hopes to improve on this with the P6.

The average factory-installed DRAM content will continue to rise, reaching about 35MB in 2000; however, the dollar value will peak in 1997, then show a decline over the next few years. This decline is due to DRAM price erosion, but any change in the DRAM price forecast would make a substantial difference.

Dataquest has used analysis gained from the *PC Teardown* reports to model an estimate of the "other" semiconductor content; this consists of logic, PC chipsets, disk controllers and so on. We have forecast an increasing value for this area as new functions are added, such as MPEG I, video and voice recognition.

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In Summary

- 16.3 million PCs will be manufactured in Europe in 1995.
- A 25 percent growth for 1995/1994.
- PC semiconductor consumption of $9.2 billion in 1995.
- A 49 percent growth on 1994/1995.
- 32 million PCs will be manufactured in Europe in 2000.
- A16.2 percent CAGR between 1994 and 2000.
- PC semiconductor consumption of $18.4 million in 2000.
- A 20.1 percent CAGR between 1994 and 2000.
- The PC accounts for 38.2 percent of the semiconductor market by 2000.
- Watch for a production shift towards Central and Eastern European states.

Dataquest will continue to track PC production throughout the year in the new **PC *Watch*** service, and **Semiconductor Application Markets Europe** will publish preliminary estimates for 1995 PC production in January 1996.

By Andrew Norwood

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Global Markets Insight For Information Technology Companies

PC Watch

Dataquest's ***PC Watch*** *service is the leading information source for analysis of European personal computer production, with quarterly production and shipment statistics. Dataquest has been tracking European personal computer production for over seven years, combined with the knowledge of Dataquest's European and Worldwide Personal Computer Groups. This service is the preeminent source of vital information to support the marketing efforts of component and subsystem vendors to the European personal computer industry.*



Perspectives

Each month you will receive a Perspective which will give a comprehensive account of the European personal computer industry. The Perspective will not only cover production issues but also look at related personal computer topics such as memory, microprocessors, personal computer shipments, software, and storage.



Market Statistics

Personal Computer Production Quarterly Roundup: Dataquest continually monitors personal computer production. Every quarter Dataquest will publish estimates for total personal computer production, and production by each of the major vendors. Every quarter Dataquest will also forecast total and top vendor production for the next two quarters including an analysis of the information.

European Personal Computer Shipments Quarterly Roundup: Dataquest European Personal Computer Group continually tracks European personal computer shipments, each quarter. *PC Watch* will provide estimates of total European personal computer shipments and personal computer shipments by each of the major vendors, along with an analysis of the numbers.

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Perspectives



Semiconductor Application Markets Europe

Dataquest Predicts

GSM—The Second-Biggest Components Market by 2000

Abstract: *GSM is now up and running in Europe, with market share and acceptance appearing to exceed expectations, so the system could be described as an unqualified success. Production in the European GSM market is forecast to accelerate to 35 million units by 2000. In this report, we give statistics of current GSM networks around the world, and details of manufacturing locations in Europe. Statistics for current and future production are provided, along with factors that could influence forecasts. Finally, three scenarios are given for forecast market shipments based on different penetration levels.*

Introduction

Europe has witnessed the inception, introduction and deployment of the system, but the wait has been worth it. Market share and acceptance are exceeding all initial expectations. An indication of the success of GSM on a worldwide scale is shown in Table 1, which lists the current and proposed GSM cellular networks that now extend to 194 networks in 75 countries.

But is GSM a success? This question is still debated in some world regions, with proponents of AMPS and CDMA suggesting that GSM has only been accepted reluctantly and that there are problems with the standard. Unfortunately, these doubts cannot always be discounted as sour grapes in a competitive environment—some see them as the truth.

The lack of support for IS54 (digital AMPS) and the activities of Qualcomm with IS95 (CDMA) has split the already divided competition—to the considerable advantage of GSM outside of Europe. This recent success could be reversed if GSM supporters become complacent, as US AMPS manufacturers begin to present a united front.

Cellular Handset Manufacturers

Motorola, Nokia and Ericsson have the largest share of European production at the moment. Table 2 shows that there are also a number of second-tier players with production sites in Europe.

Dataquest

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Table 1
Current and Proposed GSM Networks Worldwide

	Number of Networks	
Country	GSM	DCS-1800
Andorra	1	
Australia	3	
Austria	1	
Bahrain	1	
Belgium	2	
Brunei	1	
Bulgaria	1	
Cameroon	1	
Chile		1
China	7	
Croatia	1	
Cyprus	1	
Czech Republic	2	
Denmark	2	
Eygpt	1	
Estonia	2	
Fiji	1	
Finland	3	
France	2	2
French Polynesia	1	
Germany	2	1
Gibraltar	1	
Greece	2	
Guernsey	1	
Hong Kong	3	6
Hungary	2	
Iceland	1	
India (Regional)	36	
India	8	
Indonesia	3	
Ireland	2	
Italy	2	
Jersey	1	
Jordan	1	
Kuwait	1	
Laos	1	
Latvia	1	
Lebanon	2	
Lithuania	1	
Luxembourg	1	
Macau	1	

(continued)

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Table 1 (Continued)
Current and Proposed GSM Networks Worldwide

	Number of Networks	
Country	GSM	DCS-1800
Malaysia	2	3
Mauritius	1	
Morocco	1	
Namibia	1	
Netherlands	2	
New Zealand	2	
Nigeria	1	
Norway	2	
Oman	1	
Pakistan	1	
Philippines	2	
Poland	1	
Portugal	2	
Qatar	1	
Reunion	1	
Romania	1	
Russia	19	
Saudi Arabia	2	
Singapore	2	1
Slovenia	1	
South Africa	2	
Spain	2	
Sri Lanka	1	
Sweden	3	
Switzerland	1	1
Syria	1	
Taiwan	1	
Thailand	1	1
Tunisia	1	
Turkey	2	
Uganda	1	
UAE	2	
United Kingdom	2	2
Vietnam	2	
Zaire	1	

Source: Dataquest (May 1995)

Production capacity is being increased at the moment to meet the anticipated future demand. Most notably, Nokia Mobile Phones has recently put in place capacity to double production at its Salo plant in Finland. Dancall has announced a $30 million investment to increase production capacity of cellular phones at its Pandrup facility in Denmark. Sony has completed plans for production of GSM handsets at its Colmar facility in France.

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Other players in the cellular market at the moment are either producing analog cellular or branding GSM handsets, as shown in Tables 3 and 4. These other players must be considered as potential original equipment manufacturers (OEMs) of GSM handsets in the future as the market grows.

Table 2
GSM Handset Manufacturing Locations in Europe

Company	City	Country
Nokia	Salo	Finland
	Bochum	Germany
Motorola	Easter Inch	United Kingdom
	Flensburg	Germany
Ericsson	Linköping	Sweden
	Kumla	Sweden
AEG/Matra	Berlin	Germany
Siemens	Kamp Linsfort	Germany
Mitsubishi	Rennes	France
Sony	Colmar	France
NEC	Telford	United Kingdom
Alcatel	Laval	France
Panasonic	Thatcham	United Kingdom
Hagenuk/Cetelco	Kiel/Storving	Germany/Denmark
Dancall	Pandrup	Denmark
Philips	Nürnburg	Germany
Benefon	Salo	Finland
Orbitel	Worksop	United Kingdom

Source: Dataquest (May 1995)

Table 3
Future Possible GSM Handset Producers

Company	OEM
Ascom	Ericsson
Audiovox	Hagenuk
Bosch	Motorola
Hitachi	Nokia
Sharp	Ericsson
Toshiba	Hagenuk

Source: Dataquest (May 1995)

Table 4
Other Analog Handset Producers

Company	Country
Goldstar	Korea
Kokusai	Japan
Maxon	Korea
Oki	Japan
Samsung	Korea
Sanyo	Japan

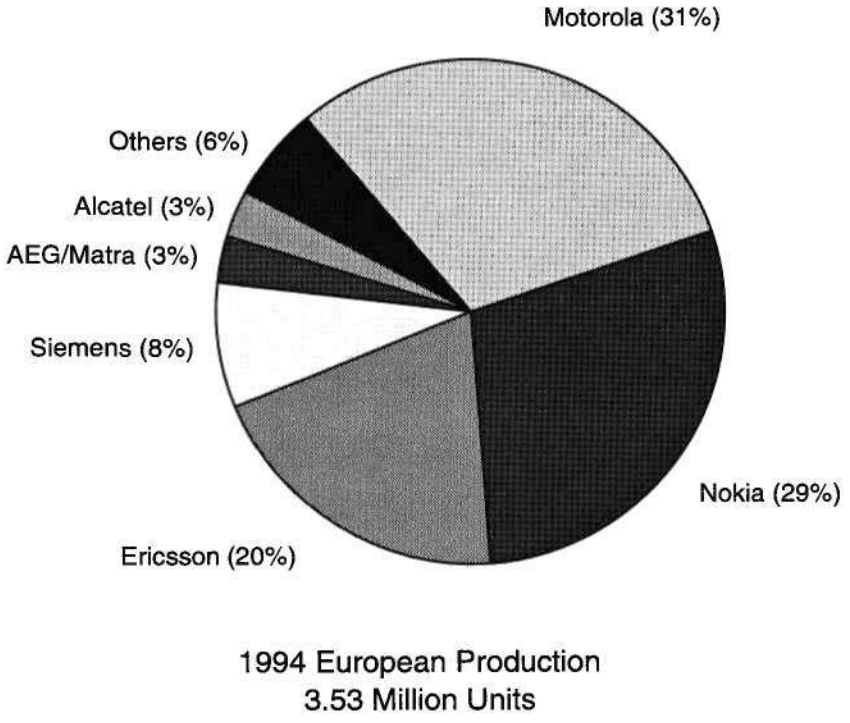
Source: Dataquest (May 1995)

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GSM Handset Production Share

In 1994 Motorola had a 31 percent share of European GSM handset production, as shown in Figure 1. Nokia is close behind with a 29 percent share, but we expect it to close the gap on Motorola in 1995. Although Ericsson's production volume grew dramatically in 1994, it only managed to maintain its production share at 20 percent, the same as 1993. Most of the gains of the big two players were at the expense of Siemens and the other players, which all saw a fall in production share. The reasons for this fall in production share may have been a function of component availability or lack of production capacity, rather than a product/marketing limitation.

Figure 1
European GSM Handset Production Share



Source: Dataquest (May 1995 Estimates)

GSM Handset Production Forecast

The production of GSM handsets in Europe is driven by a number of factors, not just the European market. In this forecast GSM includes DCS-1800 unless specifically stated otherwise. Three areas that impact GSM handset production in Europe are discussed:

- Production for European markets
- Production for export markets
- The change from analog to digital

Table 5 shows Dataquest's European GSM handset production forecast. In 1995 we expect about 10 percent of the production to be for export to non-European markets. By 2000 we expect this to have changed, with more than 25 percent of European production being for non-European markets.

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Table 5
European GSM Handset Production 1992-1999

	1992	1993	1994	1995	1996	1997	1998	1999	1994-1999 CAGR
European Unit Production (M)	0.54	1.25	3.53	7.70	12.80	18.56	25.70	31.66	55%
Ex-Factory ASP ($)	$800	$600	$480	$420	$380	$340	$300	$260	-11.5%
Ex-Factory Revenue ($M)	$435	$751	$1,696	$3,236	$4,866	$6,310	$7,710	$8,231	37.1%

Source: Dataquest (May 1995 Estimates)

Production in Europe for European Markets

At present Motorola, Nokia and Ericsson have the major share of the market and production. Although all these companies have handset manufacturing operations outside Europe, we expect they will all keep the majority of GSM handset production at facilities in Europe during the forecast period. This is determined at the moment by time-to-market constraints that will prevail for the next three to four years. During 1994 and early 1995 GSM handset demand was greater than the industry could supply; we expect this situation to continue till at least 1998. As demand continues to exceed supply, each of these OEMs will benefit from production close to the market.

As second- and third-generation digital cellular handsets are entering the market, offshore "low-cost" labor rates are less important. New designs have reduced the labor required in assembly. Handset production volumes are increasing to well over 1 million pieces per annum for the major players, justifying investment in high levels of automation.

The labor content/cost in cellular telephone assembly is important, but at the moment there are more critical factors. As long as demand exceeds supply, the most important factor for OEMs is putting in place production capacity and securing adequate component supply contracts. There is growing evidence that digital cellular production for Europe will stay in Europe. Major investments in production capacity in Europe by Nokia, Ericsson and Dancall are complemented by the growing number of Japanese companies committing production to Europe. Sony, Panasonic, NEC and Mitsubishi have located research and development centers in Europe; all are expected to be producing GSM handsets in Europe by mid-1995.

The single most important factor to date limiting supply/manufacture of digital cellular handsets is availability of electronic components, both active and passive. Throughout 1994, components went into supply shortage/allocation—one month tantalum capacitors, the next month digital signal processors (DSPs), the next flash memory.

Production in Europe for Non-European Markets

The long-term trend is to manufacture cellular handsets within the regional market served, when the volumes justify, as happened with the PC. There are three areas of opportunity for GSM outside Western Europe; these include:

- The Asia/Pacific region
- Central and Eastern Europe
- Africa and the Middle East

North America could also become an opportunity for a derivative of GSM with, for example, the microcellular derivative DCS-1800 operating in the allocated frequency spectrum at 1.9 GHz. This opportunity has most commonly been called PCS-1900. It is too early to identify and forecast the

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PCS-1900 opportunities in North America for GSM-based derivatives, with many other competing standards and solutions proposed. What is clear is that when these auctioned licenses turn into services in 1996/1997, there will definitely be some based on GSM.

The largest prospect outside Europe during this forecast period is the major opportunities in the Asia/Pacific region. Three of the "Four Tigers" economies of Asia (the exception being South Korea) have chosen GSM networks, as have virtually all other Asian and Oceanic countries. India is planning 36 regional networks and 8 other major metropolitan area networks. China, with 7 major regional networks, underlines the vast potential in the Asian region. The Asian market is not expected to challenge Europe as the largest GSM market in the forecast period. It will be a major market for digital cellular, with shipments in excess of 20 million by the year 1999, as forecast in the new Dataquest Focus Report *Cellular Telephony Market Worldwide Overview* (PERS-WO-FR-9501) from the **Personal Communications** service.

Cellular handsets for this market will be supplied primarily from European production sites until 1998. After 1998 we should expect to see major producers such as Nokia, Motorola and Ericsson gradually switch to local production for Asia/Pacific markets.

Central and Eastern European economies are growing slowly; early introductions of lower-cost analog cellular technology (NMT-450) were to provide a quick alternative to the long-term installation programs for telecommunications networks. Each of the major countries now has a GSM network implemented. The difference between this market opportunity and those of Europe, Asia and perhaps the United States is the lack of a consumer market for cellular telephones. The major European telecommunications companies are well placed to benefit from this market, and handsets will almost exclusively come from European production sites.

Analog versus Digital Cellular Production

The trend in Europe is for digital cellular to quickly become the dominant cellular technology for both the consumer and business markets. Analog cellular subscribers are expected to peak in 1996. Market shipments of digital cellular will exceed analog in 1995. By 1999, digital shipments will be more than 12 times bigger than those of analog, as shipments of analog handsets dwindle to about 1.5 million units.

European analog cellular production peaked in 1994 at 2.1 million units. Production will rapidly decline as capacity is switched to digital handsets and analog production is moved to the Asia/Pacific region.

Industry Forecast Extremes

In a fast-growing, competitive market, as is the case for GSM, there is often much misinformation. This is most in evidence in market forecasts from major handset manufacturers. Many factors could influence an unrealistically optimistic forecast, including the following:

- OEMs' ability to secure the lowest possible component prices that will be given with high-volume requirements.
- In times of component shortage, OEMs need to bargain for high levels of cooperation from component suppliers. This cooperation will be secured by the OEMs over their competition if they have forecast higher levels of production.

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- One of the most important aspects to handset manufacturers is to get semiconductor vendors "turned on" to the whole opportunity of digital cellular. These handset OEMs are competing for mind-share within the semiconductor vendors against the insatiable demands of the PC industry. They have to be able to convince semiconductor companies at the very highest level that investment in capacity will be required. The majority of current and planned investments are geared towards meeting the needs of the PC industry. Additional or alternative capacity investment needs to be targeted at the needs of the whole cellular industry.
- GSM has so far been more successful than the initial expectations. It must be anticipated, therefore, that there will be an element of wishful thinking in forecasts by cellular handset manufacturers.

Component suppliers have already experienced the demands of the cellular industry in 1994, which they failed to meet—handset production was limited by component shortages. This must be due in some part to component suppliers not believing the market forecasts of handset manufacturers. In this report Dataquest forecasts the production of cellular handsets in Europe. However, the major European handset manufacturers are procuring some components in Europe to service the needs of their worldwide manufacturing operations. There are possible circumstances when component shipments to European handset manufacturers are not a good indicator of European handset production.

Three European Market Scenarios

In the fast-growing, competitive and lucrative market there is an indisputable need for market and hence production forecasts. At present, production forecasts vary wildly from different sources. In this section on European cellular handset markets, we discuss three market scenarios that will place the bounds of probability on any forecast. The three scenarios should encompass the most pessimistic and the most optimistic forecasts for the cellular telephone market.

In 1993 the estimated penetration (the number of handset users per population) of cellular telephones in Europe was 2.3 percent, based on a population of 380 million. Dataquest estimates that retirements in 1994/1995 are running at 25 percent and that 1994 penetration has reached about 3.7 percent; and that by 2000 Europe will reach a penetration rate of about 15 percent.

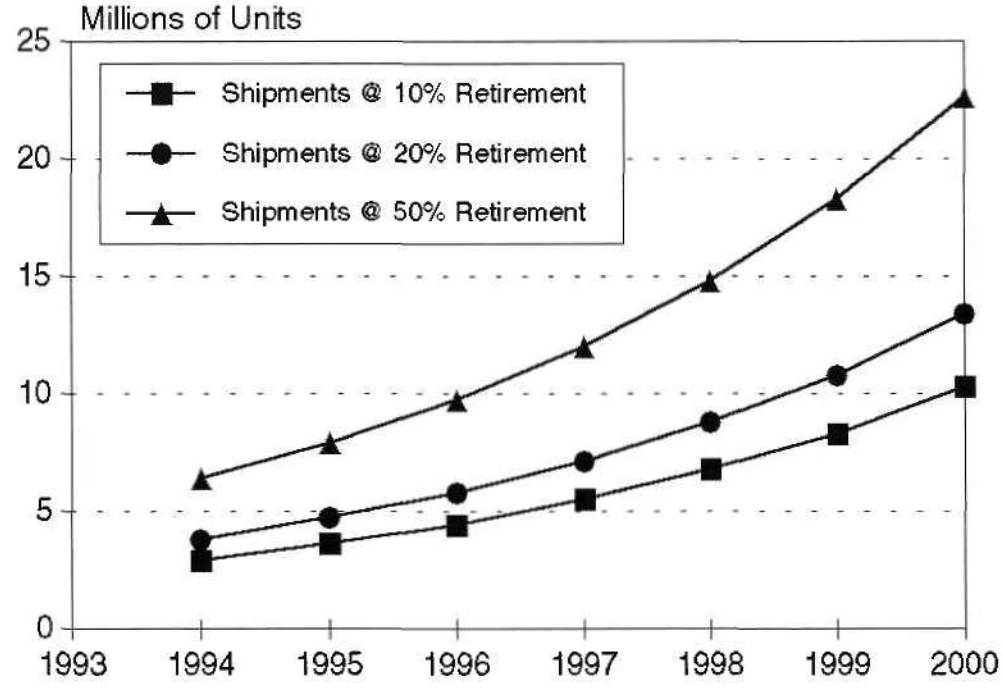
In each of the market scenarios the following three terms are used:

- **Penetration**: This is defined as the total number of cellular telephone users divided by the Western European population, expressed as a percentage. For these three scenarios a fixed European population of 380 million is used throughout the forecast period.
- **Retirements:** This is defined as the total number of telephones permanently removed (retired) from the network, divided by the total number of telephones connected to the network, expressed as a percentage.
- **Shipments:** This is defined as the number of units of cellular handsets shipped each year.

The three scenarios in Figures 2, 3 and 4 show the shipments necessary to achieve a target penetration in the year 2000 of 10 percent, 20 percent and 50 percent respectively. Each of the figures have three lines showing possible retirement rates of 10 percent, 20 percent and 50 percent. Each line indicates the annual unit shipments needed to meet the target penetration.

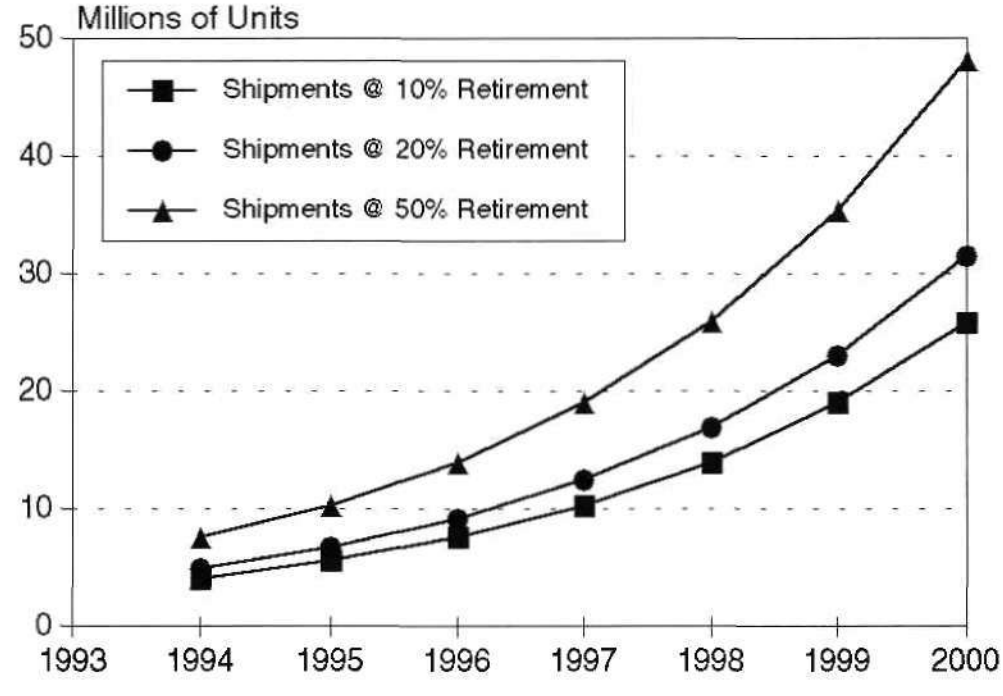
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Figure 2
Scenario 1—Market Shipments as a Function of Retirements to Achieve 10 Percent Penetration



Source: Dataquest (May 1995 Estimates)

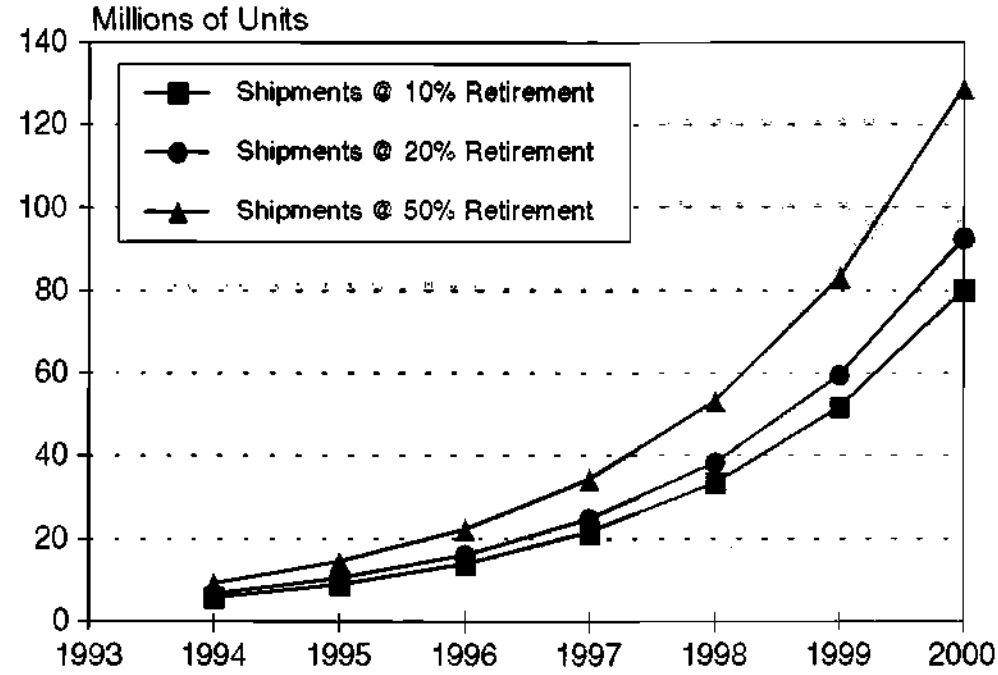
Figure 3
Scenario 2—Market Shipments as a Function of Retirements to Achieve 20 Percent Penetration



Source: Dataquest (May 1995 Estimates)

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Figure 4
Scenario 3—Market Shipments as a Function of Retirements to Achieve 50 Percent Penetration



Source: Dataquest (May 1995 Estimates)

Dataquest Perspective

The European GSM market and production is already big, but production is forecast to accelerate to 35 million units by 2000. In 1994 the components industry failed to meet the needs of the GSM manufacturers. There is a major investment required in component capacity to enable the forecast 35 million units of production. Companies that make the necessary investment have the opportunity to take part in the second biggest product market after the PC.

By David Moorhouse

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Dataquest Perspective



Semiconductor Application Markets Europe

Dataquest Predicts

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European PC Production 1994: The Year in Review

Summary

The Semiconductor Application Markets Europe group has gathered preliminary data for its annual survey of PC production in Europe. In this issue of *Dataquest Predicts* we present these results; a more detailed report will be published later in 1995.

PC unit shipments in 1994 for Western Europe continued to grow, although not at the same pace as in 1993. However, PC manufacturing growth in Western Europe has outpaced the market because PC vendors have set up or increased European production and Western Europe is being used to supply Central and Eastern Europe. During 1995, production is unlikely to outpace the market due to the maturing nature of PC manufacturing in Europe.

1994 Production by Manufacturer

Table 1 shows preliminary estimates of effective PC production for the top 15 PC manufacturers in Europe. Dataquest estimates that effective PC production in 1994 increased to 11.8 million units (10.2 million in 1993); this represents a 15.7 percent growth over last year. (See Dataquest Definitions section for a full explanation of *effective production*.) Again, the major companies showed the most healthy increase, growing on average at 27.8 percent, with the "others" category achieving a 7.4 percent decline over last year.

For 1995, Dataquest estimates that the top 15 companies will grow at approximately 20 percent. Dataquest's new service ***PC Watch*** provides more information on individual companies' estimated quarterly production and total year estimates for 1995; for more information, see the back page.

The DRAM shortage that started in the last quarter of 1992 is set to continue well into 1995. Large PC producers have been able to satisfy most of their needs, while smaller players have struggled to source products; this has been an extra burden on the second- and third-tier players, which are already suffering with narrow margins.

Dataquest

Program: Semiconductor Application Markets Europe
Product Code: SAMM-EU-PD-9501
Publication Date: January 12, 1995
Filing: File behind the tab labelled: Perspectives

Table 1
Preliminary 1994 Effective European PC Production (Thousands of Units)

Rank	Vendor	1993	1994	Growth 1993/94
1	IBM	1,500	1,600	6.7%
2	Compaq	950	1,350	42.1%
3	Apple	800	910	13.8%
4	Olivetti	606	725	19.6%
5	Dell	400	550	37.5%
6	Vobis	441	550	24.7%
7	Hewlett-Packard	280	500	78.6%
8	Escom	270	425	57.4%
9	Digital Equipment	210	400	90.5%
10	Siemens Nixdorf	290	350	20.7%
11	Zenith Data Systems	200	300	50.0%
12	ICL (Nokia Data)	260	270	3.8%
13	Actebis	180	260	44.4%
14	Peacock Computers	150	175	16.7%
15	Tulip Computers	144	175	21.7%
	Other Companies	3,519	3,260	-7.4%
	Total	10,200	11,800	15.7%
	Total Top 15 Companies	6,681	8,540	27.8%

Source: Dataquest (January 1995 Estimates)

Outlook for 1995

During 1994 we saw a number of new companies moving production into Europe; these included AST and Gateway 2000, as well as established manufacturers such as Compaq, Dell and Mitac expanding production. As we move into 1995, there are very few new facilities being built or expanded. In fact, if one looks at the top PC companies in Europe, in terms of sales all of the top 20 are currently manufacturing in Europe, it is necessary to a go long way down the list to the likes of Epson and Fujitsu to find companies outside of Europe. Most of the major manufacturers have also undertaken manufacturing expansion programs in the last few years; with available capacity to increase production, it is therefore hard to see where any major investment in production capacity could come from. The only area where Europe does have the opportunity to grow is in notebook production; 1994 saw a number of companies increasing notebook production.

With that in mind, Europe's PC production growth rates are now more likely to be in line with the growth in European unit shipments rather than ahead of it because of production moving into Europe. Dataquest will be forecasting individual company production levels for the major manufacturers in its new ***PC Watch*** service.

By Andrew Norwood

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Table 2
Dataquest's PC Production Definitions

Full Stuffing of Motherboard—Effective Production Where all semiconductor components for a PC motherboard are loaded onto a printed circuit board.
Part Stuffing of Motherboard—Effective Production Where some semiconductor components (usually memory modules and/or microprocessors) for a PC motherboard are loaded onto a printed circuit board.
Screwdriver Assembly Where all components being used for the manufacture of a PC consist of subassembled components purchased by your company. This usually means that little or no semiconductor stuffing/purchase is performed at this site.
Subcontract Assembly The manufacture of partially stuffed or fully stuffed PC motherboards that are contracted out to an outside company.

Source: Dataquest (January 1995)

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Global Markets Insight For Information Technology Companies

PC Watch

Dataquest's ***PC Watch*** *service is the leading information source for analysis of European personal computer production, with quarterly production and shipment statistics. Dataquest has been tracking European personal computer production for over seven years, combined with the knowledge of Dataquest's European and Worldwide Personal Computer Groups. This service is the preeminent source of vital information to support the marketing efforts of component and subsystem vendors to the European personal computer industry.*



Perspectives

Each month you will receive a Perspective which will give a comprehensive account of the European personal computer industry. The Perspective will not only cover production issues but also look at related personal computer topics such as memory, microprocessors, personal computer shipments, software, and storage.



Market Statistics

Personal Computer Production Quarterly Roundup: Dataquest continually monitors personal computer production. Every quarter Dataquest will publish estimates for total personal computer production, and production by each of the major vendors. Every quarter Dataquest will also forecast total and top vendor production for the next two quarters including an analysis of the information.

European Personal Computer Shipments Quarterly Roundup: Dataquest European Personal Computer Group continually tracks European personal computer shipments, each quarter. *PC Watch* will provide estimates of total European personal computer shipments and personal computer shipments by each of the major vendors, along with an analysis of the numbers.

If you have not already signed up for this new service or wish to find out more about PC *Watch* please contact Andrew Norwood on +44 1494 422 726.

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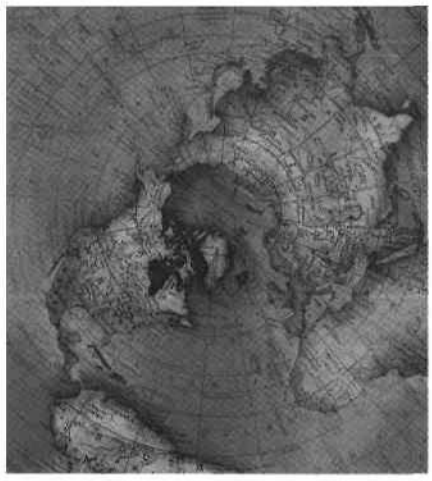
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Focus Studies

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V.32 bis/V.34 Modem Production in Europe: Turn On, Log In and Reach Out

Focus Report

1995

Program: Electronic Equipment Production Monitor
Product Code: SAPM-EU-FR-9505
Publication Date: November 27, 1995
Filing: Focus Studies

V.32 bis/V.34 Modem Production in Europe: Turn On, Log In and Reach Out



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Chapter 1
Executive Summary and Introduction

V.32 bis/V.34 Modems: Market Overview

- In 1994, 1.9 million V.32 bis/V.34 modems were shipped in Europe.
- V.32 bis/V.34 modem shipments as a percentage of total voiceband modem shipments are estimated as follows:
  - 1994: 69 percent
  - 1995: 89 percent
  - 1999: 98 percent

V.32 bis/V.34 Modems: Production Overview

- V.32 bis/V.34 modem production in Europe was 1.1 million units in 1994, and is forecast to rise to 3.0 million units in 1999. This represents a compound annual growth rate (CAGR) of 22 percent.
- In 1994, the leading V.32 bis/V.34 modem producers (by units) were:
  - Creatix: 38.2 percent
  - SAT: 5.5 percent
  - Philips: 4.1 percent
- The average factory selling price (ASP) of a V.32 bis/V.34 modem is estimated to be:
  - 1995: $152
  - 1999: $64

V.32 bis/V.34 Modems: Component Market Overview

- The 1995 average component-sector costs (component volume of 100,000 units for pricing purposes) are estimated as follows:
  - ICs: $65.104
  - Discretes: $2.753
  - Passives: $5.067
  - RF/Passive: $0.708
  - Miscellaneous: $11.267
- The 1995 average component-sector costs (component volume of 1 million units for pricing purposes) are estimated as follows:
  - ICs: $54.036
  - Discretes: $2.202
  - Passives: $4.206
  - RF/Passive: $0.609
  - Miscellaneous: $9.690
- The 1999 average component-sector costs (component volume of 1 million units for pricing purposes) are estimated as follows:
  - ICs: $43.229
  - Discretes: $2.026

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- Passives: $3.659
- RF/Passive: $0.566
- Miscellaneous: $9.206

- The 1995 market values (component volume of 100,000 units for pricing purposes) are estimated as follows:
  - ICs: $162.8 million
  - Discretes: $6.9 million
  - Passives: $12.7 million
  - RF/Passive: $1.8 million
  - Miscellaneous: $28.2 million
- The 1999 market values (component volume of 1 million units for pricing purposes) are estimated as follows:
  - ICs: $129.7 million
  - Discretes: $6.1 million
  - Passives: $11.0 million
  - RF/Passive: $1.7 million
  - Miscellaneous: $27.6 million

Introduction

This Focus Report is one in a series of evaluations of key types of electronic equipment, manufactured in Europe. These items of equipment are leading indicators of electronic market production within Europe. For each product type, the report lists the 10 largest producers (OEMs, the brand owners), or those who make up 75 percent of European production. The reports detail manufacturing (including contract electronics manufacture, CEM) and design (R&D) locations, unit production, equipment bill of materials (BOM) and typical high-volume component pricing.

Evaluation Methodology

Representative, leading-edge, typically configured models are acquired for review. All the electronic components are listed. Appropriate descriptive information, such as part number, manufacturer (where known) and package type is recorded. A destructive analysis is often performed on the ASICs to determine the foundry source, technology and gate count.

Pricing Methodology

Once an exhaustive list of components is compiled, a price is determined for each line item. Each item has a price forecast, to give the reader some idea of how the cost of each element could vary. Pricing is derived from the following sources:

- Dataquest's Semiconductor Procurement Service
- Dataquest's Mass Storage Service
- Cost models
- Press releases
- Industry quotes and surveys

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- Catalogues and distributor information
- Industry sources

Component prices are based on 100,000-component quantities (not product quantities). These prices are usually (though not always) based on prices supported by the component-vendor, obtained via component distributors. In addition, component prices based on 1 million–component quantities (not product quantities) are provided. These prices are partly based on prices supported by the component vendor, and partly based on an empirical cost model.

The 100,000-component quantities may be considered single "spot" purchases. They are priced in accordance with the prevailing lead time for that component. They do not, and cannot, take account of specific long-term partnerships between component vendors and equipment manufacturers which may result in further discounts, delivery within lead time, and other arrangements.

Component databases are updated throughout the year, depending upon the price volatility of the particular element. Basic ASIC pricing is derived from scanning electron microscope (SEM) analysis and Dataquest's proprietary ASIC cost model. Bare PCB prices are derived from Dataquest's pricing survey and industry sources.

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Chapter 2
The V.32 bis/V.34 Modem Market in Europe

The ownership patterns and the use of PCs has changed dramatically over the past five years. Although networks of PCs in the corporate environment have been common for some time, the rapid growth of standalone PCs in the small office and home environments has brought with it a need to connect to the outside world.

Using a modem for PC communication is not a new concept, but in the past modems tended to be restricted to corporate networks, and a limited number of home computer enthusiasts. Now, however, modem shipments have soared as a result of the following factors: companies encouraging teleworking and mobile computing; along with the use of electronic mail, PC fax technology and widespread access to the Internet by both home and corporate users.

Modern modems offer exceptional price performance, and the increasing number of networked applications and services will lead to further growth in European modem shipments and production.

Product Definition

This report deals with V.32 bis and V.34 voiceband* modems. The V.32 bis and V.34 modem standards are explained in more detail in chapter 3. This report does not cover modems which do not support these standards.

Market Opportunity

The voiceband modem market is dominated by modems which support the V.32 bis and (more recent) V.34 standards. V.32 bis and V.34 modems made up 69 percent of total voiceband shipments in Europe during 1994. This is forecast to rise to 89 percent in 1995 and to 98 percent by 1999.

In Europe, over the period 1990 to 1994, the average shipment price of a V.32 bis modem fell with a CAGR of minus 34 percent, and the average shipment price of a V.34 modem fell with a CAGR of minus 38 percent. Over the same period, shipments of V.32 bis modems rose with a CAGR of 213 percent, and shipments of V.34 modems rose with a CAGR of 382 percent.

The fall in price is both a result of the large increase in demand, and has also helped to fuel the demand. Booming PC shipments, and a large untapped home-user market, offer a massive opportunity to bundle modems with multimedia PCs, or sell as add-ons through retail channels.

The ISDN Threat

The technical aspects of Integrated Services Digital Network (ISDN) are briefly covered in chapter 3; but put simply, this technology offers faster data transfer speeds than current (or future) modem technology. The widespread use of ISDN depends as much on the connection costs charged by public telecoms operators (PTOs) as on the cost of the equipment. Reduced PTO charges and equipment costs (together with the requirement to send more data in less time) will lead to a decline in modem shipments (and production) towards the end of the forecast period.

* Voiceband modems use the available bandwidth (usually about 3 kHz) of a "standard" voice-grade telephone-network line (or other networks with similar characteristics).

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European Production

In 1994, 59 percent of V.32 bis/V.34 modems shipped in Europe were manufactured in Europe. This will rise to 65 percent in 1995, and eventually fall back to 56 percent in 1999. There are several reasons why OEMs choose to manufacture in Europe:

- Higher-value modems (using state-of-the art-technology) need to reach the market as soon as possible, in order to command a price premium for any performance advantage.
- Modems require approval (from a PTO approvals board) in each country in which they are sold. It is easier (and quicker) to carry this out in close collaboration with the design and manufacturing facilities.
- Modems are telecommunications products, and fit within Europe's historically strong manufacturing base for telecoms equipment.

Unit Production

The CAGR from 1994 to 1999 for V.32 bis/V.34 modem production in Europe is 22 percent. This growth is made up of the decline in V.32 bis production, by minus 27 percent over the period, and the very rapid growth of V.34 production, growing by 84 percent over the period. Table 2-1 shows production of V.32 bis/V.34 modems in Europe from 1993 to 1999.

Figure 2-1 shows production of V.32 bis/V.34 modems in Europe from 1993 to 1999. The forecast for total production starts to fall from 1998 onwards; this is due to two factors: the emergence of a data transfer protocol faster than V.34, and the increase in ISDN links (in preference to modem links).

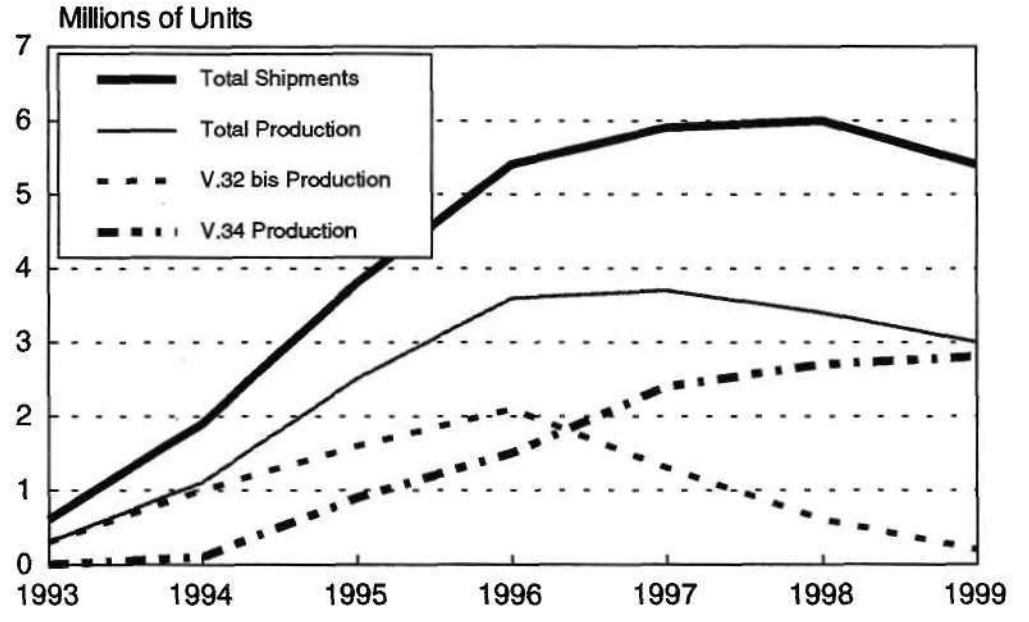
Table 2-1
V.32 bis/V.34 Modem Production in Europe—History and Forecast
(Thousands of Units)

	1993	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Total Production	295	1,114	2,505	3,624	3,731	3,359	2,998	22%
V.32 bis Production	273	983	1,636	2,083	1,341	609	199	-27%
V.34 Production	22	131	869	1,541	2,390	2,750	2,799	84%

Source: Dataquest (November 1995 Estimates)

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Figure 2-1
V.32 bis/V.34 Modem Shipments and Production in Europe



Source: Dataquest (November 1995 Estimates)

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Chapter 3
V.32 bis/V.34 Modem Technology

Technology Overview

The purpose of a modem is to convert digital signals from a computer into an analog signal for transmission via a voiceband network. Figure 3-1 shows a block diagram of a generic V.32 bis/V.34 modem, and how it interfaces with a PC.

The telephone line interface has two main functions: driving a voiceband network line with the correct power levels and loading characteristics; and connecting the modem to the network (when necessary), while maintaining suitable electrical isolation.

The "data pump," which is a digital signal processing (DSP) IC, codes (to the V.32 bis standard, for example) the outgoing digital data, prior to the digital-to-analog conversion for voiceband transmission. It also performs the reverse operation (of analog-to-digital conversion followed by decoding) on incoming data. The device also negotiates connection protocols (such as speed and error correction standards) with the modem it is communicating with over a voiceband network.

The microcontroller provides overall control of the modem functions. It runs error correction algorithms (such as V.42), controls fax modem features, controls the PC interface, and controls the data fed to and from the DSP IC.

The nonvolatile memory (usually EEPROM or flash) stores the control software (firmware) for the microcontroller, and in some cases also stores the software for the DSP IC as well. This enables upgrades to the operating software to be loaded into nonvolatile memory. The volatile memory (usually SRAM) stores basic session information, such as the telephone number dialled and the connection speed settings.

External and Internal Modems, and UARTs

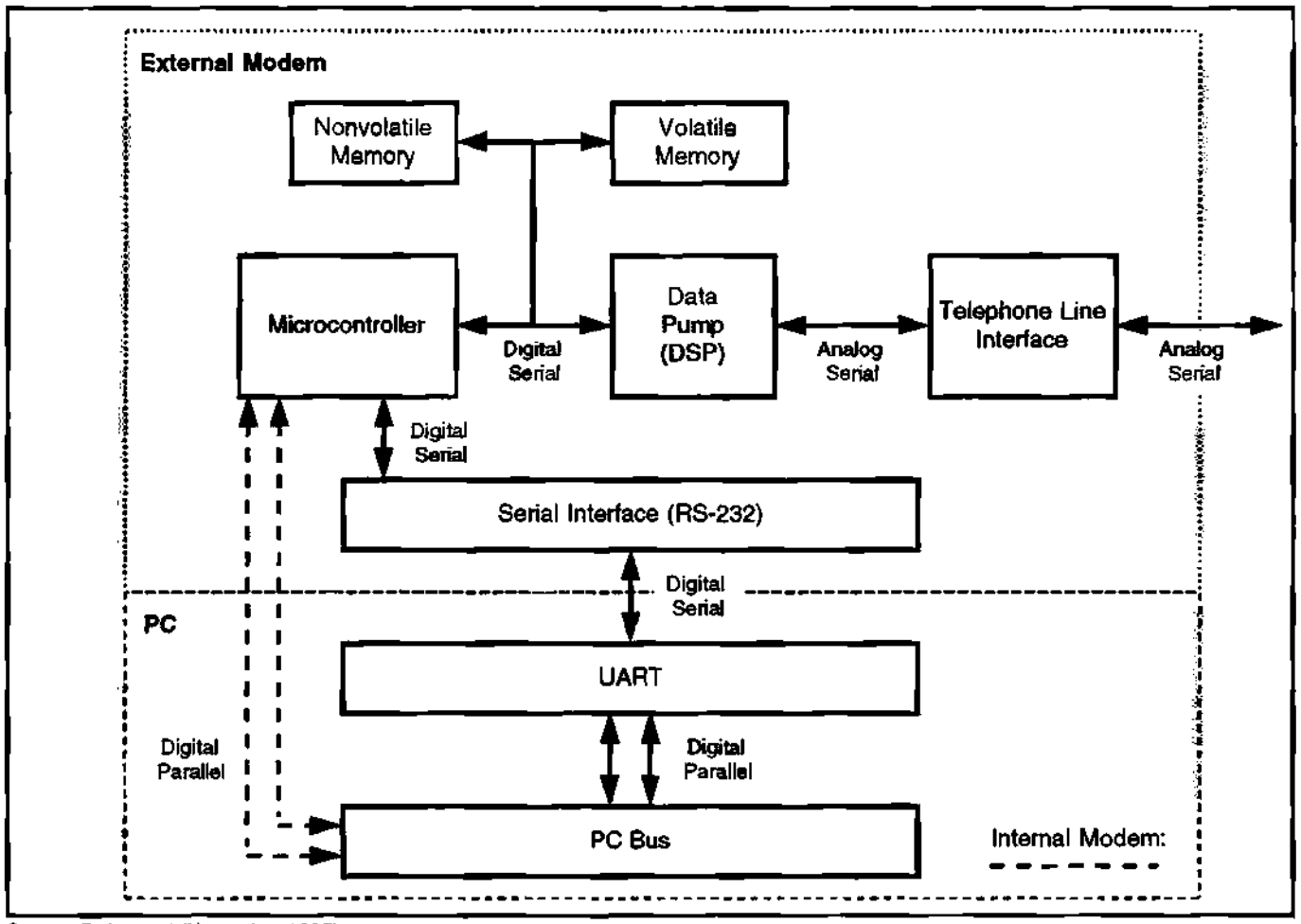
The microcontroller feeds the DSP IC with a serial stream of digital data (for coding and then conversion to an analog signal). The microcontroller can accept digital information in serial or parallel. An external modem uses a serial (RS-232) interface in order for the microcontroller to connect to the serial port of a PC.

The PC serial port is connected to a universal asynchronous receiver transmitter (UART), which converts the data stream from serial to parallel in order to interface with the PC bus. Most current PCs are typically fitted with a 16550 UART device, which has a 16-character first-in first-out (FIFO) buffer. Older UART devices (with smaller buffers) may suffer from incoming data overwriting data waiting in the buffer, before the system software can fetch it.

Internal PC modems can interface directly with the PC bus. Internal modems either have a 16550 UART device on the add-in card, or emulate the functionality of a 16550 UART within the microcontroller. In Figure 3-1, the parallel link from the PC bus to the microcontroller is shown by two dashed lines.

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Figure 3-1
Internal/External PC Modem



Source: Dataquest (November 1995)

V-Series Standards

The V-Series recommendations (effectively standards) define communication protocols for the transfer of data using public telephone networks. The standards are ratified and administered by group-14 of the International Telecommunications Union (ITU), the ITU-T (formerly the CCITT).

The V-Series covers a range of technical standards and protocols, including: error detection and correction, transmission quality, voiceband modem protocols, coding and signalling rates, as well as specifications covering power levels over networks.

The V.32 bis (*bis* refers to the second edition of the V.32 standard) standard relates to voiceband modems with a modem-to-modem data rate of up to 14,400 bit/s. The V.34 standard relates to voiceband modems with a modem-to-modem data rate of up to 28,800 bit/s. V.42 deals with error detection and correction, and V.42 bis relates to data compression.

Modem Chipsets

The modem chipset market is very competitive, offering common standards and features at low cost. It has been dominated for almost 10 years by Rockwell, which has tended to invest in emerging technologies in order to bring new products to market before the competition.

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Recent research by Dataquest shows that in 1994, Rockwell had 64 percent of the V.32 bis chipset market (by shipments), followed by Cirrus Logic with 11 percent, and Texas Instruments with 10 percent. Rockwell's share of the V.34 market was 85 percent (of shipments), followed by AT&T with 9 percent, and Texas Instruments with 3 percent.

Emerging Technology

Modem technology is primarily driven by price/performance, as each manufacturer competes to offer faster transfer rates at lower cost. The most recent example of this is the increase from 14,400 bit/s to 28,800 bit/s. Many of the data transfer standards (such as V.32 bis and V.34) have emerged as manufacturers' proprietary standards (such as V.Fast and V.FC), before being ratified by the ITU-T.

Because modems have become commodity products, manufacturers are constantly offering more functionality in order to differentiate their products. This means that current state-of-the-art modem technology may well be mainstream within a year. The most significant technologies that will be offered over the next year are data transfer at 33,600 bit/s, and digital simultaneous voice and data (DSVD).

A faster data transfer rate of 33,600 bit/s has emerged, and is currently offered as a proprietary standard by several chipset and modem manufacturers. These proprietary standards will form the basis for a V.34 bis standard, which is currently being studied by the ITU-T. A transfer rate of 33,600 bit/s is likely to be one of the fastest rates achieved using analog (modem) technology, and in many cases the 33,600 bit/s rate will not be achieved due to poor voiceband network conditions. To transfer data over voiceband networks at significantly faster rates, it is necessary to use a digital technology such as ISDN.

DSVD has been developed by chipset, modem and PC manufacturers, to use one voiceband network line to transmit digitized voice and data simultaneously (to the same destination). This technology is based on efficient coding algorithms, and intelligent time-divisioned transmission (and reception) of digitized voice and data packets. It can be used to support collaborative working, and situations where it is necessary to discuss data or information held on a computer, using shared applications.

ISDN

Modems have to convert digital information (from computers) into a modulated analog waveform in order to be transmitted over a voiceband network. ISDN offers digital transmission from end to end, which is a far more efficient way of transferring data. Basic rate ISDN typically offers two 64,000 bit/s digitized voice/data channels. The 64,000 bit/s rate is almost twice as fast as current state-of-the-art modems, and modems are unlikely to transfer data much faster than 33,600 bit/s.

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Chapter 4
Major Manufacturers

Market Leaders in Europe

Creatix Dominates

Table 4-1 shows how the 1.1 million V.32 bis/V.34 modems produced during 1994 were split by manufacturer. Creatix has achieved its dominance of the market by selling low-cost V.32 bis/V.34 modem models in high volume, predominantly in its home market of Germany. It has a similar low-cost/basic-features strategy to U.S. Robotics (which also dominates shipments to this market segment across Europe, but does not manufacture in Europe).

Table 4-1
1994 V.32 bis/V.34 Modem Production by Manufacturer (Thousands of Units)

Company	Unit Production	Production Share (%)	Cumulative Share (%)
Creatix	425.2	38.2%	38.2%
SAT	61.6	5.5%	43.7%
Philips	45.1	4.1%	47.7%
Psion Dacom	44.2	4.0%	51.7%
Motorola ISG	38.5	3.5%	55.2%
Racal	35.4	3.2%	58.4%
Pace Micro Communications	33.5	3.0%	61.4%
Hotline Export	30.9	2.8%	64.1%
Dataflex Design	26.1	2.3%	66.5%
Elsa	22.4	2.0%	68.5%
Olitec	18.8	1.7%	70.2%
Telindus	18.4	1.7%	71.8%
3X	18.0	1.6%	73.4%
Cray Communications	15.0	1.3%	74.8%
Others	280.9	25.2%	100.0%
Total Production	1,114.0		

Source: Dataquest (November 1995 Estimates)

Other Manufacturers

Many of the other OEMs produce higher-value modems (than Creatix, for example), and therefore tend to ship fewer units, mainly into corporate customers. Like Creatix, they can be dependent on a major market; for example SAT, Philips and 3X in France, and Racal in the United Kingdom.

Production in Europe

Most companies which ship modems in Europe also manufacture in Europe, and because of the need for PTO approval, modems are not generally exported to non-European markets.

In the past, there have been significant imports of "grey market" modems (which have not been approved by PTO approvals boards). These modems were shipped in from Asia/Pacific or the United States, and were significantly

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cheaper than many of the corporate-targeted modems manufactured in Europe. However, as European OEMs have focused on lower-cost modems (targeted at the home user), the price differential has been removed, and consumers are buying locally manufactured and approved modems (rather than unapproved imported modems).

European Locations

Table 4-2 shows the manufacturing and design locations of Europe's major V.32 bis/V.34 producers. Most of the companies use their own manufacturing facilities, but some modem OEMs use contract electronic manufacturers. Pace Micro Communications uses three CEMs based in England, Hotline Export subcontracts 100 percent of its production to a Swedish CEM, and Elsa subcontracts about 10 percent of its production (to smooth fluctuations in demand) to a German CEM.

Table 4-2
V.32 bis/V.34 Modem Manufacturing and Design Locations in Europe

Company	Location	Country	R&D	Production
Creatix	Saarbrücken	Germany	✓	✓
SAT	Hamburg	Germany	✓	✓
Philips	Rouen	France		✓
	Paris	France	✓	
Psion Dacom	Milton Keynes	England	✓	✓
Motorola ISG	Crawley	England		✓
Racal	Warrington	England	✓	✓
Pace Micro Communications	Shipley	England	✓	
	CEMs	England		✓
Hotline Export	Stockholm	Sweden	✓	
	CEM	Sweden		✓
Dataflex Design	London	England	✓	✓
Elsa	Aachen	Germany	✓	90%
	CEM	Germany		10%
Olitec	Nancy	France	✓	✓
Telindus	Heverlee	Belgium	✓	✓
3X	Paris	France	✓	✓
Cray Communications	Swindon	England	✓	
	Watford	England		✓

Source: Dataquest (November 1995)

Investment in Production

Along with Creatix, U.S. Robotics dominates the low-cost V.32 bis/V.34 modem market (shipping 285,000 V.32 bis/V.34 units in Europe during 1994). However, U.S. Robotics does not currently manufacture any products in Europe. The company has stated that it wishes to have some manufacturing presence in Europe, but has not yet announced specific plans. Obviously, any announcement by U.S. Robotics about European production has significant implications for component consumption.

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Chapter 5
Teardown and Component Spend Analysis of the Creatix SG 2834 Data/Fax Modem

The modem chosen for teardown is the Creatix SG 2834 data/fax modem. It supports modem-to-modem data transfer rates up to V.34 standard, error correction and compression using V.42 and V.42 bis, and fax transmission and reception. The teardown includes all electronic components on the modem PCB. It does not include the external power supply, the telephone cable and the PC serial interface cable.

Teardown Summary

- Product availability:
  - February 1995
- Design and manufacturing aspects:
  - Mix of surface-mount (mainly digital) and through-hole (mainly analog) components
  - Four-layer PCB design, ground plane under digital components
  - Very compact and cost-reduced design—that is, no power switch, no rework wiring, and full use of PCB top-side real estate

Component Spend Analysis

Component spend analysis uses the component pricing (from the bill of materials), and the market forecasts for V.32 bis/V.34 modem production, to calculate the size of the market for each type of component. The BOM is in appendix A. Table 5-1 shows V.32 bis/V.34 modem production in Europe from 1993 to 1999.

Figure 5-1 shows the cost distribution between semiconductors, discrete semiconductors, passive components, RF/passive components and miscellaneous components (based on component volumes of 100,000 units).

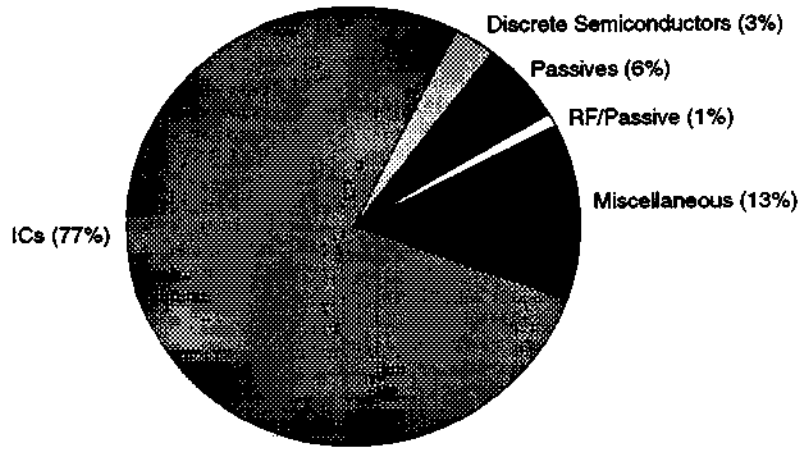
Table 5-1
V.32 bis/V.34 Modem Production in Europe, Factory ASP and Factory Revenue—History and Forecast

	1993	1994	1995	1996	1997	1998	1999	CAGR 1994-1999
Production (thousands of units)	295	1,114	2,505	3,624	3,731	3,359	2,998	22%
Factory ASP ($)	$357	$201	$152	$114	$95	$78	$64	-20%
Factory Revenue ($K)	$105,289	$223,996	$381,017	$412,740	$353,254	$261,283	$192,048	-3%

Source: Dataquest (November 1995 Estimates)

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Figure 5-1
Component Cost Distribution—Creatix SG 2834 Teardown (Based on Component Volumes of 100,000 Units)



Total Cost = $84.366

Source: Dataquest (November 1995 Estimates)

Component Sector Analysis

The bill of materials is divided into component sectors. For the modem, these sectors are:

- ICs, **Table 5-2**
- Discrete Semiconductors, **Table 5-3**
- Passives, **Table 5-4**
- RF/Passive, **Table 5-5**
- Miscellaneous, **Table 5-6**

For each component sector the following information is listed:

- Device reference, device type, quantity, and manufacturer (where known)
- Average device cost for 1995 and 1996 (and percent cost change 1995 to 1996)
- Total cost of the parts in a modem (device cost × quantity) for 1995 and 1996
- The total volume of parts required by the market, for 1995 and 1996
- The total value of the market for a specific part (and the component sector), for 1995 and 1996

Integrated Circuits (ICs)

ICs account for 77 percent of the teardown cost, and are dominated by the value of the Rockwell chipset. Most of the remaining value is in the volatile and nonvolatile memory devices. The spend analysis is in Table 5-2.

Discrete Semiconductors

These make up 3 percent of the teardown cost, and include a voltage regulator, a high-voltage transistor and a bridge rectifier. Table 5-3 shows the discrete semiconductor spend analysis.

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Passive Components

The passive components make up 6 percent of the teardown. Table 5-4 shows the passive component spend analysis.

RF/Passive Components

The RF/passive components make up 1 percent of the teardown cost; the two components are both crystal oscillators. Table 5-5 shows the RF/passive component spend analysis.

Miscellaneous Components

The miscellaneous components make up 13 percent of the teardown cost; these include two modem specific relays and a line transformer. Table 5-6 shows the miscellaneous component spend analysis.

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Table 5-2
Creatix SG 2834—IC Spend Analysis

Device Reference	Device Type	Manufacturer	Quantity	Unit Cost ($) 1995 (Q4)	Unit Cost ($) 1996 (Q4)	Total Cost ($) 1995 (Q4)	Total Cost ($) 1996 (Q4)	Cost Change 1995-1996	Market Volume (M) 1995	Market Volume (M) 1996	Market Value ($M) 1995	Market Value ($M) 1996
RC288DPi	Data pump	Rockwell	1	36.669	29.335	36.669	29.335	-20%	2.5	3.6	91.673	105.606
L3902-53	DSP	Rockwell	1	17.655	14.124	17.655	14.124	-20%	2.5	3.6	44.138	50.846
M27C1001-70XF1	EPROM, 128K×8, 70nS	SGS-Thomson	1	3.202	3.010	3.202	3.010	-6%	2.5	3.6	8.005	10.836
KM62256CLG-5L	SRAM, 32K×8, 70nS	Samsung	1	3.082	2.959	3.082	2.959	-4%	2.5	3.6	7.705	10.652
TLP627-2	Dual opto-isolator, Darlington output	Toshiba	1	0.513	0.498	0.513	0.498	-3%	2.5	3.6	1.283	1.793
TLP624	Opto-isolator, transistor output	Toshiba	1	0.358	0.347	0.358	0.347	-3%	2.5	3.6	0.895	1.249
SN75188	Quad RS-232C/ ITU-T V.24 line driver	Texas Instruments	1	0.313	0.304	0.313	0.304	-3%	2.5	3.6	0.783	1.094
SN75189A	Quad RS-232C line receiver	Texas Instruments	2	0.332	0.322	0.664	0.644	-3%	5.0	7.2	1.660	2.318
TL7705AC	Voltage supervisor	Texas Instruments	1	0.651	0.631	0.651	0.631	-3%	2.5	3.6	1.628	2.272
24C16J	EEPROM, 2K×8	Catalyst Semi.	1	1.650	1.650	1.650	1.650	0%	2.5	3.6	4.125	5.940
LM386	Audio power amplifier	National Semi.	1	0.347	0.337	0.347	0.337	-3%	2.5	3.6	0.868	1.213
Total						**$65.104**	**$53.839**				**$162.760**	**$193.820**

Source: Dataquest (November 1995 Estimates)

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Table 5-3
Creatix SG 2834—Discrete Semiconductor Spend Analysis

Device Reference	Device Type	Manufacturer	Quantity	Unit Cost ($)		Total Cost ($)		Cost Change	Market Volume (M)		Market Value ($M)	
				1995 (Q4)	1996 (Q4)	1995 (Q4)	1996 (Q4)	1995-1996	1995	1996	1995	1996
Diode	Small signal		7	0.040	0.039	0.280	0.273	-2%	17.5	25.2	0.700	0.983
Diode	Rectifier		2	0.092	0.090	0.184	0.180	-2%	5.0	7.2	0.460	0.648
LED	3 mm		7	0.037	0.036	0.259	0.252	-3%	17.5	25.2	0.648	0.907
Transistor	Transistor		2	0.048	0.047	0.096	0.094	-2%	5.0	7.2	0.240	0.338
MPSA42	Transistor	Motorola	1	0.105	0.103	0.105	0.103	-2%	2.5	3.6	0.263	0.371
LM2940T-5	Voltage regulator, 5V 1A	National Semi.	1	1.250	1.213	1.250	1.213	-3%	2.5	3.6	3.125	4.367
KSE340	High-voltage transistor	Samsung	1	0.322	0.312	0.322	0.312	-3%	2.5	3.6	0.805	1.123
DF04S	Bridge rectifier, 400V 1A	General Instruments	1	0.257	0.249	0.257	0.249	-3%	2.5	3.6	0.643	0.896
Total						**$2.753**	**$2.676**				**$6.883**	**$9.634**

Source: Dataquest (November 1995 Estimates)

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Table 5-4
Creatix SG 2834—Passive Component Spend Analysis

Device Reference	Device Type	Manufacturer	Quantity	Unit Cost ($) 1995 (Q4)	Unit Cost ($) 1996 (Q4)	Total Cost ($) 1995 (Q4)	Total Cost ($) 1996 (Q4)	Cost Change 1995-1996	Market Volume (M) 1995	Market Volume (M) 1996	Market Value (M) 1995	Market Value (M) 1996
Capacitor	Electrolytic 2200uF, 16V	Nichicon	2	0.057	0.056	0.114	0.112	-2%	5.0	7.2	0.285	0.403
Capacitor	Electrolytic 470uF, 16V		1	0.057	0.056	0.057	0.056	-2%	2.5	3.6	0.143	0.202
Capacitor	Electrolytic 4.7uF, 100V	Samhwa	1	0.057	0.056	0.057	0.056	-2%	2.5	3.6	0.143	0.202
Capacitor	Electrolytic 100uF, 16V		2	0.143	0.140	0.286	0.280	-2%	5.0	7.2	0.715	1.008
Capacitor	Electrolytic 47uF, 16V		1	0.143	0.140	0.143	0.140	-2%	2.5	3.6	0.358	0.504
Capacitor	Electrolytic 22uF, 35V		6	0.143	0.140	0.858	0.840	-2%	15.0	21.6	2.145	3.024
Capacitor	Electrolytic 10uF, 35V		3	0.130	0.127	0.390	0.381	-2%	7.5	10.8	0.975	1.372
Capacitor	680nF, 250V	Philips	1	0.24	0.235	0.240	0.235	-2%	2.5	3.6	0.600	0.846
Capacitor	33nF, 250V		2	0.062	0.061	0.124	0.122	-2%	5.0	7.2	0.310	0.439
Capacitor	Various		31	0.031	0.030	0.961	0.930	-2%	77.5	111.6	2.403	3.348
Thermister	0.7mA 175V		1	0.251	0.243	0.251	0.243	-3%	2.5	3.6	0.628	0.875
Resistor	10R, 10%, 0.3W		1	0.005	0.005	0.005	0.005	-2%	2.5	3.6	0.013	0.018
Resistors	Various		50	0.005	0.005	0.250	0.250	-2%	125.0	180.0	0.625	0.900
Inductor	Balun, 10 × 5 mm		4	0.046	0.045	0.184	0.180	-3%	10.0	14.4	0.460	0.648
Connector	DS-25, female		1	0.683	0.669	0.683	0.669	-2%	2.5	3.6	1.708	2.408
Connector	US RJ-11/FCC-68, female		1	0.342	0.335	0.342	0.335	-2%	2.5	3.6	0.855	1.206
Connector	5 mm power, socket		1	0.122	0.120	0.122	0.120	-2%	2.5	3.6	0.305	0.432
Total						**$5.067**	**$4.954**				**$12.668**	**$17.834**

Source: Dataquest (November 1995 Estimates)

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Table 5-5
Creatix SG 2834—RF/Passive Component Spend Analysis

Device Reference	Device Type	Manufacturer	Quantity	Unit Cost ($) 1995 (Q4)	Unit Cost ($) 1996 (Q4)	Total Cost ($) 1995 (Q4)	Total Cost ($) 1996 (Q4)	Cost Change 1995-1996	Market Volume (M) 1995	Market Volume (M) 1996	Market Value ($M) 1995	Market Value ($M) 1996
Crystal	40.320 MHz		1	0.372	0.361	0.372	0.361	-3%	2.5	3.6	0.9	1.3
Crystal	14.74 MHz		1	0.336	0.326	0.336	0.326	-3%	2.5	3.6	0.8	1.2
Total						**$0.708**	**$0.687**				**$1.770**	**$2.473**

Source: Dataquest (November 1995 Estimates)

Table 5-6
Creatix SG 2834—Miscellaneous Component Spend Analysis

Device Reference	Device Type	Manufacturer	Quantity	Unit Cost ($) 1995 (Q4)	Unit Cost ($) 1996 (Q4)	Total Cost ($) 1995 (Q4)	Total Cost ($) 1996 (Q4)	Cost Change 1995-1996	Market Volume (M) 1995	Market Volume (M) 1996	Market Value (M) 1995	Market Value (M) 1996
Piezo buzzer	12 mm		1	0.168	0.163	0.168	0.163	-3%	2.5	3.6	0.420	0.587
Transformer			1	0.747	0.732	0.747	0.732	-2%	2.5	3.6	1.868	2.635
Transformer	P1200	Etal	1	1.240	1.203	1.240	1.203	-3%	2.5	3.6	3.100	4.331
DIL-CL-1A81-9-13M	Relay	Meder	1	1.963	1.904	1.963	1.904	-3%	2.5	3.6	4.908	6.854
BA5W-K	Relay	Takamisawa	1	2.760	2.677	2.760	2.677	-3%	2.5	3.6	6.900	9.637
PCB	Four-layer, 13 8 × 75 mm		1	4.389	4.257	4.389	4.257	-3%	2.5	3.6	10.973	15.325
Total						**$11.267**	**$10.936**				**$28.168**	**$39.370**

Source: Dataquest (November 1995 Estimates)

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High-Volume Pricing

The bill of materials pricing is based on component volumes of 100,000 units. However, producers such as Creatix will buy in greater volume—in many cases, direct from the manufacturer. Besides avoiding distribution, an equipment manufacturer can source many part types from a single vendor, and negotiate further discounts.

Table 5-7 shows 1995 component pricing, based on quantities of 100,000 and 1 million units.

Table 5-7
1995 High-Volume Component Pricing for V.32 bis/V.34 Modems

Device Reference	Device Type	Manufacturer	Quantity	1995 (Q4) Total Cost ($) Vol. = 100,000	Vol. = 1 Million
ICs					
RC288DPi	Data pump	Rockwell	1	36.669	29.464
L3902-53	DSP	Rockwell	1	17.655	14.186
M27C1001-70XF1	EPROM, 128K×8, 70nS	SGS-Thomson	1	3.202	3.013
KM62256CLG-5L	SRAM, 32K×8, 70nS	Samsung	1	3.082	2.961
TLP627-2	Dual opto-isolator, Darlington output	Toshiba	1	0.513	0.498
TLP624	Opto-isolator, transistor output	Toshiba	1	0.358	0.347
SN75188	Quad RS-232C/ITU-T V.24 line driver	Texas Instruments	1	0.313	0.304
SN75189A	Quad RS-232C line receiver	Texas Instruments	2	0.664	0.644
TL7705AC	Voltage supervisor	Texas Instruments	1	0.651	0.632
24C16J	EEPROM, 2K×8	Catalyst Semi	1	1.650	1.650
LM386	Audio power amplifier	National Semi.	1	0.347	0.337
Subtotal				**$65.104**	**$54.036**
Discrete Semiconductors					
Diode	Small signal		7	0.280	0.239
Diode	Rectifier		2	0.184	0.157
LED	3mm		7	0.259	0.203
Transistor	Transistor		2	0.096	0.082
MPSA42	Transistor	Motorola	1	0.105	0.090
LM2940T-5	Voltage regulator, 5V 1A	National Semi.	1	1.250	0.978
KSE340	High-voltage transistor	Samsung	1	0.322	0.252
DF04S	Bridge rectifier, 400V 1A	General Instruments	1	0.257	0.201
Subtotal				**$2.753**	**$2.202**

(continued)

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Table 5-7 (Continued)
1995 High-Volume Component Pricing for V.32 bis/V.34 Modems

Device Reference	Device Type	Manufacturer	Quantity	1995 (Q4) Total Cost ($) Vol. = 100,000	Vol. = 1 Million
Passives					
Capacitor	Electrolytic 2200uF, 16V	Nichicon	2	0.114	0.095
Capacitor	Electrolytic 470uF, 16V		1	0.057	0.048
Capacitor	Electrolytic 4.7uF, 100V	Samhwa	1	0.057	0.048
Capacitor	Electrolytic 100uF, 16V		2	0.286	0.239
Capacitor	Electrolytic 47uF, 16V		1	0.143	0.120
Capacitor	Electrolytic 22uF, 35V		6	0.858	0.718
Capacitor	Electrolytic 10uF, 35V		3	0.390	0.326
Capacitor	680nF, 250V	Philips	1	0.240	0.201
Capacitor	33nF, 250V		2	0.124	0.104
Capacitor	Various		31	0.961	0.804
Thermister	0.7mA 175V		1	0.251	0.190
Resistor	10R, 10%, 0.3W		1	0.005	0.004
Resistors	Various		50	0.250	0.209
Inductor	Balun, 10 × 5 mm		4	0.184	0.139
Connector	DS-25, female		1	0.683	0.572
Connector	US RJ-11/FCC-68, female		1	0.342	0.286
Connector	5 mm power, socket		1	0.122	0.102
Subtotal				**$5.067**	**$4.206**
RF/Passive					
Crystal	40.320 MHz		1	0.372	0.320
Crystal	14.74 MHz		1	0.336	0.289
Subtotal				**$0.708**	**$0.609**
Miscellaneous					
Piezo buzzer	12 mm		1	0.168	0.14
Transformer			1	0.747	0.68
Transformer	P1200	Etal	1	1.240	1.06
DIL-CL-1A81-9-13M	Relay	Meder	1	1.963	1.68
BA5W-K	Relay	Takamisawa	1	2.760	2.36
PCB	Four-layer, 138 × 75 mm		1	4.389	3.76
Subtotal				**$11.267**	**$9.690**
Total				**$84.899**	**$70.743**

Source: Dataquest (November 1995 Estimates)

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Market Value in 1999

The 1999 forecasts for modem production, and component-sector values (in dollars), are used to predict the size of the European market for each component-sector. By 1999, V.32 bis modem production will have declined to almost nothing, and V.34 modem production is likely to have reached its peak. Production facilities will be increasing capacity for manufacturing V.34 bis modems (including DSVD technology), and ISDN combination modems.

A 1999 market value could be based on a V.34 modem, designed around a single IC chipset. However, a single IC implementation is unlikely to use significantly fewer components than the low-cost Creatix 2834 modem in 1995. Instead, the 1999 component forecast is based on a combination of mature V.34 technology, and newer V.34 bis technology.

The forecasts in Table 5-8 are based on component quantities of 1 million units. These forecasts are based on annual price reductions, component integration, efficiency improvements in component manufacturing, and overall market conditions.

Table 5-8
1999 High-Volume Component Pricing for V.34/V.34 bis Modems

Component Type	V.32 bis/V.34 Modem Content ($)		No. of V.32 bis/V.34 Modems (M)		Component Market Value ($M)	
	1995	1999	1995	1999	1995	1999
ICs	54.036	43.229	2.5	3.0	135.1	129.7
Discrete Semiconductors	2.202	2.026	2.5	3.0	5.5	6.1
Passives	4.206	3.659	2.5	3.0	10.5	11.0
RF/Passive	0.609	0.566	2.5	3.0	1.5	1.7
Miscellaneous	9.690	9.206	2.5	3.0	24.2	27.6
Total	$70.743	$58.686			176.9	176.1

Source: Dataquest (November 1995 Estimates)

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Appendix A
Bill of Materials

Device Reference	Device Type	Manufacturer	Quantity	1995 (Q4) Unit Cost ($)	Package	1995 (Q4) Total Cost ($)
ICs						
RC288DPi	Data pump/DSP	Rockwell	1	36.669	PLCC-68	36.669
L3902-53	Microcontroller	Rockwell	1	17.655	PLCC-84	17.655
M27C1001-70XF1	EPROM, 128K×8, 70nS	SGS-Thomson	1	3.202	DIL-32	3.202
KM62256CLG-5L	SRAM, 32K×8, 70nS	Samsung	1	3.082	SOP-28	3.082
TLP627-2	Dual opto-isolator, Darlington output	Toshiba	1	0.513	DIL-8	0.513
TLP624	Opto-isolator, transistor output	Toshiba	1	0.358	DIL-4	0.358
SN75188	Quad RS-232C/ITU-T V.24 line driver	Texas Instruments	1	0.313	SOP-14	0.313
SN75189A	Quad RS-232C line receiver	Texas Instruments	2	0.332	SOP-14	0.664
TL7705AC	Voltage supervisor	Texas Instruments	1	0.651	SOP-8	0.651
24C16J	EEPROM, 2K×8	Catalyst Semi.	1	1.650	SOP-8	1.650
LM386	Audio power amplifier	National Semi.	1	0.347	SOP-8	0.347
Discrete Semiconductors						
Diode	Small signal		7	0.040	SMT	0.280
Diode	Rectifier		2	0.092	SMT	0.184
LED	3 mm		7	0.037	PIH	0.259
Transistor	Transistor		2	0.048	SOT-23	0.096
MPSA42	Transistor	Motorola	1	0.105	TO92	0.105
LM2940T-5	Voltage regulator, 5V 1A	National Semi.	1	1.250	TO220	1.250
KSE340	High-voltage transistor	Samsung	1	0.322	SOT82	0.322
DF04S	Bridge rectifier, 400V 1A	General Instruments	1	0.257	SMT-4	0.257
Passive Components						
Capacitor	Electrolytic 2200uF, 16V	Nichicon	2	0.057	PIH-Radial	0.114
Capacitor	Electrolytic 470uF, 16V		1	0.057	PIH-Radial	0.057
Capacitor	Electrolytic 4.7uF, 100V	Samhwa	1	0.057	PIH-Radial	0.057
Capacitor	Electrolytic 100uF, 16V		2	0.143	SMT	0.286
Capacitor	Electrolytic 22uF, 35V		6	0.143	SMT	0.858

(continued)

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(Continued)

Device Reference	Device Type	Manufacturer	Quantity	1995 (Q4) Unit Cost ($)	Package	1995 (Q4) Total Cost ($)
Capacitor	Electrolytic 47uF, 16V		1	0.143	SMT	0.143
Capacitor	Electrolytic 10uF, 35V		3	0.130	SMT	0.390
Capacitor	680nF, 250V	Philips	1	0.240	PIH	0.240
Capacitor	33nF, 250V		2	0.062	PIH	0.124
Capacitor	Various		31	0.031	SMT-1206	0.961
S07K175GS2	Varistor	Siemens-Matsushita	1	0.251	PIH	0.251
Resistor	10R, 10%, 0.3W		1	0.005	PIH-Axial	0.005
Resistors	Various		50	0.005	SMT-1206	0.250
Inductor	Balun, 10 × 5 mm		4	0.046	PIH	0.184
Connector	DS-25, female		1	0.683	PIH	0.683
Connector	US RJ-11/FCC-68, female		1	0.342	PIH	0.342
Connector	5 mm power, socket		1	0.122	PIH	0.122
RF/Passive Components						
Crystal	40.320 MHz		1	0.372	Can-PIH	0.372
Crystal	14.7 4 MHz		1	0.336	Can-PIH	0.336
Miscellaneous Components						
Piezo buzzer	12 mm		1	0.168	PIH	0.168
Transformer			1	0.747	PIH	0.747
Transformer	P1200	Etal	1	1.240	PIH	1.240
DIL-CL-1A81-9-13M	Relay	Meder	1	1.963	PIH	1.963
BA5W-K	Relay	Takamisawa	1	2.760	PIH	2.760
PCB	4 layer, 138 × 75 mm		1	4.389		4.389
Total						**$84.899**

Source: Dataquest (November 1995 Estimates)

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Focus
Studies



Semiconductor Application Markets Europe

Focus Analysis

Television IRD Markets and Production in Europe: Part 1

Abstract: *The integrated receivers/decoders (IRD) market is in transition. Analog IRD markets will eventually fade as digital technology emerges as the natural progression for television transmission. This report is the first of two presenting the results of our 1995 IRD manufacturer survey for Europe. The second part of this series will look at market developments in the digital IRD markets.*

Executive Summary

The last decade ushered in advancements for "multimedia" applications that embrace traditional terrestrial television, communications and computer technology broadening viewers' choice. Among the earlier and first-generation multimedia systems are teletext, cable and satellite receivers. These initially emerged on the market as integrated receivers/decoders (IRDs). During 1994, an estimated 5.0 million IRDs were manufactured in Europe, of which 80 percent were satellite receivers. Still a large proportion of the overall market is satisfied by imports from the Far East. Dataquest estimates that the semiconductor market for IRDs in 1994 reached $208 million. Analog IRDs accounted for $203 million. Dataquest estimates that analog IRD semiconductor consumption will have dwindled to $57 million by 1999.

In 1995 the total market for both analog and digital IRDs is expected to reach nearly $320 million. As analog IRD technology is upgraded to digital, Dataquest estimates that by the year 2000, the overall European IRD semiconductor market is forecast to exceed $1.0 billion.

This report is the first of two presenting the results of our 1995 IRD manufacturer survey for Europe. The second part of this series will look at market developments in the digital IRD markets.

FILE COPY:
MARIA VALENZUELA

Definition: What Is an IRD?

An integrated receiver/decoder is an additional electronic equipment which, connected to a television set, will provide the viewer with access to additional broadcast channels (including existing terrestrial channels). Typically, IRDs act as an interface between the TV set and cable- or satellite-broadcast

Dataquest

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television networks. An IRD incorporates both the functionality of a TV tuner, with the ability to decode (or "unscramble") conditional access transmissions. Today's IRDs are based on analog broadcasting transmission systems. Dataquest defines analog as PAL or SECAM* video transmission standards; and not hybrid analog/digital standards based on D2-MAC* technology.

Developments are now under way in Europe to deliver television broadcasts in digital cable/satellite by the end of 1996, and digital terrestrial broadcasting which will utilize new types of IRD by the end of 1997.

Introduction

Since the introduction of television in the 1930s, there has been continued research in advancing television technology: from broadcasting, transmission, through to home television reception. Monochrome television (405 lines) was replaced by color television (625 lines). More recently, the industry has experienced the development of audio technology such as NICAM digital sound; Dolby surround-sound; in the video area with teletext; and future developments for wide-screen televisions.

But there are limitations with terrestrial television. Terrestrial television is broadcast on allocated bandwidths assigned by national governments. The infrastructure for terrestrial television provides a number of transmission stations that broadcast within the television bandwidths for each national television channel. Depending on a combination of total television coverage area and channel bandwidth frequency distribution, the national terrestrial television frequency spectrum is quickly filled up. This limits the number of channels for viewing, and consequently restricts the choice of channels.

Strictly speaking, broadcasters' efforts to improve transmission of television led to the development of analog cable and satellite TV. Cable television itself could be described as a technology evolution of community antenna TV (CATV) systems.

CATV systems were developed for those communities where terrestrial broadcast signals were weak, and where received, the signals produced poor picture and sound quality. In a CATV system, a master antenna is located at a remote site where signal reception is strong. This signal is filtered and amplified and piped through cable to homes in the community. Until recently, CATV systems were very common in remote communities in the United States.

Cable and Satellite Television

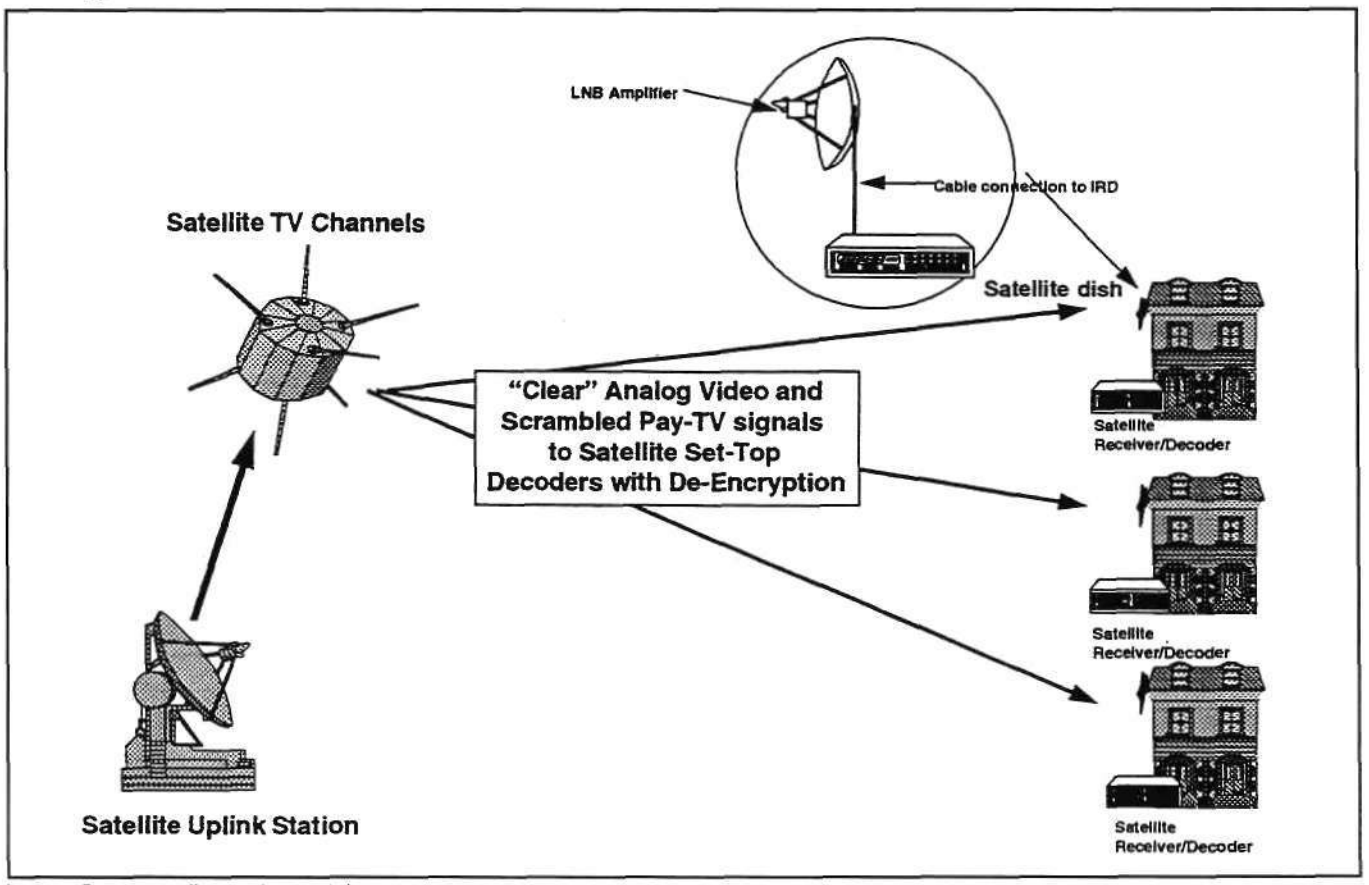
The first television set-top boxes that emerged more than 20 years ago were teletext-decoders. As the technology developed and component prices fell, teletext was taken for granted, and nowadays is provided as a standard built-in feature in most European televisions.

The next generation of set-top box was analog receiver/decoder systems providing access to broadcast television services via cable or satellite. Cable and satellite TV services were introduced to give the viewer better reception and more choice in television programs. The justification for having a set-top box was for slightly different reasons. IRDs include different technologies in cable or satellite broadcast transmission (depending on operator) and conditional access (CA).

* PAL = Phase Alternating Line; SECAM = Sequential Couleur Avec Mémoire (sequential color with memory); D2-MAC = Duobinary-Multiplexed Analog Component

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Figure 1
Analog Satellite DTH TV Infrastructure



Source: Dataquest (November 1995)

Each of these systems (cable or satellite) can be built into television sets and nowadays, in some countries, cable and/or satellite receivers are integrated into high-end television sets. In recent years, new technologies in digital compression for video and audio, and new network technologies, have paved the way for the development of a digital receiver standard. These emerging technologies and their implications for the semiconductor industry will be discussed in the second of this two-part series of reports.

DTH Satellite TV Architecture

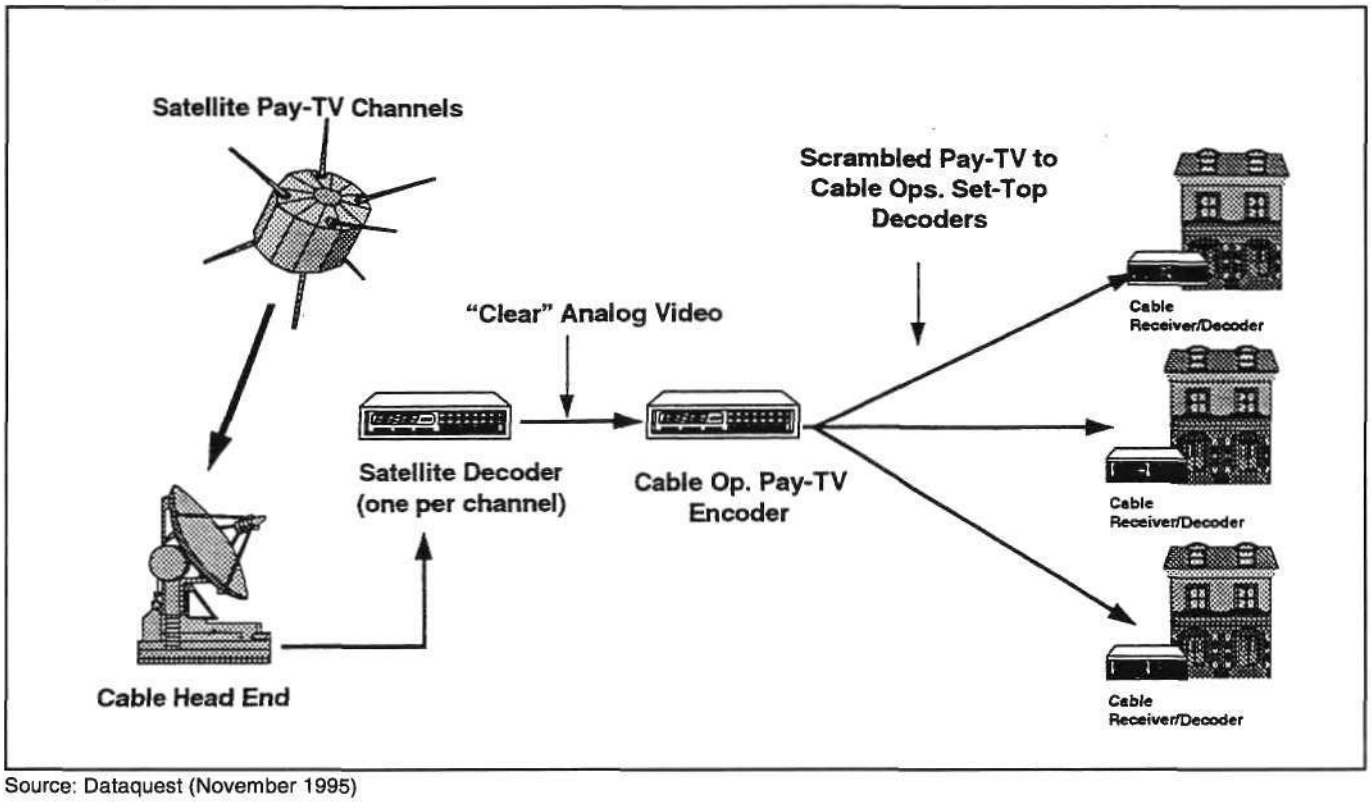
Figure 1 shows the infrastructure for satellite television networks and how IRDs are used. Satellite TV or direct-to-home (DTH) satellite television broadcasts both "clear" televisions signals and scrambled television signals. These signals are received by external satellite dishes (aerial) which have a built-in low noise block (LNB) amplifier. Inside the home a satellite receiver/decoder decodes signals received by the external dish (aerial) and unscrambles broadcast signals. Most satellite operators have a custom broadcasting encryption algorithm. Within the IRD, the encrypted signal is decoded. Conditional access is enabled usually via a smart card supplied by the satellite operator.

Cable TV Architecture

Figure 2 presents an overview of an analog cable television infrastructure and how cable IRDs are applied in this environment. Cable TV generally relies on both terrestrial and satellite television broadcast which is received by the cable operator's head-end system and piped through the cable network to the home.

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Figure 2
Analog Cable TV Infrastructure



Source: Dataquest (November 1995)

A dedicated satellite decoder system transmits clear analog video satellite signals to an encoder. The encoder scrambles the pay-television signals and feeds the scrambled signals down the cable network. Cable television IRDs in the home receive/decode these signals for viewing. Cable IRDs also rely on conditional access. The CA function is built in the IRD and programmed via the cable network by the operator.

Analog Cable and Satellite IRD Markets in Europe

The analog cable and satellite IRD markets are quite different. Fewer cable IRDs are sold on the European retail market. Most cable IRDs are distributed by the cable operator to subscriber households, and a larger proportion of cable receiver systems are built into TV sets.

Satellite IRDs and satellite dishes, however, are sold through conventional retail channels, but there is no relationship between the number of satellite dishes sold and the number of satellite IRDs sold. Some households use satellite master antenna television (SMATV) technology (where a master satellite dish is installed on a building, and cables are piped into flats/apartments—usually found in blocks of flats or in some residential communities; the signals are fed through amplifiers to each flat/apartment).

Dataquest estimates the overall market for television IRDs in Europe to have reached nearly 7.0 million units during 1994. Some of these systems were replacements, others were second sets, and a few were destined for "grey" markets. Because satellite broadcast coverage areas overlap national country borders, some illegitimate markets exist for satellite television, and this is not visible through subscription figures; therefore, subscription figures do not tally with market estimates.

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The European IRD market is quite complex. Each country has its own legislation and regulations governing telephony and broadcasting. National governments influence the development of cable and satellite broadcasting. Hence, there are no generic cable and or satellite IRDs available on the market. The issue of conditional access also means that each system is unique to the operator company (see Table 5 for a listing of operators active in Europe).

Television channels available from cable/satellite television operators are designed to cover specific types of program. The satellite channels are packaged like magazines giving viewers more choice, and helping the service operator to succinctly define viewer interests.

As operators could argue the case that viewer interests allows for a classification of interest groups, advertisers are attracted to the option of buying qualified interest group slots. Each side emerges a winner, as these types of advertisement attract premium rates.

Examples of dedicated channels include:

- News
- Music
- Sports
- Movie
- Education
- Adult entertainment
- Cultural/ethnic interests
- Environmental studies

IRD Market Trends

Key trends spurring the IRD market in Europe are as follows:

- Research surveys show that programs are the primary motivation for subscriptions to cable or satellite television services.
- However, television ratings across Europe suggest that viewing hours appear to be static. Moreover, viewer evidence suggests that of those households that have subscription cable/satellite television, prime time viewing is dominated by terrestrial television program viewing.
- There is no evidence to suggest a strong demand or need for subscription cable or satellite television (for example "I must have ...").
- Most satellite television viewers have to *buy* their own receivers/decoders and satellite dishes *before subscribing* to the channel services.
- Especially in the United Kingdom, a secondary motivation which is helping cable companies gain market share is the provision of telephony services—often at more competitive rates than those of the national public telecommunications operator (PTO) rates.
- The European IRD market is forecast to grow in units from 7.6 million in 1994 to 12.6 million in 1999 (representing an 8.4 percent growth rate). Most of the growth is likely to occur in the cable IRD market.
- The analog IRD market is forecast to peak in 1995. Digital systems will account for the majority of future market growth.

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- European market for subscription television continues to grow. However, demand for cable/satellite services is not very strong (that is, there is no compelling need for cable or satellite services).
- PTOs facing competition in their basic services are keen to offer cable or satellite television.
- The UK telecoms market is liberalized, and legislation excludes British Telecommunications (BT) from offering television broadcasting over cable until 1998.
- The majority of cable operators are US companies that are bringing in their own IRDs (where applicable).
- Liberalization of European telecommunications industry will likely introduce more cable television services across Europe.
- Satellite will grow, and to some extent compete with cable, but will not prevent cable from growing rapidly.
- Satellite television is pushing digital faster than cable. Digital satellite promises to offer a cheaper solution than digital terrestrial or cable.
- Satellite and cable IRDs may disappear into television sets.

Subscription Grows for Cable and Satellite in Europe

Table 1 shows that the rate of subscription for cable and satellite television services across Europe has nearly doubled in the last four years. It provides some basic statistics about European cable and satellite markets and shows that Western Europe has an installed base of nearly 90 percent of total European subscriptions.

Subscription figures do not reflect the IRD market installed base, as some countries offering cable services (particularly Germany) do not require separate IRDs. The figures do not reflect unit production of set-top boxes either as some purchases are made during the year for replacements, upgrades and second sets.

Furthermore, as mentioned earlier, in most continental countries cable receivers are built into television sets and there is no additional need for the consumer to buy a IRD. This often distorts the apparent market view for the cable IRD market in Europe. However, the sheer volume of subscribers for cable television services in Europe suggests that a move to digital cable broadcasting could result in a potentially strong and healthy growth in European cable receiver production.

Table 2 provides our estimates of the market for IRDs in Europe between cable and satellite television. Overall, European cable connections exceed satellite dish installations. The table also shows that satellite IRD production is at least six times the size of cable IRD production. Figure 3 shows the forecast out to 2000 for cable and satellite IRDs.

To the consumer, the cost of ownership for cable television seems to be much lower than for satellite (short-term analysis): IRDs are supplied by the cable TV operator, whereas usually satellite IRDs are purchased by the consumer.

Cable television operators also offer relatively cheaper telephony services alongside cable television. Often, cable start-up costs compared with satellite TV are more attractive for low-premium subscribers who have a static budget for consumer leisure spending.

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Table 1
Trends in European Cable and Satellite Subscribers
(Millions of Subscribers)

Region	1990	1992	1994
Total Western Europe	26.1	37.4	48.4
Total European Union	23.9	34.8	45.5
Total Other Western Europe	2.3	2.6	2.9
Central and Eastern Europe	2.0	0.4	4.6
Total Europe	30.4	40.5	55.8

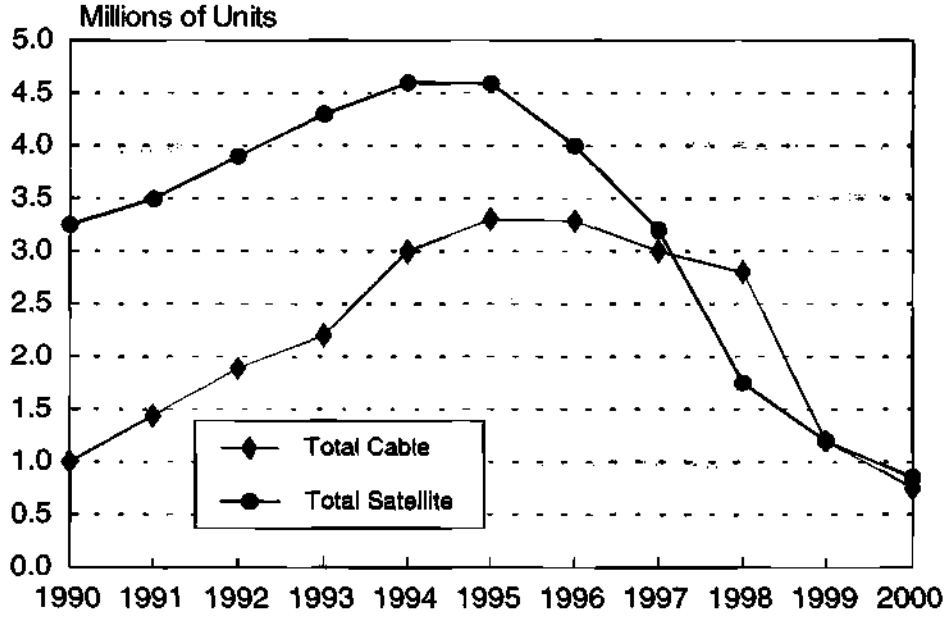
Source: Industry estimates, and Dataquest (November 1995 Estimates)

Table 2
European Analog Cable and Satellite IRD Markets and Production
(Millions of Units)

	1993	1994	1995
Shipments			
European Cable IRD Market	2.2	3.0	3.3
European Satellite IRD Market	4.3	4.6	4.6
Production			
European Cable IRD Production	0.2	0.5	0.6
European Satellite IRD Production	4.1	4.5	4.4

Source: Dataquest (November 1995 Estimates)

Figure 3
European Analog IRD Market Forecast



Source: Dataquest (November 1995 Estimates)

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The market for cable/satellite television has been slow to develop, although cable and satellite TV operators continue to find effective ways of increasing subscriptions and revenue. However, because of the relatively lower infrastructure costs associated with satellite television, this service has gained more subscribers faster than cable television across Europe. This has made competition for subscribers more intense. From the telecommunications side, cable companies are offering cheap telephony services; and from the media side, satellite television companies are offering a wider range of television choice, quality and flexibility.

In Europe, on-demand services—for example, music-video-on-demand and video games (using analog near-video-on-demand technology)—are some of the more recent efforts to provide more viewer choice and attract more subscriptions, advancing toward emerging digital standards. As a result, the existing market for analog television IRDs is facing a technology evolution stimulated by multimedia concepts. This evolution is affecting manufacturers of both satellite and cable TV receiver equipment.

The introduction of interactive television using digital broadcasting techniques presents requirements for a new semiconductor engine for compressed digital video and audio. This technology means additional manufacturing costs to existing analog television sets.

The justification of incorporating a digital IRD engine in a television is not yet anticipated. However, it is more likely that by the end of this decade, a small proportion of the high-end television market sector will include some digital terrestrial television sets.

Dataquest believes that future market drivers for digital broadcasting will include the following:

- Interactive television
- Video-on-demand
- Electronic mail messaging
- Gambling and adult entertainment
- Home banking
- Catalogue/home shopping

But the operational aspects of digital television and the functions listed above involve further development of multimedia technologies—the convergence of the "three C's" (communications, consumer and computer electronics). As a result, products for digital television are being developed by the major companies in each of the three "C" segments. To date, many of the European cable operators are telecoms companies. In continental Europe, where most of the PTOs have not been liberalized, national telecoms operators own the cable networks—for example, Deutsche Telekom and France Telecom.

The total number of television households during 1994 within the European Union (EU) is estimated at 140 million. Overall, cable and satellite subscription penetration of television households across the EU is about 32 percent. In individual countries, some trends can be identified (see also Table 3):

- The Netherlands has the highest penetration of cable and satellite services, estimated at 95 percent of all television households.
- Germany has the highest concentration of cable and satellite television accounting for nearly 50 percent of all European subscriptions.

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- The United Kingdom appears to be the beta-site for commercial cable television by most US telecommunication companies seeking to expand operations in Europe after the Europe-wide deregulation of the telecommunications industry.

Table 4 offers some comparisons in operation between cable and satellite TV.

Table 3
European Union Country Markets, Cable and Satellite Subscribers (Thousands of Subscribers)

Country	1990	1992	1994
Germany	9,007	15,673	21,339
Netherlands	4,950	5,400	6,031
United Kingdom	1,222	2,737	4,206
Belgium	3,377	3,521	3,694
Sweden	1,582	2,050	2,223
Austria	680	1,320	1,962
Denmark	1,178	1,385	1,568
France	462	833	1,305
Finland	691	892	1,045
Ireland	410	435	760
Portugal	15	38	558
Spain	143	205	413
Luxembourg	104	226	276
Italy	40	66	87
Greece	1	4	4
Total	23,862	34,785	45,471

Note: Each country has developed its own independent infrastructure for cable and satellite television. The result is that some countries, notably Germany, do not require IRDs for cable television transmission—the cable television receivers are built into TV sets for the German market. For pay-TV services, the cable TV operator issues a "dongle" for each subscriber. Significantly, the biggest single European country market for pay television services (cable and satellite television markets) is Germany.
Source: Industry estimates, and Dataquest (November 1995 Estimates)

Table 4
Cable TV versus Satellite TV, a Comparison

Satellite TV	Cable TV
Wireless connection to network	Need wired cable link to network
Mobile television—possibility	Fixed location television
Cheaper to install (satellite operator)	Expensive to install (cable operator)
Cheaper option for remote areas	Expensive option for isolated areas
One-way communication	Two-way communication
Open circuit (CA software piracy)	Closed circuit (better security control)

Source: Dataquest (November 1995)

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Pay-TV

Pay-TV refers to the technology for providing television programming through advance purchase/subscription. The viewer pre-purchases an exclusive program/channel (usually non-terrestrial), which is delivered via cable or satellite at the time of broadcast.

Pay-TV is most common in the United States and is often referred to as pay-per-view television. Pay-per-view is often associated with programs, rather than channels, that can be bought for "live-broadcast" viewing. This is usually a further segmentation in exclusive television broadcast services. As an example, filming rights to major world events such as a football league game or a boxing match may be purchased by a television company and redistributed to other operators on a pay-per-view basis. Each viewer pays a fixed rate fee to gain access to an unscrambling technology for the encrypted broadcast. Here in Europe, many operators are developing infrastructure for subscription television. But the transition from analog technology to a digital broadcast technology seems to be paving the way for pay-per-view in Europe.

Currently, most cable and satellite operators in Europe are set up to provide basic programming through packaged program options based on a monthly subscription rate. There are no further exclusive programs available via pay-per-view.

In terms of pay-TV operators, Canal Plus (including Canal Plus International) and BSkyB emerge as the major players in Europe. These two players account for more than 80 percent of European satellite subscriptions.

Table 5 shows the market share of pay-TV operators by subscriptions. These are the leading European operator companies, and many of them also have subsidiary companies in other countries outside Europe. Because pay-TV requires conditional access technology, many of the pay-TV operators have licensed specific companies to build IRDs.

Conditional Access

Conditional access is the term used to describe the electronic key that opens up the encryption technology. The key itself does not unscramble broadcast signals but allows the user access to unscramble signals. This allows the operator to charge subscribers for the right to decode and view scrambled television channels or programs.

Table 5
European Pay-TV Operators, Market Share by Number of Subscribers, As a Percentage of Total Market

Operator	1994
Canal Plus France	34.1%
BSkyB	30.0%
Canal Plus Int.	17.9%
FilmNet	7.2%
Telepiù	5.7%
TV1000	4.2%
Teleclub	0.09%
Others	0.81%

NA = not applicable
Source: Industry estimates, and Dataquest (November 1995 Estimates)

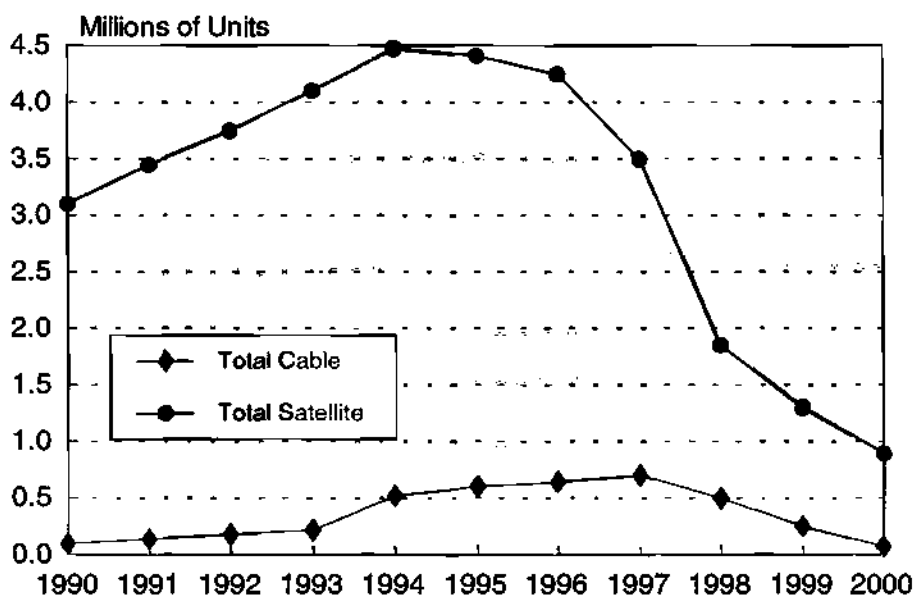
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European IRD Production and Semiconductor Market Forecast

European manufacturers are building IRDs for local and export markets outside of Europe. However, Europe still imports IRDs for European use. The difference between European IRD production (Figure 4) and the size of the total European IRD market suggests that opportunities for additional IRD production in Europe is quite substantial.

In the cable TV business, many cable operators in Europe are owned by the US telecommunications companies. As a result, few cable operators use locally manufactured analog cable IRDs for the European market.

Figure 4
European Analog IRD Production Forecast



Source: Dataquest (November 1995 Estimates)

IRD Production Trends

Key trends affecting production of IRDs in Europe are as follows:

- 5.0 million IRDs were produced in Europe during 1994.
- Dataquest believes the market for analog television IRDs peaked in 1994.
- Dataquest estimates that 5.5 million IRDs will be produced in Europe during 1995, representing an annual growth rate of 10.6 percent.
- Satellite receivers represent the largest volume of IRD production in Europe.
- The majority of Europe's cable receivers are "built-in" television sets.
- Most of Europe's cable receivers are imported from the United States and the Far East.
- Cable receiver production in Europe is only 12 percent of all European IRD production.
- Introduction of Digital Video Broadcast (DVB) cable IRDs is expected to rapidly increase production of cable IRD boxes in Europe.
- Traditional consumer electronics companies are likely to remain dominant suppliers of home television IRDs.

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Table 6
European Analog Cable IRD Market and Production Forecast, and Semiconductor Consumption Analysis

	1994	1995	1996	1997	1998	1999	CAGR
Market Unit Shipments (M)	3.00	3.30	3.29	3.00	2.80	1.20	-17%
Market Unit Shipments (AGR)	36%	10%	0%	-9%	-7%	-57%	
Percent European Production	50%	51%	50%	45%	40%	35%	
European Unit Production (M)	0.52	0.60	0.64	0.70	0.50	0.25	-14%
Ex-Factory ASP ($)	$88	$88	$88	$88	$88	$88	0%
Ex-Factory Revenue ($M)	$46	$53	$56	$62	$44	$22	-14%
Avg. Semi. Content (per unit) ($)	$21	$20	$20	$20	$20	$20	-1%
European Consumption ($M)	$11	$12	$13	$14	$10	$5	-14%

Source: Dataquest (November 1995 Estimates)

Cable Television IRD Production

In Europe, the market for cable IRD production is dependent on the country of origin of the cable TV service operators. Therefore, in countries where there is little national or European participation in the provision of a cable television service, the IRDs are usually manufactured outside Europe—in the United States or the Far East. Table 6 shows Dataquest's forecast for the analog cable market and production, together with semiconductor consumption.

Leading Manufacturers of European Cable and Satellite IRDs

Sagem and Pace are the major manufacturers of IRDs in Europe. Sagem has a strong relationship in France with Canal Plus, the leading European service provider, and Pace has a very strong relationship with BSkyB. Table 7 shows cable and satellite television IRD production estimates for Europe.

The table shows that the largest European IRD manufacturer, Sagem, has a 24 percent share of European IRD production. The second-largest player is Pace. Pace emerged as a strong European manufacturer of IRDs after originally winning a contract to supply satellite television kit to the merged Sky and British Satellite Broadcasting (BSB) into BSkyB.

Companies included in the "others" category include Arcon, Bekotechnik, JVC, Mitsubishi, Panasonic, Philips, Sharp and Sony.

Thomson and Philips had earlier abandoned their participation in this business choosing to support the proposed European standard D2-MAC. In the end, few consumers opted for this D2-MAC standard and there was no market to address.

Dataquest also believes that Pace provides OEM support for several other IRD manufacturers. Most brands of analog set-top box sold in the European markets are OEM brands. This means that there are fewer manufacturing locations than brands since many manufacturers use subcontract facilities.

Major European IRD Manufacturer Locations

During the last 12 months several companies have made announcements about IRD manufacturing plans in Europe. Compared to the selection of brands available on the European market, fewer companies actually do have manufacturing plants in Europe. Table 8 provides a listing of analog IRD production and R&D locations.

The manufacturing trend in Europe often involves brand manufacturers using an OEM or subcontractor to build the boxes until they have established a market share that is big enough to sustain a factory line.

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Table 7
European Analog IRD Production by Manufacturer (Thousands of Units)

Company	Unit Production	Production Share (%)	Cumulative Share (%)
Sagem	1,200	24	24
Pace	900	18	42
Thomson Multimedia	550	11	53
Technistat	500	10	63
Nokia	300	6	69
Grundig	295	6	75
Others	1,255	25	100
Total Production	5,000		

Source: Dataquest (November 1995 Estimates)

Table 8
Analog IRD and R&D Locations in Europe

Company	Location	Country	R&D	Production
Grundig	Llantrisant	Wales	✔	✔
	Fürth	Germany	✔	✔
Nokia	Salo	Finland	✔	✔
	Motala	Sweden		✔
Pace	Poznan	Poland		✔
	Shipley	England	✔	✔
Philips	Le Mans	France		✔
	Suresnes	France	✔	
Sagem	Pontois	France	✔	
	Rouen	France		✔
Technistat	Dresden	Germany	✔	
	Eisenach	Germany		✔
	Vogtland	Germany		✔
Thomson Multimedia	Angers	France	✔	✔

Source: Dataquest (November 1995)

Recent moves in allocating factory lines to IRD manufacture include Grundig, Mitsubishi and Sony. Grundig is reviewing its manufacturing strategy and hopes to finalize plans to cease IRD production in Germany and concentrate manufacture in the United Kingdom only. Sony and Mitsubishi are among the newest entrants in the manufacturing arena. Until recently, these manufacturers were using subcontractors to build their boxes for them.

Satellite IRDs currently account for the greater proportion of IRD manufacture in Europe, at 92 percent. In 1994, satellite IRD production reached 4.47 million and the market forecast is for production of 1.3 million units by 1999, with a compound annual growth rate (CAGR) of minus 22 percent (see Table 9). Dataquest estimates that 90 percent of the European satellite IRD market is supported by local European manufacturing.

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Table 9
European Analog Satellite IRD Market and Production Forecast, and Semiconductor Consumption Analysis

	1994	1995	1996	1997	1998	1999	CAGR
Market Unit Shipments (M)	4.60	4.59	4.00	3.20	1.75	1.20	-24%
Market Unit Shipments (AGR)	7%	0%	-13%	-20%	-45%	-31%	
Average Selling Price ($)	235	225	211	201	190	180	-5%
European Market Revenue ($M)	1,081	1,033	843	642	333	216	-28%
Percent European Production	100%	100%	100%	100%	100%	100%	
European Unit Production (M)	4.47	4.41	4.25	3.50	1.85	1.30	-22%
Ex-Factory ASP ($)	$157	$150	$140	$134	$127	$120	-5%
Ex-Factory Revenue ($M)	$700	$661	$597	$467	$234	$156	-26%
Avg. Semi Content (per unit) ($)	$43	$43	$42	$41	$40	$40	-1%
European Consumption ($M)	$192	$188	$179	$144	$74	$52	-23%

Source: Dataquest (November 1995 Estimates)

IRD Semiconductor Content Analysis

Because of the relatively low production volume of cable IRDs in Europe, our semiconductor content research and bill-of-material analysis is based on an analog satellite IRD. Cable IRDs have a lower semiconductor content (in value) as some of the complex encryption systems employed in satellite receivers are simplified. Figure 5 shows the breakdown analysis of semiconductor content by product category in a typical satellite IRD.

Our analysis of a typical IRD without surround-sound processors but incorporating NICAM stereo and a PANDA noise reduction system (similar to Dolby noise reduction) contained $43 worth of semiconductors. Integrated circuits account for 72 percent of the total value of semiconductor content, and the remainder is largely discrete semiconductor devices accounting for 25 percent of the overall semiconductor content. LED optoelectronic devices account for the remaining 3 percent.

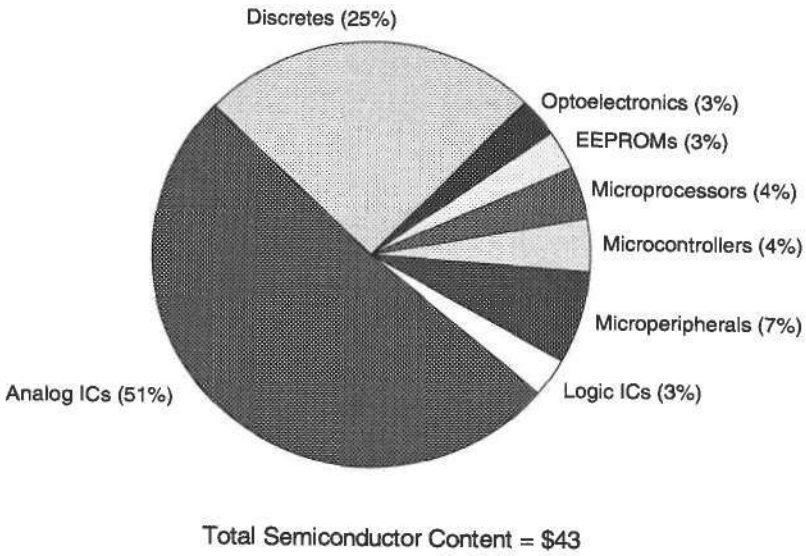
Semiconductor Market Forecast for Analog IRD

Dataquest estimates that in 1994, the European semiconductor market for analog (cable and satellite) IRDs exceeded $200 million. The "average" analog IRD has more than simple sound reproduction capability. Dolby pro-logic surround-sound processors are built into some of the top-range sets. Features like teletext capability are also being built into some receivers.

Figure 6 shows Dataquest's semiconductor market forecast based on the production forecasts shown in Tables 6 and 9.

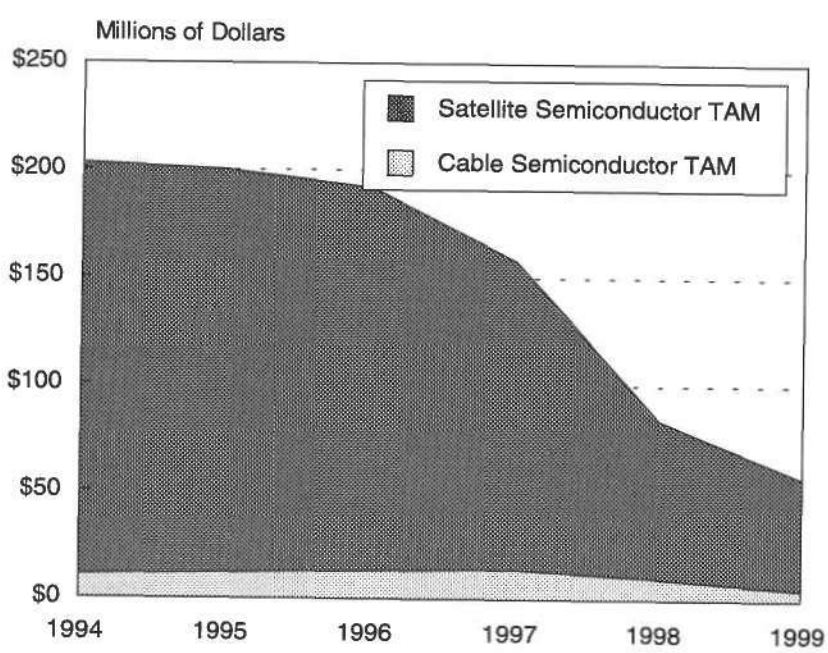
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Figure 5
European Analog IRD Semiconductor Content Breakdown



Source: Dataquest (November 1995 Estimates)

Figure 6
European Analog IRD Semiconductor Market



Source: Dataquest (November 1995 Estimates)

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Dataquest Perspective

Dataquest believes that the overall analog IRD market is in transition. Analog IRD markets will eventually fade out as digital technology emerges as the natural progression for television transmission. Paradoxically, although the analog IRD market is in decline, the analog IRD manufacturers have never been as important as they are now to the semiconductor industry. The existing analog IRD manufacturers will emerge as the dominant manufacturers for digital IRDs.

By all indications, subscription/pay-television is set to grow. The culture for subscription and pay-TV is being nurtured now. The emergence of new channels, new programs and new services through technology developments in industries such as banking, retailing and information acquisition will fuel this transition. Dataquest forecasts that growth in subscription cable/satellite television will most likely follow from here.

For semiconductor vendors, the new digital technology represents the next big opportunity. Dataquest believes the market will be developed very rapidly in Europe as both cable and satellite companies strive to gain market share. The new DVB-digital IRDs have very high semiconductor content of nearly $200 per box. These new boxes are also very memory-intensive with at least 4M DRAM content. The second part of this report will present the semiconductor market forecast for digital IRDs.

In terms of analog IRD manufacturers, many of these will remain the players in the digital IRD market. These manufacturers will require more semiconductor components to satisfy their markets, and many of these manufacturers already have quite substantial orders at hand for 1996 and beyond.

By Mike Williams

For More Information...

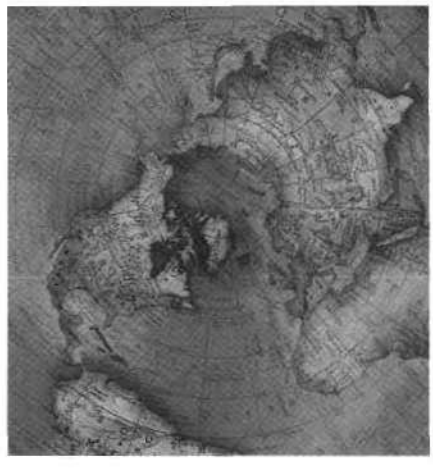
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Semiconductors in Rigid Disk Drives: A Focused Analysis

Focus Report

1995

Program: Semiconductor Application Markets Europe
Product Code: SAMM-EU-FR-9502
Publication Date: October 31, 1995
Filing: Focus Studies

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Market Trends

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Chapter 1
Introduction

The rigid disk drive (RDD) industry is driven by several factors, but technology holds the reins of magnetic storage. Semiconductor devices play a critical role in the rapid increases in capacity and performance. The current industry dynamics are described in four statements:

- Magnetic storage densities increase at 60 percent per year, bringing with them the associated increases in track and linear bit densities, as well as single-platter capacities.
- Semiconductor devices impact both the cost and performance of rigid disk drives.
- Disk drive product life cycles are nine months.
- Disk drive price erosion is 12 percent per quarter.

These factors combine to make the industry one that is exciting to participate in, but that has a high degree of risk associated with every move for OEMs as well as their suppliers.

Disk drives depend more heavily each year on semiconductors and microcode for improvements in recording densities as well as cost reductions. As recently as five years ago, the contribution of the electronics and printed circuit board (PCB) to the cost of a disk drive was only 25 percent. Now that function represents more than 50 percent of the burdened cost of a drive. The increase in percentage does not necessarily represent an increase in cost, but semiconductor prices have not eroded as fast as prices of heads and media.

The increased data-rate pressures on read channel performance, integration of device control and I/O control into single ASICs, and increased use of cache RAM and flash program memory all combine to increase the value of the semiconductors in a typical drive. More and more semiconductor vendors have developed parts and are offering them at competitive prices to an industry with a unit volume growth rate of 18 percent per year through 1999.

This report is intended to give the reader a background in the opportunity offered by serving the rigid disk drive industry and a review of the implementations currently being offered. It includes a perspective from both the disk drive and semiconductor applications views and presents relevant information gathered by a global group of Dataquest analysts. Dataquest's Computer Storage Worldwide group's focus is primarily on information relating to finished products (rigid disk drives), such as unit shipment forecasts and history, pricing, drive density trends, and technology trends. The Semiconductor Application Markets Worldwide group examines technology trends and issues in semiconductor components, with particular emphasis on identifying emerging applications and market trends.

Small form factor RDDs include the 3.5-inch, 2.5-inch and 1.8-inch disk drives. This report focuses on these products and includes an overall snapshot of the state of the mass storage industry and the semiconductor components that are used in their design and manufacture.

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Chapter 2
Disk Drive Industry Review: 1994 and 1995

Summary

The rigid disk drive industry continues to be a nearly unique case study for the business world. No other manufacturing industry has been subjected to the stresses of high-technology hypergrowth and the resulting impact on its participants. The disk drive industry is made up of a sales revenue community with sales struggling to reach $20 billion, with its component suppliers estimated to be about $10 billion. With data recording densities growing at a 60 percent compound annual rate, the products produced have the potential of outstripping the wildest dreams of the computer user. The combination of technological advances in recording heads, disk platters, and specialty semiconductors has positioned the entire industry on a growth path to the stars.

The disk drive market continues to thrive with good backlogs and limited supply because of component shortages. Virtually all of the currently shipping products were announced within the past nine months, and advanced areal densities have resulted in new requirements for head, media and chip vendors, as well as tougher production ramps in the drive factories. Demand is strong at about 20 million drives per quarter, but a slow summer quarter in 1995 and product transitions will tend to keep the annual sales total close to Dataquest's forecast of 80.2 million units for the year.

The year 1995 has been, generally, a successful one for most vendors, with many sales and profit records set. Coming off of a banner growth year, most suppliers were jockeying for position with new products and placed component orders that portended another 35-percent unit volume growth year. Subsequent shortages at the head and media level of supply have combined with unusually difficult production ramp rates to keep the apparent growth rate at 17 percent, as Dataquest had predicted.

This year, there were indications that the summer slowdown began in June, restricting second-quarter sales to 20.9 million units, slightly up from the 20.6 million level of the previous quarter. The distribution channel was crammed with inventory. Continued corporate delays in buying decisions for networked PC upgrades will keep that segment quiet until 1996, so it appears that the year's big growth must come from home PC buyers in the December quarter. The much anticipated Windows 95 operating system from Microsoft will fuel immediate upgrades in memory and hard disks from the retail channel, but the massive replacement system upgrades will hold off until December 1995 and later. Doubtless, 1996 will be a banner year for Pentium computers and disk drives.

Inventories diminished in the first calendar quarter of 1995, but, contrary to "normal" behavior, the gross margins for the disk industry also fell. Usually, these two indicators are linked in the opposite direction. Things went exactly the other way in the June quarter, when gross profits recovered to 17.3 percent of sales and inventories rose from 31.6 percent to 33.5 percent of sales. No matter what the indicators show, the industry has experienced seven straight quarters of strong growth without a major recession, and all factors point to easy completion of a two-year stretch without a major problem.

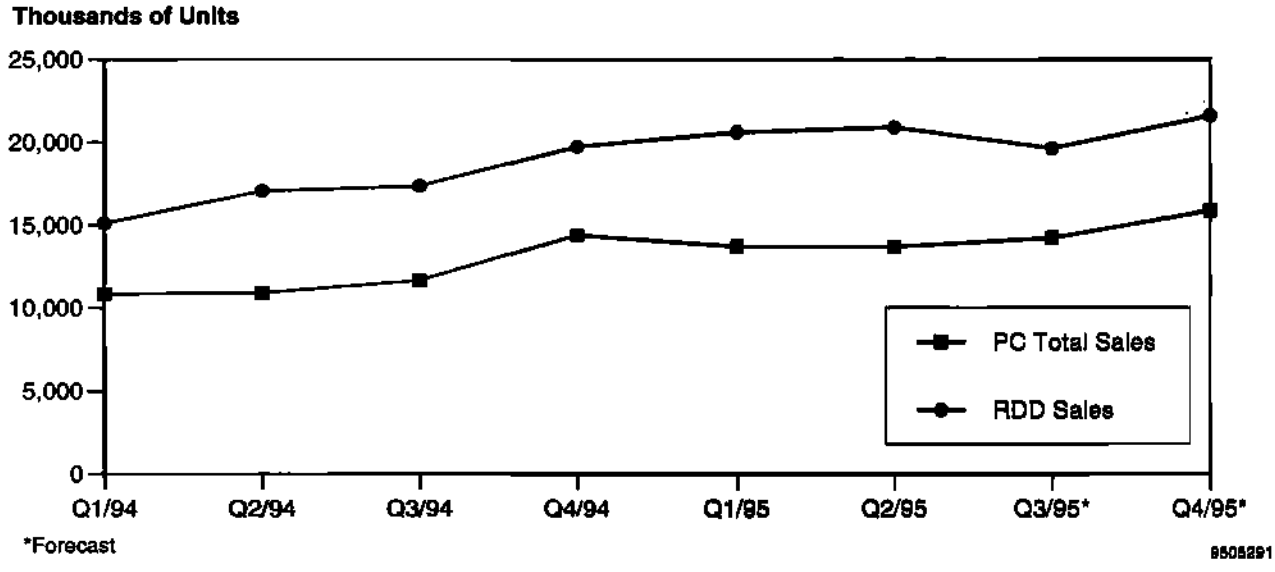
Fuelled by strong orders from PC OEM buyers and a healthy distribution market, disk drive sales continued to grow in the first few weeks of 1995. The quarterly increase was only 4 percent—a far cry from the annualized 35 percent increase in 1994. Total drive sales were 20.6 million units in the first 90 days of 1995, compared with 15.1 million in the same period in 1994. Personal

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computer sales sagged somewhat with a 5 percent decrease from December's sales. Both PC and drive sales were constant in unit volumes between the first two quarters of 1995. Figure 2-1 shows quarterly sales of disk drives and PCs for 1994 and 1995.

Products sold in the first half of the year showed a fast increase in popular technology. Companies like Quantum that have large PC customers and that tend to offer lower-capacity, entry-level products found that their average capacity shipped in 1994 was under 300MB. In 1995, this entry-level range began over 400MB and will wrap up the year at about 850MB on the average. Table 2-1 shows the average capacities of all disk products shipped, reported by each of the suppliers to the entry-level market.

Figure 2-1
Worldwide Quarterly PC and RDD Sales



Source: Dataquest (October 1995 Estimates)

Table 2-1
Average Capacity Shipped Worldwide per Quarter (Megabytes)

Company	First Quarter 1994	Second Quarter 1994	Third Quarter 1994	Fourth Quarter 1994	First Quarter 1995	Second Quarter 1995
Quantum	240	270	270	270	450	560
Maxtor	240	300	356	428	547	664
Conner	250	340	400	470	540	645
Western Digital	300	330	418	500	623	595

Source: Dataquest (October 1995 Estimates)

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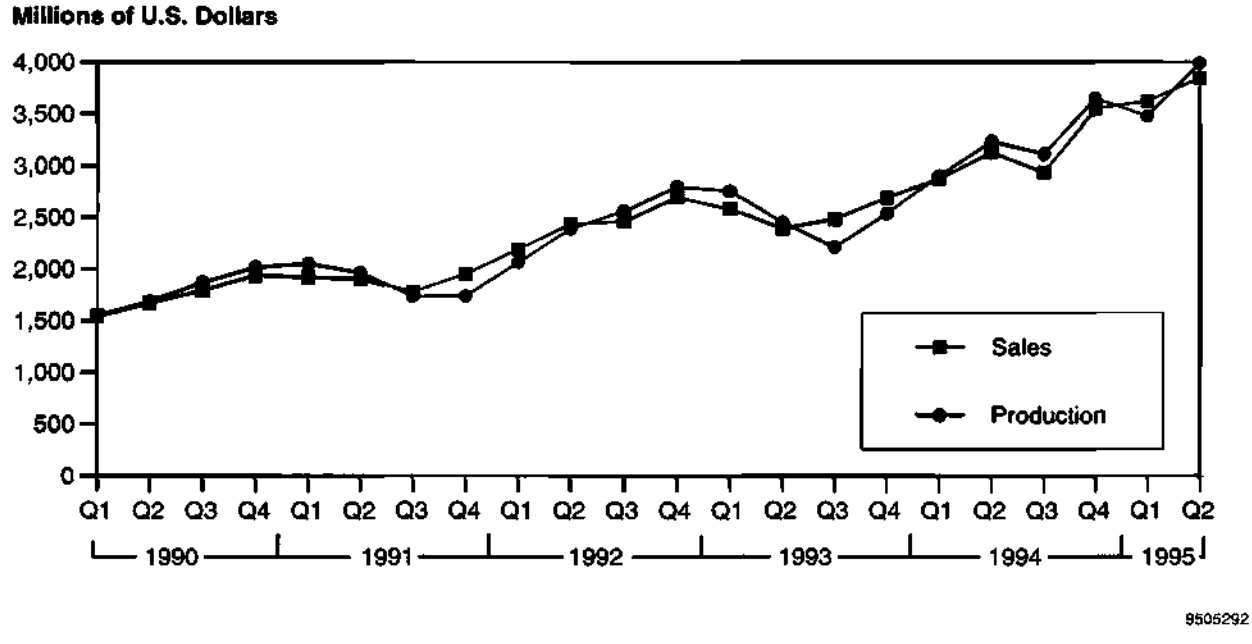
Performance by Company

Sales of disk drives by the top suppliers continued to grow and inventories were kept to a minimum, mostly as a result of component shortages. Dataquest tracks the key public companies (Conner, Maxtor, Micropolis, Quantum, Seagate and Western Digital) and presents information quarterly on sales and production status. The production figure is simply the sales revenue adjusted by the quarterly change in inventory. Figure 2-2 presents these results for the total group.

The figure shows good progress and exceptional control of inventory and production rates since the last major overproduction period in 1993. At the end of June 1995, the inventories climbed somewhat, and an industry tempering of production schedules is expected for the third quarter, ending in September. If production rates are driven hard during this period, there is likely to be the beginning of another glut.

There are strong indications, however, that disk drive producers are tempering their production plans, partly because of a more conservative approach to business, but mostly because of transitions from profitless 425MB and 540MB product lines to new product groups. A reluctance to build large quantities of two-platter 630MB and 850MB drives is developing, and these strategic moves may find the industry with a shortage of deliverable products just as the Christmas rush begins.

Figure 2-2
RDD Industry Quarterly Worldwide Sales and Production



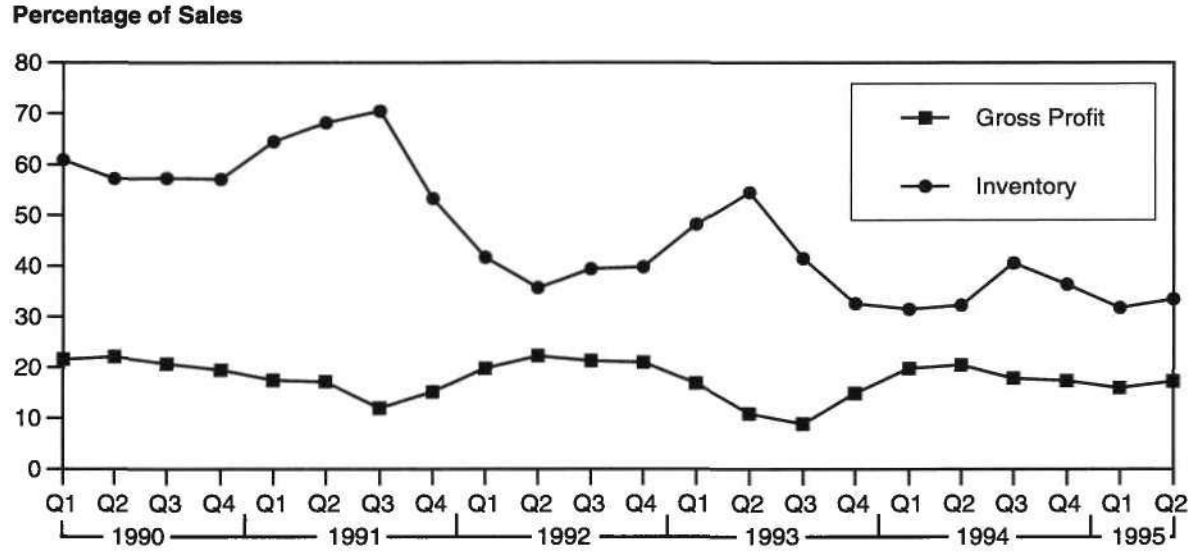
Source: Dataquest (October 1995 Estimates)

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Profitability and Prices

The name of the game is profitability, and the disk drive industry is finding profits elusive. Figure 2-3 shows the effect of inventory levels in the industry and the gross profit resulting from doing business at these levels.

Figure 2-3
Rigid Disk Drive Industry Worldwide Inventory and Gross Profit



Source: Dataquest (October 1995 Estimates)

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Chapter 3
Disk Drive Technology Review

Overview

Magnetic recording technology continues to be a major driving force in the rigid disk drive industry. With a goal of increasing areal density (amount of information per square inch of media) 60 percent per year, drive makers are pressed to the wall to purchase or develop components that will facilitate such an aggressive product schedule. This race, when coupled with what seem to be preordained price points for one- and two-platter disk drives, regardless of capacity, shrinks product life cycles to periods of nine months or less.

Dataquest believes that the requirement for increasingly higher recording densities could force companies into a position within the next two years where it will be impossible to produce high-yielding products to meet the growth curve, resulting in a lengthening of product cycles, a shortage of products, and a return to stability in pricing. This unusual situation would stem from the industry's inability to produce massive quantities of magnetoresistive (MR) heads or the disk drives that use them.

Generally, the 3.5-inch disk drive market is expanding at a record pace, segmenting into desktop PC products and high-performance server-class drives. It is likely that 1995 will be the last year when companies can make low-cost drives using metal-in-gap (MIG) ferrite inductive heads. The next salvation for these products is the thin-film inductive heads used in proximity recording, skimming to near-contact with the disk surface. MR heads are still pretty much IBM's domain, with Fujitsu and Hitachi also manufacturing production quantities of disk drives using this technology. Most vendors have announced or will announce MR-based products by the end of 1995, but there will be insufficient heads available from any source to allow mass production until 1997.

The 2.5-inch products now available are mostly based on glass substrate media, and IBM has successfully produced industry-leading quantities of drives using MR heads. These little drives are quickly moving into the gigabyte range, but pricing has squeezed most of the profit out of the industry. The price at which 1.8-inch drives can be manufactured is not low enough to convince mobile computer users to buy them, and the technology attributable to this market segment has been moving at a snail's pace.

What's Real?

Table 3-1 lists the areal densities and single-platter capacities that were actually shipping in high volumes at the time this document was prepared. Figure 3-1 illustrates Dataquest's estimates of single-platter capacities that will ship in volume over time, by diameter.

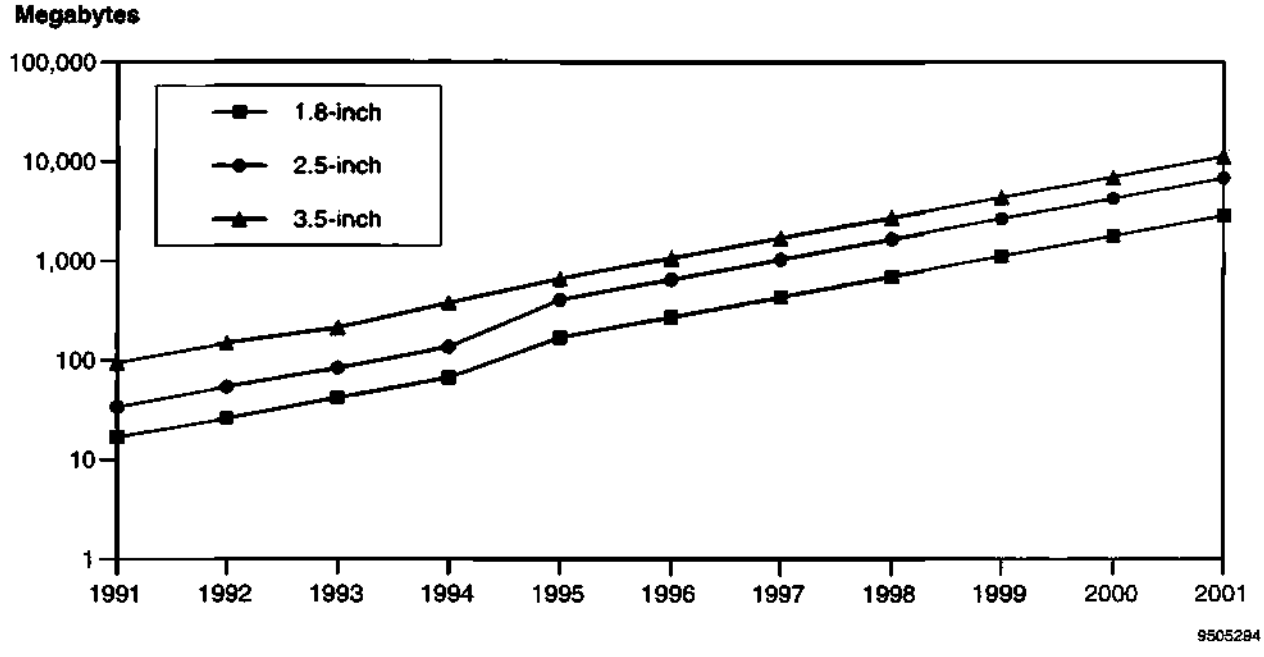
Table 3-1
Current Technology Levels

	Platter Capacity (MB)	Maximum Drive Capacity (MB)	Areal Density (Mb/Sq. In.)	Technology Notes
1.8-inch	170	341	630	Smooth metal media, PRML
2.5-inch	405	1,215	700	MR heads, glass media
3.5-inch	850	4,300	663	MR heads

Source: Dataquest (October 1995 Estimates)

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Figure 3-1
Single-Platter Capacity Worldwide Forecast



Source: Dataquest (October 1995 Estimates)

Current Products

For a list of all of the disk drives in production (or announced for production) in mid-1995, see appendix A. The complete specifications for the drives are included and the list is sorted by company, drive diameter, and capacity. Since the product cycles are so short, it is difficult to predict how long this list will remain current, but it certainly is a snapshot in time of the drive industry.

1.8-inch RDD

Once again, the 1.8-inch market failed to live up to market projections. For 1994 and 1995, the market remains at about 300,000 units, with little hope for an immediate boost. As the anticipated market dwindled, so did the number of producers and the new product announcements.

The current technology upon which leading products are based is either glass or smooth metal media with inductive thin-film heads. The highest areal density, 630Mb per square inch on the Integral Peripherals Viper 340 drive, is a two-platter product. The track density is listed at 5,100 TPI and the linear bit density is 123,600 BPI. Flying height of the ramp-loaded heads is 1.8 microinches. Ramp loading prevents the heads from landing on the polished media. The read channel uses an advanced partial-response, maximum likelihood (PRML) chip to boost the bit density. These drives seek at 12ms on the average and have a rotational rate of 4,500 rpm. The highest internal data rate is 6 MB/sec and the best power rating is 2.1W maximum for read and write operations.

The single-platter capacity of this form factor sits at 170MB and has not risen to the anticipated 200MB level predicted for the type II PCMCIA card drives. Maxtor announced a type II drive series called the MobileMax Lite with 85MB per platter, but the products were shelved until some future date. Dataquest expects announcements of an increase in the single-platter drives to 200MB at

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COMDEX in November 1995. All products to be announced in 1995 and 1996 will be type III drives.

Shock sensors are critical in these products and are found in all drives. Write gate is turned off and the heads are retracted upon shock, or upon increased g-forces. This action prevents off-track data "smear" and head slap on the media.

Dataquest believes that MR head technology will be introduced in this form factor in 1997. Proximity recording and PRML channels will provide continued density improvements. Most of the 1.8-inch products sold today use the PCMCIA interface, with only a few of the old IDE-interfaced products being made to finish up aging orders.

2.5-Inch RDD

The 2.5-inch market has finally moved into an area of interest for most of the industry, but lack of profitability still plagues most of the suppliers. IBM and Toshiba continue to be major market share holders, but others are gaining steam.

IBM is the technology leader with its Travelstar 1.2GB product, offering the highest areal density at 700Mb per square inch. The track density is 6,350 tpi and the linear bit density is 110,300 bpi through the use of MR heads. The single-platter capacity of these drives is 405MB, and the largest is a three-platter, 17-mm-high product.

Maxtor announced a 1.34GB, four-platter drive in the 12.5-mm format, using thin-film inductive heads and 1,900-oersted media to achieve an areal density of 468Mb per square inch. Maxtor's 2.5-inch offerings leverage heavily off of the MobileMax 1.8-inch technology and have only seven chips on a tiny, one-third-size board. The shock sensor protection is also carried over. Maxtor's peak-detect read channel keeps the maximum power usage down to 1.7W in the active mode.

Toshiba continues to use glass-based media to achieve its high densities. The largest Toshiba drive is a five-platter product with 1.35GB in a 19-mm-high drive. Toshiba's areal density is not available.

The market for these drives is still demanding the highest capacity, the lowest form factor, and the most power-efficient operation. Often confusing these drives with the higher-volume 3.5-inch products, buyers have forced their prices down rapidly, compounding the profitability issues. This fact keeps most vendors away from the form factor. Dataquest's history and forecast of mobile computer shipments tracks the sales of 2.5-inch drives precisely, indicating that there is not much use for these drives outside of notebook and laptop PCs.

Dataquest continues to forecast that, as read channel rates soar toward 200 Mbit/s, the high-performance 3.5-inch drive designers will find it difficult to procure inexpensive integrated circuits that will operate in that range. Instead of yielding to the temptation to slow the drive spin rate to accommodate available parts, designers will move the performance drive platform to the smaller circumference of the 2.5-inch drives. Dataquest believes that 2.5-inch drive rotational rates of 12,000 to 14,000 rpm will arrive in 1997 and that these products will be welcomed into high I/O disk array configurations. At that time, single-platter capacities will be approaching 1GB.

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The primary interface for 2.5-inch drives is the IDE connection, with SCSI-interface products diminishing in demand. As the performance products come on the market, it will be necessary to once again produce SCSI drives but, in 1997, the parallel SCSI interface will have given way to one or more of the serial interface standards. The Serial Storage Architecture (SSA) and Fibre Channel-Arbitrated Loop (FC/AL) interfaces will be of particular use in the small dimensions of the 2.5-inch drives, since their connection takes substantially less real estate on the drive than parallel SCSI. These serial interfaces also offer much higher channel data rates.

There is a unique form factor that has cropped up in 1994 to 1995. Kalok has been re-formed under the corporate name JTS, and the clever designers have come up with a 3-inch-diameter disk drive that is targeted directly at the 2.5-inch notebook market. This somewhat larger diameter provides for more storage capacity per platter than the 2.5-inch but is configured as a two-platter, 10.5-mm-high drive with nominal dimensions of 10 × 90 × 120 mm. This product will be assembled at Xyratex in Havant, United Kingdom, using components manufactured by JTS in India. The capacity of the initial drives is believed to be 650MB, with a quick movement upward to 850MB. Offering a lower cost per megabyte, the JTS drives should give the 2.5-inch producers a run for their money. Production was planned to begin late in the third quarter of 1995.

3.5-inch RDD

This form factor continues to set records for sales and growth, with no end in sight; 3.5-inch disk drives are now in use all over the world in applications that range from beginner's desktop systems to the largest of mainframes and supercomputers. The advent of disk array subsystems has caused this low-cost solution to be the product of choice by IBM in its RAMAC arrays and by all of the plug-compatible manufacturers (PCM) in their mainframe solutions.

The pain inherent in achieving an overall capacity growth rate of 60 percent per year in disk technology is felt deeply by the design engineers of 3.5-inch drives. IBM's record-setting areal densities are meeting these goals, and the rest of the industry continues to meet or exceed this growth rate by using smaller inductive heads that fly closer to higher coercivity media.

The current champion in areal density is, naturally, IBM through the use of MR heads, PRML read channels, and headerless sector format. The highest density in a volume production product in August 1995 was the IBM DJAA 31210 and 31700 series of drives with 1.2GB and 1.7GB capacities. This family has an areal density of 663Mb per square inch and a single platter capacity of 850MB, with a rotational rate of 4,500 rpm. These particular drives use peak-detect read channels and MR heads and are aimed at the desktop market. IBM's DCMS-310800 and DCHS-38700 drives have been discussed in a technology announcement and are scheduled for delivery late in 1995. Their areal density is expected to be 793Mb per square inch with storage capacities of 10.8GB (5,400 rpm) and 8.7GB (7,200 rpm).

Hewlett-Packard, Quantum, Seagate and Hitachi have all announced drives with areal densities over 420Mb per square inch that are scheduled for production later in 1995 or early in 1996. All of these products use MR heads, and most products have experienced protracted delays in their schedules.

IBM's advanced drives have the highest per-platter capacity, with an expected record 1,080MB in 1995. The highest platter capacity shipping in August 1995 was the same drive with the highest areal density, the IBM DJAA series at 850MB. The highest non-MR product was Quantum's Fireball 1.09GB drive with 545MB per platter. Maxtor's 1.08GB and 1.6GB drives and Seagate's

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Medalist drives were next at 542MB per platter. Western Digital was the first to ship 540MB-per-platter drives, with early deliveries in April 1995. There is some question as to what the next platter capacity will be. Conner Peripherals is pointing toward the 635MB point by offering a two-platter, three-head drive at that capacity. Others have made 730MB a two-platter point, and still others believe that 850MB per platter will be the next big step in products.

The 1-inch-thick form factor has become a popular standard in the desktop and in some disk array subsystems. Seagate is the only 3.5-inch manufacturer to offer a smaller size, with the Decathlon 545MB, 850MB, and 1080MB drives sized at 0.75 inches thick. Seagate is the only supplier to have crammed six platters into a 1-inch-high drive on its Barracuda 2LP. Giving up a top platter head to accomplish this feat, the drive offers 2.147GB in this form factor. The highest capacity 1-inch drive shipping is the IBM DFMS-32600 with 2.66GB capacity, at 5,400 rpm. Dataquest expects to see limited volumes of 1-inch-high drives with 4GB capacities by the end of 1995.

The 3.5-inch industry has been segmented into desktop and performance products, with rotational rates the primary differentiator. Conner offers the highest-capacity 3,600 rpm product at 1.6GB and the leader in the 4,500-rpm class is IBM with its DJAA series. The 5,400-rpm performance level is the beginning of the performance-class products, but Seagate and Western Digital are moving their low-end drives up to that low latency level for product differentiation. The lowest-capacity 5,400-rpm product is 540MB. The 7,200-rpm rate is the fastest now shipped, with Quantum's Atlas 1GB drive being the smallest capacity offered in this class.

The highest-performance, high-capacity IDE drive is Seagate's 2.16GB Medalist at 5,400 rpm. There are few SCSI drives available with performance levels below 4,500 rpm, and most are in the 5,400 and 7,200 class. Most of the high-performance, high-capacity drives will be available with serial interfaces (SSA or FC/AL) in the near future.

5.25-inch RDD

The high-end server and array market still loves the high capacity attainable from the 5.25-inch form factor. The Seagate Elite 9 and the Micropolis 1991 drives at 9.1GB are the highest-density products around. Shipment of 18GB to 20GB drives is expected in 1996.

Even while we have been believing that this form factor is dead, several companies have been developing low-cost, high-capacity 5.25-inch products for the consumer market. With its 675MB per platter capacities using low-cost (non-MR) technology, the dollar per megabyte prices can be very attractive. Dataquest believes that at least three vendors will announce low-cost 5.25-inch drives for desktop use before the end of 1995. The popularity of these drives will be short-lived as the prices of high-capacity 3.5-inch drives continue to plummet, but it is a clever idea to satisfy user needs.

SMART

Self-monitoring analysis and reporting technology (SMART) is a new feature making its way into rigid disk drives. SMART drives continually monitor various parameters within the drive to predict imminent failure. These drives communicate the likelihood of failure to the host computer. When drive failure becomes likely, the system administrator can back up the disk, replace it, and restore all of the information. This allows the drive to be replaced with minimal impact on the system and users. For drives in a RAID system, data can always be reconstructed, but that is more time-consuming than replacement before failure.

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The greatest caveat with SMART for drive manufacturers is false reporting. For notification to be useful, hours of notice are preferable to minutes, but drive OEMs do not want to replace more drives than necessary. A scenario where drives report failure when failure is not imminent will merely result in more returned drives and higher warranty costs. From the user side, nobody wants to replace drives unnecessarily, but most would rather err on the side of more frequent replacements rather than face greater chances of data loss.

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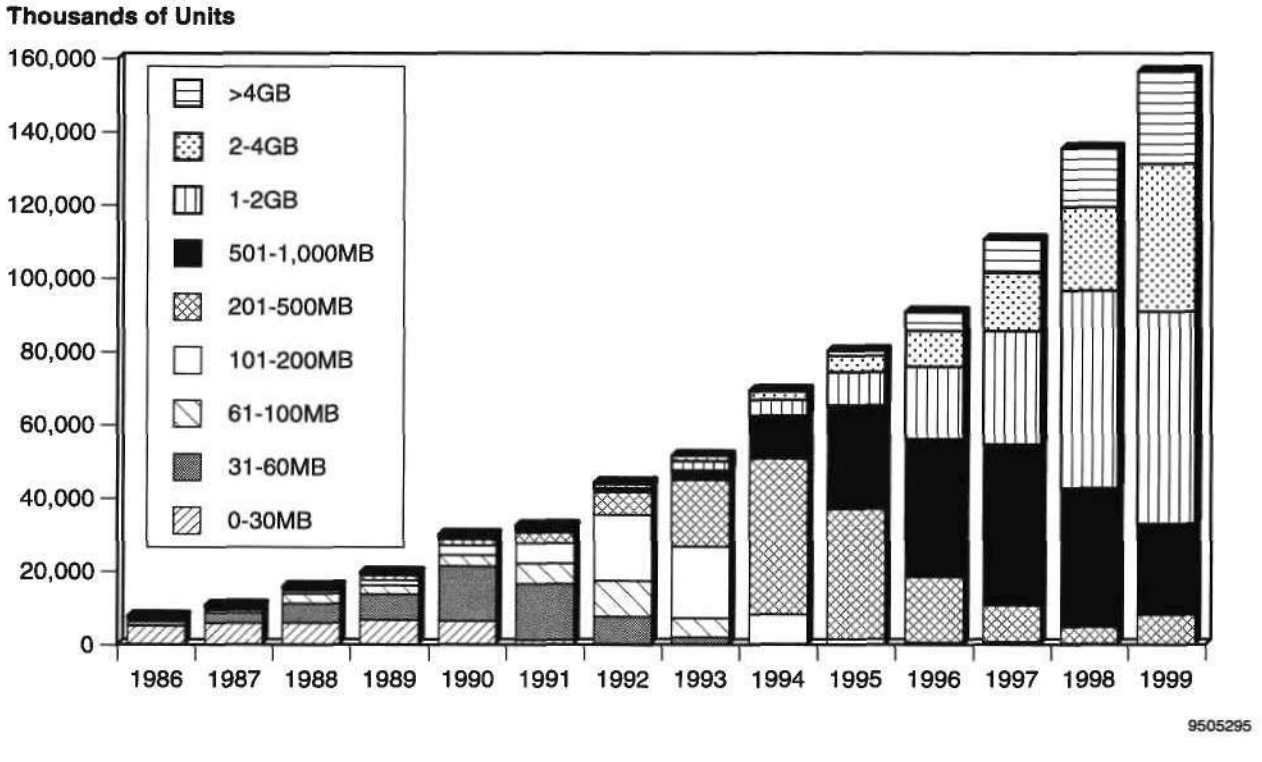
Chapter 4
Opportunities in the Rigid Disk Drive Market

Rigid disk drives continue to be the focus of attention from all segments of the computer industry because of their growing importance in system configurations and application futures. The rapid technology growth of 60 percent per year appears to be continuing and is a driving force in shortening product life cycles and lowering cost per megabyte.

The products themselves are becoming more difficult to design and build as the technology race heats up, and it is likely that technology itself may be the limiting factor in the rates of change. The inability of drive engineers and operations managers to put products into manufacturing on a nine-month cycle is becoming evident. The component suppliers are also hard-pressed to provide large enough quantities of heads, media, motors and read channel components to meet the performance and delivery demands of the advanced drive designs. This chapter outlines the unit volumes and special configuration requirements that would be of special interest to semiconductor suppliers.

While it is easy to be optimistic about the growth in unit volumes going forward, caution must be exercised in becoming too bullish about the capabilities of the industry. On the plus side, a slowdown in product cycles may be sufficient to slow the price decay curve, and profits for the industry may regain a level of respectability. The unit volume forecast for all rigid disk drives is shown in Figure 4-1, broken down by capacity ranges. It is clear from this figure that the only capacity segments of disk drives that are projected for growth are those over 1GB.

Figure 4-1
Worldwide Rigid Disk Drive Forecast by Capacity



Source: Dataquest (October 1995 Estimates)

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1.8-Inch Drives

This form factor has been around since 1991, but system requirements are once again delayed and sales volumes of the 1.8-inch drives have been small. The product has been available in two configurations: AT/IDE interfaced, and PCMCIA type III interfaced. In 1994, 92.7 percent of these drives sold were PCMCIA and the rest had IDE or proprietary interfaces. In 1995, nearly 100 percent of all drives are PCMCIA. Capacities of recently announced products have ranged from 170MB to 341MB, with the largest number of shipments in the 170MB range.

The market for these little drives is still believed to be substantial, but the cost per megabyte of this form factor is four times greater than that of 3.5-inch products, and buyers simply will not tolerate this expense. The 2.5-inch form factor has satisfied the needs of the mobile computer user, and removability is accomplished by some companies by simply encapsulating the entire 2.5-inch drive for easy replacement.

MiniStor was a 1994 casualty of the slowness of the market, filing for bankruptcy and eventually liquidating its assets. MiniStor was the first major client for the ZIA disk drive products. ZIA was the joint effort among Zilog, IMP and Allegro to provide a complete electronics solution for use in small disk drives. Maxtor Corporation quietly stopped producing its MobileMax drives but continues to sell off its inventory.

Integral Peripherals and Calluna are the only vendors still in production of 1.8-inch disk drives. Integral has found a market in supplying drives to Japanese PC makers that build pen-based computers for vertical markets. These systems are usually oriented to corporations or service companies needing manual inventory, patient record keeping, and delivery records, among others. Orders for this type of system come in spurts of tens of thousands of units, and suppliers of components for the little PCs are not given much lead time or visibility for future business.

Integral Peripherals was the first of the drive makers to develop a multichip module that was to be used in its advanced 1.8-inch products. This approach, while attractive because of its low profile and small area requirements, was put on the shelf early in 1995 because of its high cost. Technological advances that increase the product cost of 1.8-inch disk drives cannot be tolerated during this phase in the life cycle of the form factor.

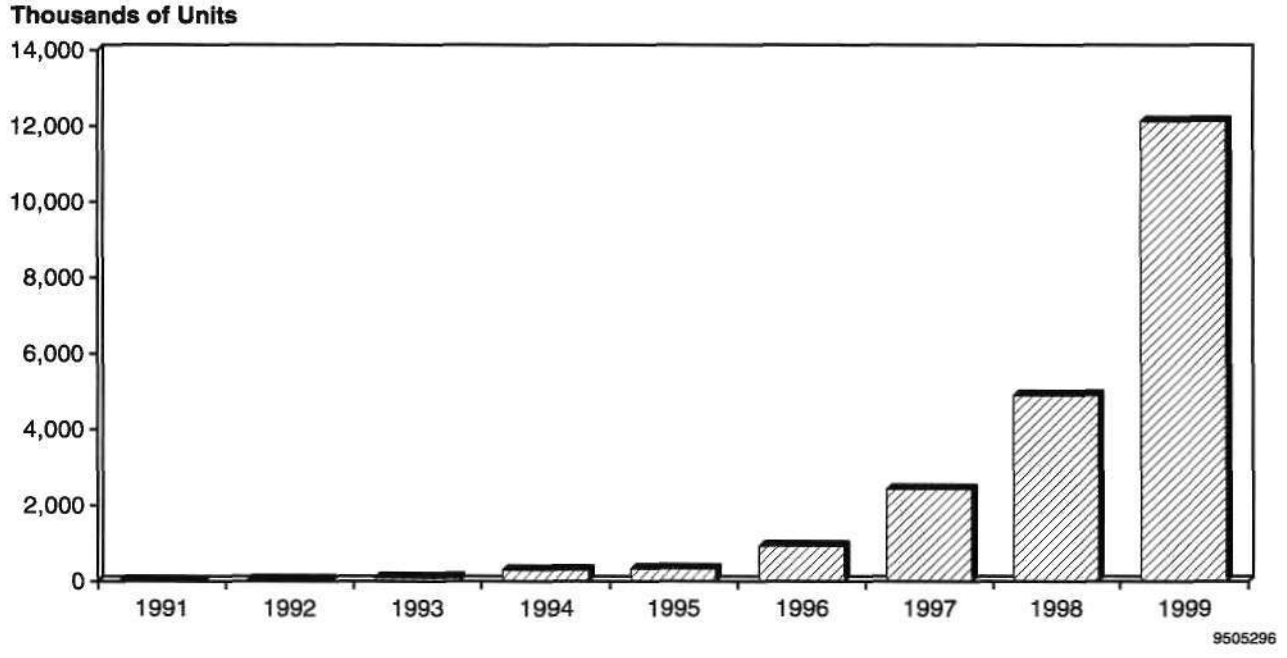
Forecast Discussion

Figure 4-2 shows Dataquest's 1.8-inch RDD forecast. This segment of the market is the most difficult to forecast because of the lack of a clear target market. It is likely that the 2.5-inch disk drives will someday take on greater use on the desktop and in server arrays. It is that migration path that will enable the market for smaller disk drives.

Dataquest has observed that users of removable cartridge disk drives normally purchase seven packs in the life of the drive. There is not likely to be such a correlation with PCMCIA products, but buyers will probably purchase more than one product. The sales of 1.8-inch drives in 1996 are expect to be just under a million units, worldwide—still not a very attractive market. The promise of use in digital cameras, mobile data collection and font cartridges continues to be no more than a dream, since the price of the tiny drives still represents a very large percentage of the purchase price of the products they are intended to support.

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Figure 4-2
Worldwide 1.8-inch Rigid Disk Drive Forecast



Source: Dataquest (October 1995 Estimates)

The highest-volume capacity in 1995 will be the 170MB-class products, with the 260MB drives right on their heels. Some 340MB products will ship, and higher capacities will be announced. The single-platter capacity of the drives could be as high as 200MB in 1996 through the use of MR heads.

Since the form factor is reasonably new, prices will not fall as dramatically as those of the more mature drives, but the OEM price per megabyte on the average of all 1.8-inch products is anticipated to drop by 25 percent per year for the next five years, and the end-user price per megabyte will fall at 24 percent per year, compounded. Unit volumes could reach 12 million units by 1999.

Advances in multichip modules, further integration of functions, smaller motors, and lower-cost components all around will be required to make this forecast come true. Here is a real opportunity for a forward-thinking component supplier to forge a position in a coming market.

2.5-inch Drives

In 1995, this form factor will reach the magical 10 million unit sales mark, turning the 2.5-inch disk drive into an interesting high-volume product. IBM and Toshiba are pushing hard to lead the industry, while Seagate and Quantum appear to be discouraged about their portion of the market. Hitachi has entered the market after initial designs contracted through MiniStor and has developed a very respectable line of 2.5-inch drives on its own. Maxtor's recent entry into this segment brings the total number of producers to 10. This high number of competitors may be the reason for discouraging results from all but the top three producers.

IBM's leadership position was attained swiftly, with contracts in place from all of the major portable computer makers. The form factor seems well suited for IBM's product and process, with never a rumor of bad performance or quality.

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Toshiba's second position reflects considerable use in its captive market, but also good acceptance from competing notebook makers.

The most recent news is that JTS and Western Digital have entered a thin 3-inch drive into the portable market to compete directly against the 2.5-inch drives. With 50 percent more capacity on a single platter and a slim, 10.5 mm thickness, the low-cost JTS drive has found considerable interest from Compaq and several other major portable suppliers as a 2.5-inch replacement. Lower cost per megabyte and higher ultimate capacity are the selling points. Production is just beginning at Xyratex in the United Kingdom, with components being assembled in India. Once the drive's durability is established, we can determine whether this product will further dilute the 2.5-inch market. The JTS drive uses the technology developed at Kalok for Point Five drives. All of the electronics are inside the head disk assembly (HDA) on a triangular board that fits in one corner of the enclosure. The high level of integration and simplicity of the system have allowed JTS to continue this process in order to provide a drive with such a thin profile. Other disk drive makers are candidates for such improvements, especially the 2.5-inch drives. A lower profile could be achieved on multiplatter drives, allowing a higher capacity for a given z-height.

Large volumes of 2.5-inch drives were built in 1991, slowing the requirement for new production in early 1992. The most important indicator of the instability of this market was the fact that Conner Peripherals sold fewer 2.5-inch drives in 1993 than in 1992 or 1991, when it led the market. Conner's share of this market fell from 55 percent in 1991 to 35 percent in 1992, 18.3 percent in 1993, and 4.4 percent in 1994. IBM surprised the industry by taking the top market share position in 1994 (26.2 percent), and it continues to expand its lead over Toshiba and Seagate.

Toshiba continues as a technology innovator in this segment, but has had difficulty making solid profit in the face of IBM's competition and the strong yen. Toshiba's share was 13.5 percent in 1992, 19.3 percent in 1993, and 23.6 percent in 1994.

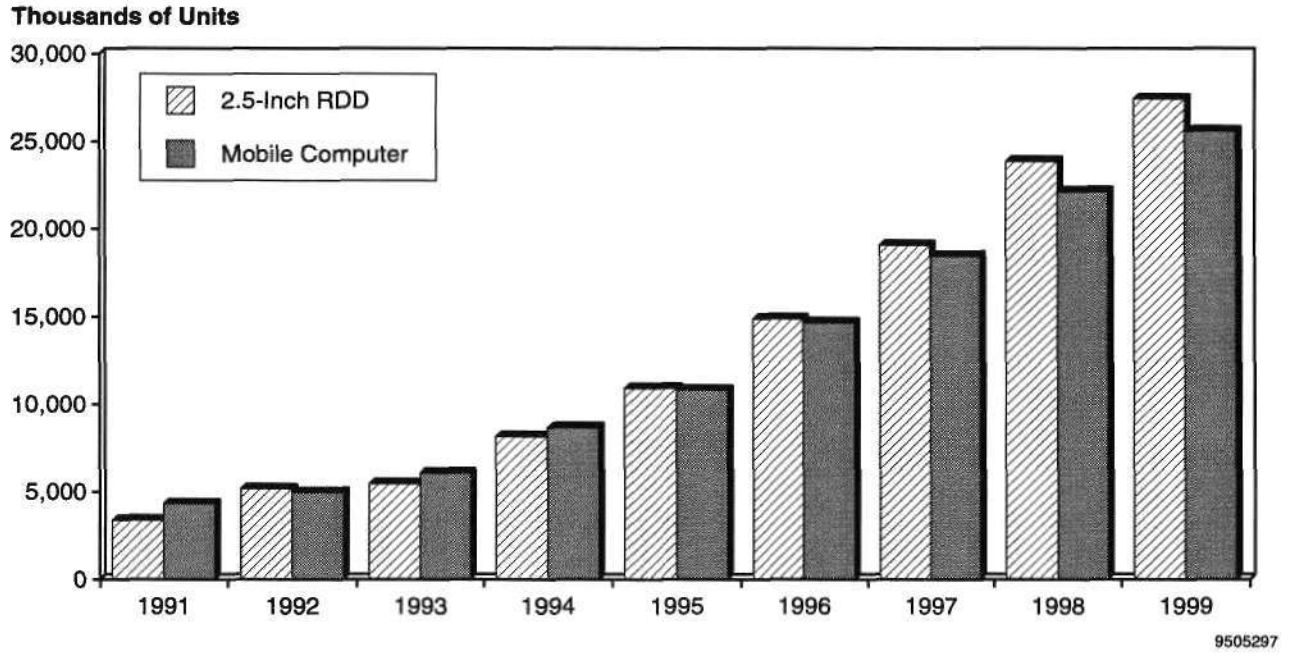
Thin-film heads are required in 2.5-inch drives with capacities over 100MB. Since applications are primarily in mobile computing, drive size, weight and power consumption specifications are critical. A 12.5 mm thickness is attainable on two-platter drives and seems to be popular with OEM buyers. Weights range between 4 ounces and 6 ounces for one- and two-platter drives. Power consumption depends on power management ICs and firmware designs, along with low-power-consuming motors. Spin-up times and power consumption curves vary by vendor.

Forecast Discussion

The 2.5-inch market is considered to be centered on the notebook and laptop mobile computer market. So far, there has been little or no interest in using 2.5-inch products on the desktop, but that may change in 1997 as 3.5-inch drives hit a performance limitation. Dataquest believes that the 2.5-inch disk drive will be the performance platform of the future, with models spinning as fast as 10,000 to 14,000 rpm. The 3.5-inch disk drives will reach 200-Mbit/s read channel data rates at linear bit densities of 170 bits per inch (bpi) and 7,200 rpm rotational rates, and the smaller circumference of the 2.5-inch disk drive may be just the solution for low-cost CMOS read channel parts. If this is the case, 2.5-inch drives could well become the drive of preference in disk arrays for transaction-based based systems in 1997.

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Figure 4-3
Worldwide 2.5-inch Rigid Disk Drive Forecast



Source: Dataquest (October 1995)

Figure 4-3 shows the Dataquest forecasts for 2.5-inch disk drives as well as their available market from the total of notebook and laptop computers. Historically, the 2.5-inch products have followed the mobile PC curve, and Dataquest's forecast for these drives through 1996 continues to follow the same curve.

The deviation from predicted mobile PC numbers that is seen in 1997 and 1998 is the result of speculation by many disk drive designers that the 3.5-inch areal densities will be excessive starting in 1997. At that time, it will be difficult to handle the internal data rates of 3.5-inch products, and 2.5-inch drives are thought to be the potential solution to the problem. The 2.5-inch products used in desktop or server applications will likely be SCSI-interfaced, with the SSA or FC/AL interfaces the likely best solution because of their small connector requirements.

Dataquest forecasts that the 810MB segment will dominate sales in 1996, with shipments of 7.5 million units. The 1998 popular point will be about 2GB, with 12.5 million units shipping in that capacity band. Prices are expected to fall by 36 percent per year for total OEM dollars per megabyte and by 38 percent to the end user.

3.5-inch Drives

Still the most popular disk drive in the world, the 3.5-inch form factor grew by 34 percent in 1994 to a total of 59.5 million units and a factory revenue of $12.5 billion. In 1993, total unit sales were 44.4 million units, worth $11 billion to manufacturers. The compound annual growth rate (CAGR) from 1995 to 1999 is predicted to be 14.2 percent in unit volumes and 9.55 percent in factory revenue. The slower revenue growth is because of continued price declines and rapid increases in recording densities in single- and dual-platter configurations.

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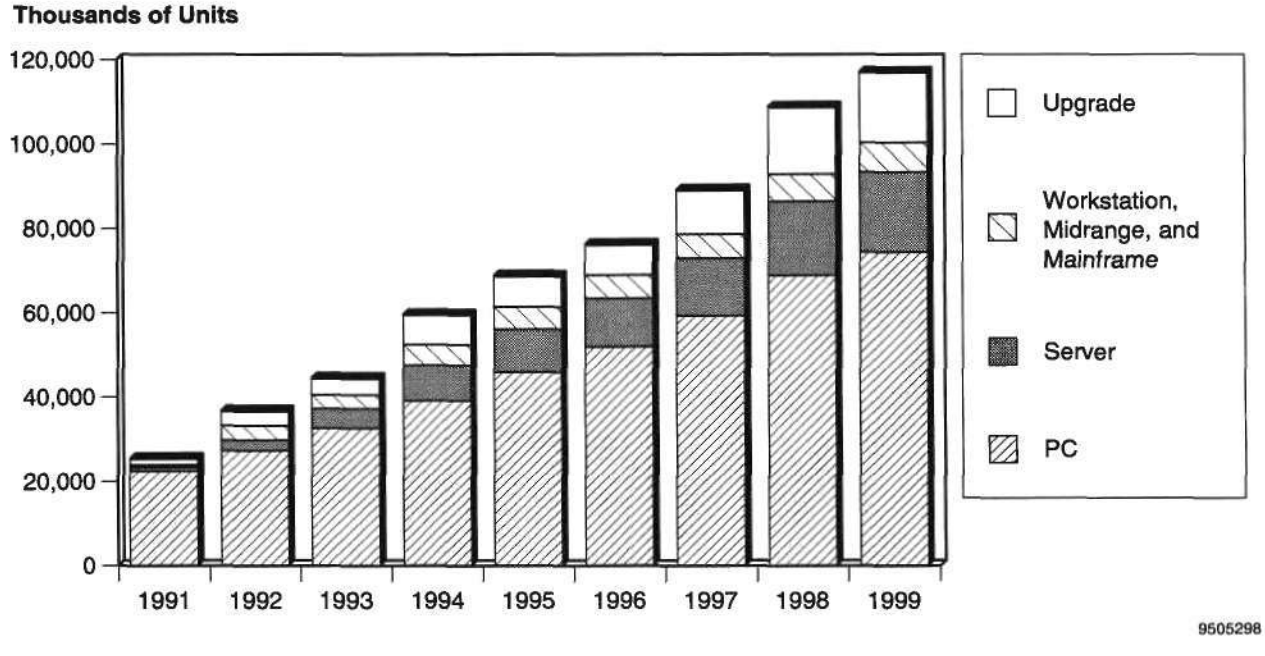
Positioned as the primary storage device of choice in desktop and midrange computers, the 3.5-inch drives are secure in their markets and have now become the drive of choice in large-scale DASD array applications. IBM's RAMAC disk array for mainframe computers uses 3.5-inch Allicat disk drives, and the RAMAC II is an array of StarFire drives. The 3.5-inch forecast is shown in Figure 4-4. The bars in the graph are segmented by the application area of use for the drives, with personal computers in one segment; all servers in another; workstation, midrange, and mainframe use in another; and the upgrade market in the last.

IBM is the technology leader in 3.5-inch products, offering a 5.25GB, eight-platter drive with 561 million bits per square inch areal density (compared with last year's 354 million bits per square inch). All of IBM's drives use advanced-generation MR heads and PRML channels to attain these densities.

The gigabyte market for 3.5-inch drives was dominated by industry captive producers in 1992, with IBM, Digital Equipment and Hewlett-Packard winning most of the major OEM business. Dataquest believes that 438,300 of these drives were sold in 1992, 2.7 million drives with capacities over 1GB were sold in 1993, and 5.8 million were sold in 1994. The market shares of the producers in this segment have changed dramatically from 1992. Digital Equipment's drive unit was acquired by Quantum, but neither has kept up the torrid pace of Seagate and IBM, the leading producers of drives over 1GB. In 1994, Seagate and IBM shipped almost the same number of products in this segment, ending the year with just under 2 million units per company, tied at 33 percent share each.

By the middle of 1993, the most popular 3.5-inch drive was the 170MB product, and a year later in 1994 the 270MB, single-platter drives were clear winners. In midyear 1995, the hottest product is 540MB, moving quickly to 625MB. By Christmas, the 850MB capacity will peak and we will enter the new year with 1GB drives as the entry-level capacity for personal computers.

Figure 4-4
Worldwide 3.5-inch Rigid Disk Drive Forecast by Market Segment



Source: Dataquest (October 1995 Estimates)

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The slim 1-inch-high drives are becoming the industry standard, with half-height 1.625-inch drives needed only for multigigabyte capacities. There is no doubt that the 1-inch format is the long-term standard for the 3.5-inch market.

Forecast Discussion

The 3.5-inch market is vigorous and still growing through the rest of the decade. The drive makers have increased capacity of all diameters to a total of more than 7.8 million drives a month, but caution is being exercised and the actual output in 1995 is about 6.9 million per month. Dataquest believes that about 70 million 3.5-inch drives will be sold in 1995.

With the dollar per megabyte prices for OEMs and end users falling at 32 percent per year for the next five years, Dataquest is forecasting that the average 3.5-inch drive will cost $0.05 per megabyte in 1999. The average capacity of these drives will reach 3.2GB in the same year.

The big trouble in 1995 is the product transition from 540MB per platter to 625MB or 850MB per platter as the areal density battles continue. The 425MB and 540MB drives have little or no profit left in them and will be brought to a swift end of life, even though there is still strong demand for 540MB in all channels. Premature price erosion will make this product transition more difficult than normal, since there will be few products to sell.

5.25-inch Drives

Sales of 5.25-inch RDD products in 1994 fell to only one-third of the 1993 level. There is little indication that the form factor will be triggered into new life even though Quantum and BMI will be introducing new, low-cost 5.25-inch desktop products at COMDEX 1995. This approach to competing with the 3.5-inch products at a cheaper dollar-per-megabyte level will not continue to be attractive when the 2GB and greater 3.5-inch drives become more available in 1996.

Only 484,000 units sold in 1994, and Dataquest expects that 250,000 will be the market size in 1995. Seagate continued to dominate this segment of the market, with Hewlett-Packard and Micropolis holding shares over 10 percent. Seagate and Micropolis are the only companies in large-scale production of this form factor.

The bulk of the sales in 1994 were again over 1GB, and the current standard of popular drives has moved to 9GB. Dataquest expects shipment of 20GB, 5.25-inch drives by the middle of 1996. The SCSI interface is most popular in this form factor.

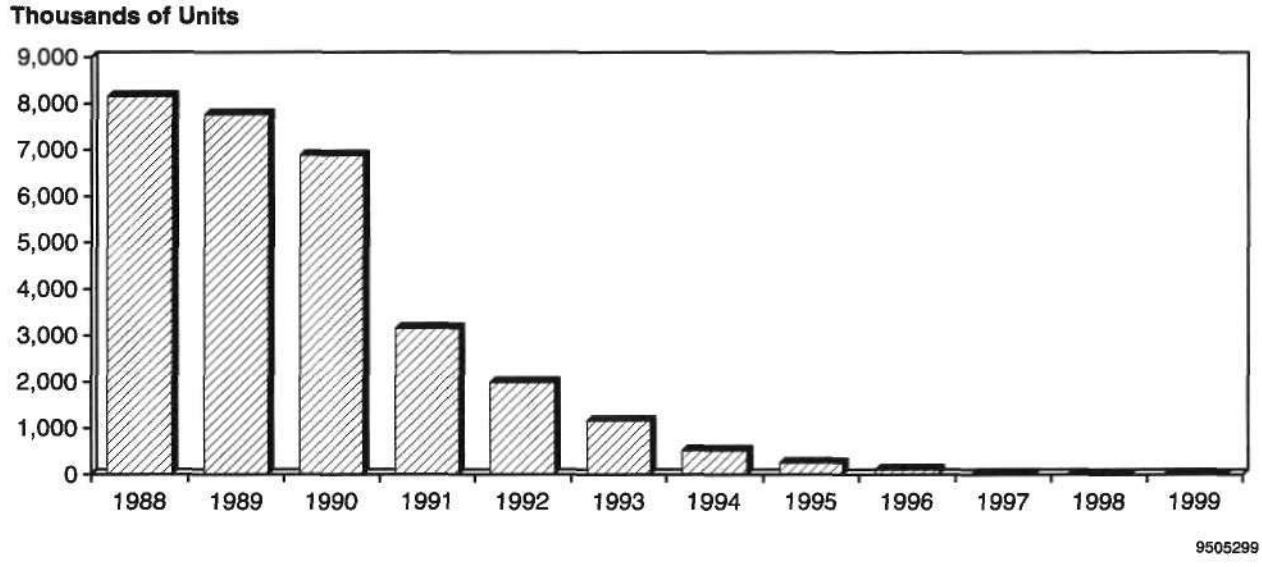
Disk arrays from EMC and StorageTek with 5.25-inch drives have been shipping into the high-end DASD market. The switch to 3.5-inch drives in these systems has already begun.

The newfound market for 5.25-inch disk drives is the video-on-demand industry. Micropolis and Seagate have both found considerable success in their 9GB drives for use in storing motion pictures for simultaneous viewing in hotels. Micropolis has joined forces with EDS for production of systems for the Spectravision systems in 2,000 hotels. It is likely that this market will continue to favor 5.25-inch drives because of their high capacities and continuous data streams.

The 5.25-inch forecast is shown in Figure 4-5.

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Figure 4-5
Worldwide 5.25-inch Rigid Disk Drive Forecast



Source: Dataquest (October 1995 Estimates)

Forecast Discussion

This form factor, in its dying days, has become popular in the video market, and Dataquest's forecasts indicate stabilization of sales at about 1 million units in 1994 and 1995. Because of earlier price erosion and higher demand, the 5.25-inch drives will fall in price only about 14 percent per year over the next five years, so good profit can be made on their sales.

In 1995, the average capacity shipped will be in excess of 10GB per drive and, by the time the form factor fades away, the average capacity will be near 20GB. Since MR heads have not yet been used widely in these drives, considerably higher densities can be anticipated.

Regional Sales

Dataquest's 1994 surveys of sales to the various regions of the world have produced unique results for each disk drive segment. Table 4-1 displays the unit market share for 1.8-inch, 2.5-inch, 3.5-inch and 5.25-inch disk drive sales demand.

Table 4-1
Regional Market Splits, Percentage of Sales

	North America	Europe	Japan	Asia/Pacific
1.8-inch	32.6	2.1	58.2	7.1
2.5-inch	57.7	8.8	15.5	18.0
3.5-inch	52.0	28.5	5.4	14.1
5.25-inch	75.4	10.4	9.6	4.6

Source: Dataquest (October 1995 Estimates)

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Rigid Disk Drive Channel Trends

Rigid disk drive sales are made through three basic channels: captive, OEM, and distribution. While not all disk drive makers have a captive outlet for their products, certainly all of them have made concerted marketing efforts in OEM and distribution sales.

Captive Channel

Only large companies such as IBM, Hitachi, Fujitsu, Toshiba and NEC have use for their own disk products in their computer systems. IBM holds a reasonable worldwide unit market share in 3.5-inch disk drives (9.6 percent) and is the market leader (26.2 percent) in 2.5-inch drives. Fujitsu, Hitachi and NEC are not major players, but do manufacture large quantities of disk drives. Toshiba is the one exception, with its number-two status (23.6 percent) in the 2.5-inch market.

Table 4-2 shows the percentage of each company's unit volume sold captively to other divisions of the same company, indicating the trends over three years.

Table 4-2
Percentage of Worldwide Sales to Captive Channel

	1992	1993	1994
IBM 2.5-inch	80	50	55
IBM 3.5-inch	90	62	67
Fujitsu 2.5-inch	NA	100	30
Fujitsu 3.5-inch	18	90	37
Hitachi 2.5-inch	NA	NA	26
Hitachi 3.5-inch	0	0	20
NEC 3.5-inch	83	53	67
Toshiba 2.5-inch	60	29	25

NA = not applicable; companies did not manufacture product during this period.
Source: Dataquest (October 1995 Estimates)

The trend is clearly toward less captive use of products, since the vendors would much rather sell large volumes of products to the merchant market and reduce the cost of the disk drives used in their own systems. Also, the industry trend has been toward multisourcing of components such as drives, and these companies are purchasing increasing amounts of competitors' products.

OEM Channel

This is the largest channel for the sale of disk drives, directed at the manufacturers of computer products. As noted, these computer companies are now multisourcing products rather than developing sole-source dependencies. This protects them against shortages and assures them of competitive pricing. OEM prices are always the lowest and are discounted deeper for larger volumes.

Distribution Channel

This channel is one that allows for sale of products to industrial and commercial distributors for resale to VARs, systems integrators, small OEMs and retail outlets. Discounts to this channel result in prices about 10 percent above OEM prices. The gray market is a competitor to this channel, because large numbers of disk drives are resold by OEM companies to brokers in an effort either to relieve inventory or to increase their volume commitments. The gray market resells at nearly OEM prices and hurts distributors badly.

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Industry Trends in Channels

Table 4-3 shows the average channel percentages for sales of 2.5-inch and 3.5-inch rigid disk drives. This is worldwide and an average of all vendors for three years.

Table 4-3
Worldwide Channel Trends, by Percentage of Sales

	1992	1993	1994
2.5-inch Captive	18.1	16.6	16.8
2.5-inch OEM	74.9	80.0	72.2
2.5-inch Distributor	6.9	3.5	11.1
3.5-inch Captive	11.1	9.2	7.3
3.5-inch OEM	54.1	61.2	61.5
3.5-inch Distributor	35.8	29.6	31.3

Source: Dataquest (October 1995 Estimates)

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Chapter 5
European Rigid Drive Market and Production

European Market Overview

The dominant demand driver for storage products in Europe is the high-volume, low-margin business generated by the PC OEM. In terms of European storage shipments, the rigid drive market represented 78 percent of the market, with optical and tape representing 16 percent and 6 percent respectively. Storage drive segmentation by technology for shipments and revenue is shown in Table 5-1.

The overall European rigid drive market remains positive throughout the forecast period, with a unit growth to 41.6 million units in 1999 up from 17.9 million units in 1994. Pressure on price and margins is not expected to slow, resulting in a growth in factory revenue to $6.41 billion in 1999 compared with $3.91 billion in 1994.

Market and product success for rigid disk drives was mixed in 1994. The year saw explosive unit shipment growth for 2.5-inch drives, high growth for 3.5-inch drive shipments, and contraction for the 5.25-inch category. European sales of 1.8-inch drives were small, but the large growth from a very small base continued to disappoint some participants. Table 5-2 shows European shipments and revenue for rigid drives by size.

Sales for 1994 were substantially above expectations as a result of strong sales of private personal computers, increased use in servers, and a strong growth in PC storage upgrades. Somewhat strangely in a supply-constrained market, profitability was a significant issue in 1994. Price erosion for 3.5-inch drives was steep, and factory average selling prices (ASP) fell from $249 in 1993 to $213 in 1994, making disk storage a real bargain for OEMs and distributors. The profit margins for some classes of 3.5-inch drives slipped to single-digit, such that some players strongly emphasized more profitable, higher-capacity products. The 2.5-inch drive market was on a roll, as high growth and better margins helped some companies to gain share and much-needed profitability.

Table 5-1
European Storage Drive Technology Forecasts by Shipments and Factory Revenue, 1993-1999 (Thousands of Units and Millions of Dollars)

Technology	1993	1994	1995	1996	1997	1998	1999
Shipments (Units K)							
Rigid Drives	14,994	17,947	21,291	24,276	29,981	37,286	41,658
Optical Drives	1,359	3,565	5,693	7,541	9,276	10,756	11,193
Tape Drives	985	1,357	1,831	2,175	2,500	2,784	3,026
Total All Types	17,340	22,870	28,815	33,993	41,757	50,825	55,877
Revenue ($M)							
Rigid Drives	4,078	3,912	3,983	4,735	5,301	6,253	6,417
Optical Drives	285	515	686	793	856	899	888
Tape Drives	625	611	771	886	935	942	977
Total All Types	4,991	5,039	5,440	6,414	7,092	8,094	8,282

Source: Dataquest (October 1995 Estimates)

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Table 5-2
European Rigid Drive Technology Forecasts by Shipments and Factory Revenue, 1993-1999 (Thousands of Units and Millions of Dollars)

Technology	1993	1994	1995	1996	1997	1998	1999
Shipments (Units K)							
1.8-inch	1	6	44	104	221	446	1,103
2.5-inch	518	717	1,309	2,082	3,051	4,295	5,484
3.5-inch	14,127	17,167	19,910	22,073	26,706	32,544	35,070
5.25-inch	348	58	28	18	4	2	1
Total All Types	14,994	17,948	21,291	24,276	29,981	37,286	41,658
Revenue ($M)							
1.8-inch	0.2	2	9	26	59	82	212
2.5-inch	135	172	311	388	460	627	805
3.5-inch	3,513	3,656	3,623	4,293	4,776	5,542	5,399
5.25-inch	403	82	40	28	6	2	1
Total All Types	4,078	3,912	3,983	4,735	5,301	6,253	6,417

Source: Dataquest (October 1995 Estimates)

The European rigid drive market from a shipments and revenue perspective will continue to be dominated by 3.5-inch drives throughout the forecast period 1995 to 1999. The 3.5-inch drives represented 96 percent of shipments in 1994, reducing to 84 percent in 1999; similarly, 1994 revenue represented 93 percent, decreasing to 84 percent in 1999.

Rigid Manufacturers' Market Shares

Quantum Corporation with its strong OEM business focus was the market leader in unit volume terms for the year, after increasing its sales to 4.2 million units, to gain a 23.7 percent share. Seagate Technology moved into second place with 19.7 percent, and Conner Peripherals was in third place with 15.2 percent. Impressive leadership in 2.5-inch drives helped IBM ease into fourth position, increasing its share to 13.2 percent; while Western Digital was in fifth place, at 13.0 percent.

Other companies with notable increases in market share included Samsung, Fujitsu, Digital Equipment and Hewlett-Packard. Digital's disk operation was sold to Quantum in October 1994, but Digital increased its share in just a nine-month period in 1994. (Digital's products sold in the last quarter of the year were counted in Quantum's total.). The results of the top 10 players are shown in Table 5-3.

European Manufacturing Trends and Production Forecast

Until a few years ago it seemed that European production of disk drives was in a terminal decline, with a number of plants closing down and production moving to the low-cost Far East. The boom in PC demand and production, recent changes in tariff structures, and the need to re-examine supply logistics, though, have refocused storage companies attention on manufacturing in Europe.

The last round of GATT negotiations produced new tariffs for storage products; these are to be reduced from the current tariff of 4.9 percent down to 0.0 percent. From January 1995, the first step reduced the tariff to 3.9 percent, to be followed with successive reductions each year.

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Table 5-3
European 1.8-inch to 5.25-inch Rigid Disk Drive Market Share by Shipments, 1994

Company	1994 Market Share
Quantum	23.7%
Seagate Technology	19.7%
Conner Peripherals	15.2%
IBM	13.2%
Western Digital	13.0%
Maxtor	6.3%
Samsung	2.8%
Fujitsu Ltd	2.4%
Digital Equipment	1.7%
Hewlett-Packard	0.8%
Others	1.3%

Source: Dataquest (October 1995 Estimates)

However, most imported disk drives come from Singapore, Malaysia or other Southeast Asian countries which are exempt from the GATT tariffs under the General Systems of Preferences (GPS) scheme for developing countries; although recently it was decided to remove Singapore from the GPS list, and Malaysia on certain products. Thus, as the GSP is lifted so the GATT tariffs will be reduced to zero, effectively meaning no change in the medium term. As a result, companies are once again re-examining their manufacturing strategy towards Europe.

Storage vendors are re-engineering logistics to remain profitable by slimming the supply chain, moving to more efficient centralized logistics and reducing localized inventory pooling. Downstream, OEMs/distributors/resellers are going in the reverse direction with the goal of moving inventory responsibility back upstream. They are moving to logistics models that require local buffering to support variable flow management necessitated by just-in-time (JIT), ship-to-line (STL), and other dynamic MRP flow control systems.

As the channel purges excess inventory, the pressure will fall back on vendors to provide more flexible product supply, with resultant demand for flexible manufacturing. There are a number of business issues prompting vendors to adopt more flexible manufacturing philosophies:

- Short product life cycles
- Difficulty of debugging and ease of replicating large-scale process
- Fast ramp-up of new products
- Variable demand for a range of products
- The need to run processes at maximum efficiency

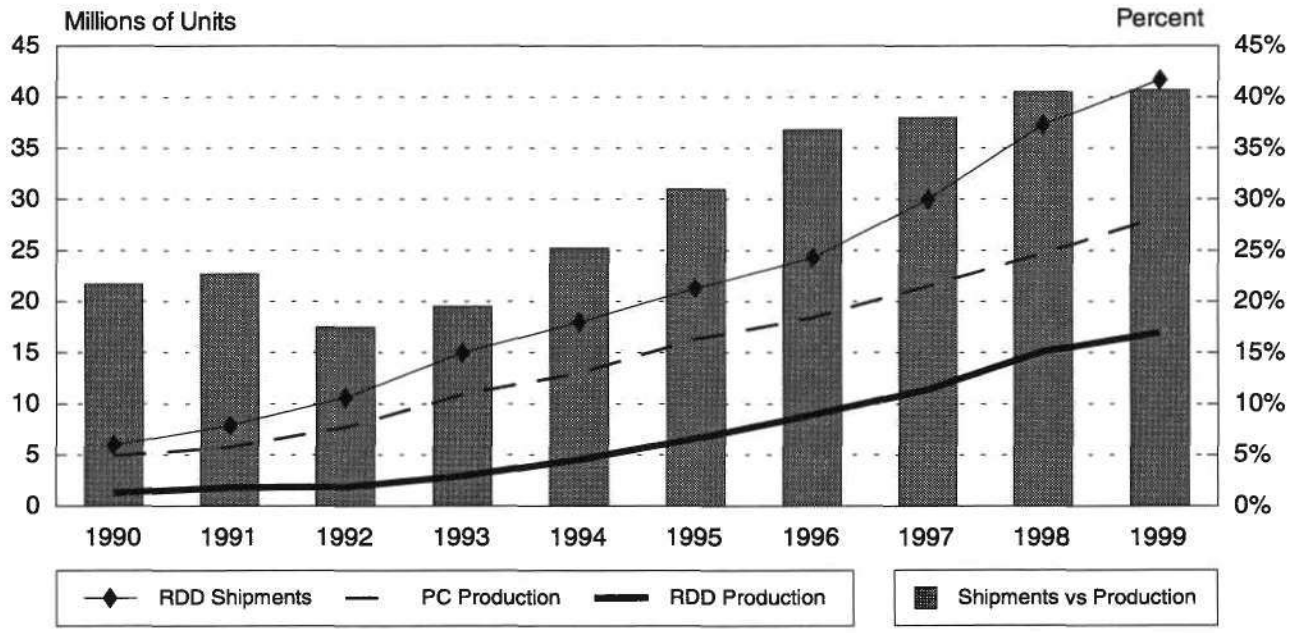
European Rigid Disk Production Forecast

With the creation of a new European rigid disk drive company, Xyratex, and two major new plant investments in Europe within the last year (IBM and Seagate), production in Europe is set to increase substantially in the next few years. Of the top five rigid disk drive companies, only one, Western Digital, does not have local production. Dataquest believes that European rigid disk drive production reached 6.6 million units in 1994, and will equal 18 million in 1999—a CAGR of 30 percent between 1995 and 1999.

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Figure 5-1 shows the correlation between European rigid disk drive shipments, European PC production, and European rigid disk drive production. The second axis (column) shows production versus shipments increasing over the forecast period from 25 percent in 1994 to just over 40 percent in 1999. Table 5-4 shows Dataquest's estimates of rigid disk drive production in Europe for 1993 to 1999 by size.

Figure 5-1
European PC Production, and Rigid Disk Drive Shipments and Production



Source: Dataquest (October 1995 Estimates)

Table 5-4
European Rigid Disk Drive Production by Segment
(Thousands of Units and Percentage of Production)

Product Type	1993	1994	1995	1996	1997	1998	1999
Unit Production (K)							
1.8-inch	0	5	95	145	225	310	350
2.5-inch	130	215	375	390	425	515	658
3.5-inch	2465	4,305	6,140	8,387	10,745	14,290	15,955
5.25-inch	35	5	-	-	-	-	-
Total	2,630	4,530	6,610	8,922	11,393	15,115	16,963
Percent Share							
1.8-inch	0.0%	0.1%	1.4%	1.6%	2.0%	2.1%	2.1%
2.5-inch	4.9%	4.7%	5.7%	4.4%	3.7%	3.4%	3.9%
3.5-inch	93.7%	95.0%	92.9%	94.0%	94.3%	94.5%	94.1%
5.25-inch	1.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (October 1995 Estimates)

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Major Manufacturers in Europe

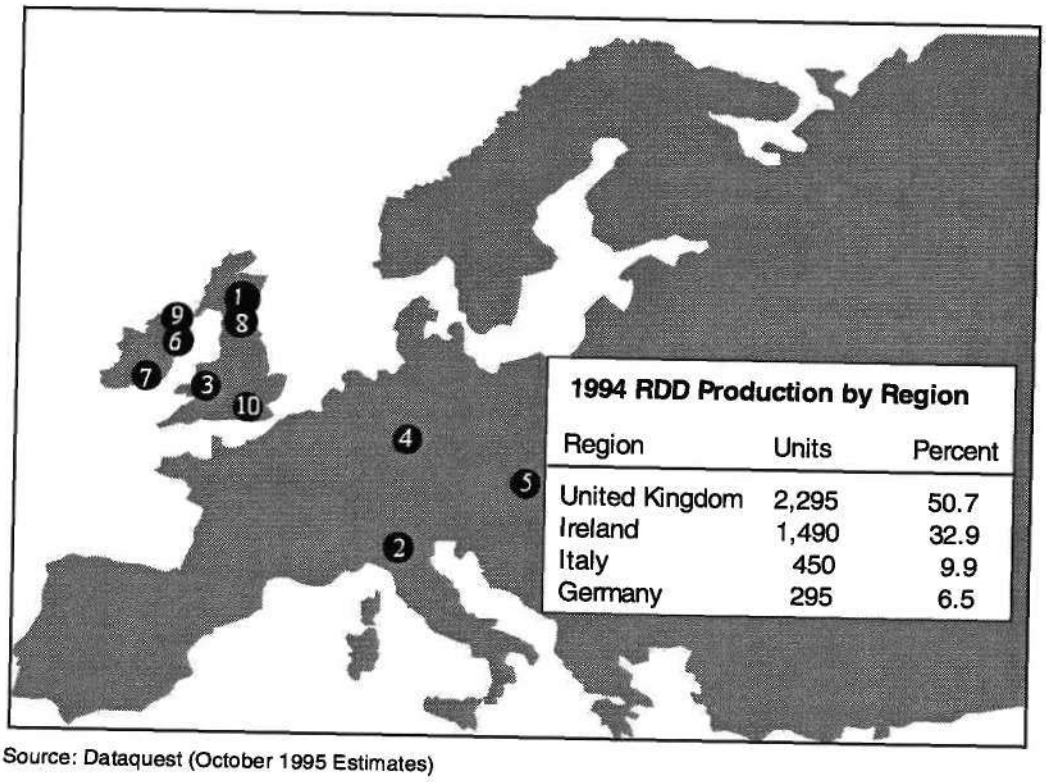
This section provides an overview of the major European manufacturing operations and discusses the key companies and their operations. Table 5-5 shows the major rigid disk drive manufacturers in Europe. Figure 5-2 illustrates the concentration of disk drive production in the United Kingdom and Ireland, which accounted jointly for 83 percent of European production in 1994.

Table 5-5
European Disk Drive Production by Location

Location	Company	City	Country
1	Calluner	Glenrothes	Scotland
2	Conner	Aosta Valley	Italy
3	Hewlett-Packard	Bristol	England
4	IBM	Mainz	Germany
5	IBM	Szekesfahervar	Hungary
6	Matsushita Kotobuki	Dundalk	Ireland
7	Seagate	Clonmel	Ireland
8	Seagate	Livingston	Scotland
9	Seagate	Londonderry	Northern Ireland
10	Xyratex	Havant	England

Source: Dataquest (October 1995)

Figure 5-2
European Regional Disk Drive Production



Source: Dataquest (October 1995 Estimates)

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Calluna Technologies

Founded in 1991 by ex-Rodine employees, Calluna specializes in 1.8-inch form factor disk drives. In November 1994, Calluna floated on London's unlisted securities exchange, raising £10 million.

All R&D and manufacture are carried out in the companies 2,320 m² facilities in Glenrothes, Scotland. Calluna bases its manufacturing strategy on modular disk drive design. The process consists of the assembly of components and functionally tested subassemblies that have been manufactured by selected suppliers off-site. This strategy takes advantage of the existing supply base to the disk drive industry, thereby securing lower overseas overheads on labor-intensive assemblies. The production facility includes two linked class 10 cleanrooms.

IBM

Szekesfahervar, Hungary

During 1994, IBM announced plans to manufacture rigid disk drives for personal computers in Szekesfahervar, Hungary, just south of Budapest. Production is scheduled to begin before the end of 1995 with a projected 1996 output of 1 million disk drives. Plant capacity is believed to be 2 million units annually. Drives manufactured there are expected to be sold primarily in the European market. Technical direction, logistics management, and engineering support will be provided by IBM's operations in Mainz, Germany.

The new Hungarian factory is owned by Mechatronika Kft., a subsidiary of Videoton. IBM had already been acting under a five-year renewable agreement with Videoton, subcontracting certain manufacturing operations of magnetic heads used in rigid drives. All investments in the 7,430 m² building will be provided by Videoton, and IBM will install manufacturing equipment. The size of the total investment was not revealed. The factory is expected to employ 830 workers; 30 of those will be IBM personnel.

Mainz, Germany

IBM's Mainz facility was founded in 1965 and until the mid 1970s the plant was mainly oriented to assembly and testing. At the end of 1994, the plant had slightly under 1,500 permanent employees. It produces complete storage devices, control units, head disk assemblies, thin-film disk and thin-film read/write heads. In addition, the Mainz facility is also responsible for the production of power supplies.

Seagate Technology

Clonmel, Ireland

In mid-1995 Seagate announced plans to invest $35 million in a rigid disk drive manufacturing facility at Clonmel, Ireland. The capacity of the 14,400 m² plant is anticipated to exceed 5 million units annually. Production was scheduled to begin in mid-October 1995, with a projected output of 3 million disk drives in 1996. The products will be sold primarily in the European market, but will also service customers in Seagate's Africa and Middle East regions.

The Clonmel facility will employ more than 800 staff, with manufacturing operations featuring some of the industry's most advanced automated process technologies. It is anticipated that the initial products made will be new generations of cost-reduced gigabyte-plus drives.

Springtown, Northern Ireland

During 1994, Seagate announced the opening of its magnetic head wafer facility based in Springtown, Northern Ireland. The plant provides enough

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wafers from which to make in excess of 100 million thin-film recording heads per year. In early 1995, Seagate announced an additional investment in its magnetic head production site; this brings the total investment to $200 million.

Livingston, Scotland

The Livingston facility is run by Seagate Microelectronics Ltd, a wholly owned subsidiary of Seagate Technology Inc. Seagate's Scottish operation came about as a result of the acquisition of a specialized chip company in 1987. The facility produces specialized IC for applications across Seagate's range of storage products. The devices are manufactured using bipolar and BiCMOS technology.

Xyratex

Xyratex was formed after a management buyout of IBM's primary European disk drive manufacturing facility in Havant, England. Price and details have not been disclosed. The new company will employ more than 2,000 workers, with annual turnover forecast to be about £ 300 million (approximately $500 million).

The Havant facility will continue to manufacture disk drives, storage systems, networking and flexible circuit products for IBM. Although Xyratex will be a key manufacturer for IBM, it will increasingly move to manufacturing products for other companies, and has already established manufacturing partnerships with two other companies to provide innovative disk drive products. One previous relationship that was made public was Havant's contract manufacturing agreement with Western Digital; the WD agreement has come to completion. The other relationship is with Nomai of France to manufacture a high-capacity removable rigid disk drive.

In addition to manufacturing, Xyratex will continue to develop its own brand of storage devices and subsystems, network consultancy services and applications software.

Dataquest estimates that 2 million rigid disk drives were made at the facility within calendar 1994, representing about 30 percent of 2.5-inch and 11 percent of 3.5-inch forecast European hard disk drive consumption.

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Chapter 6
Interface Technologies

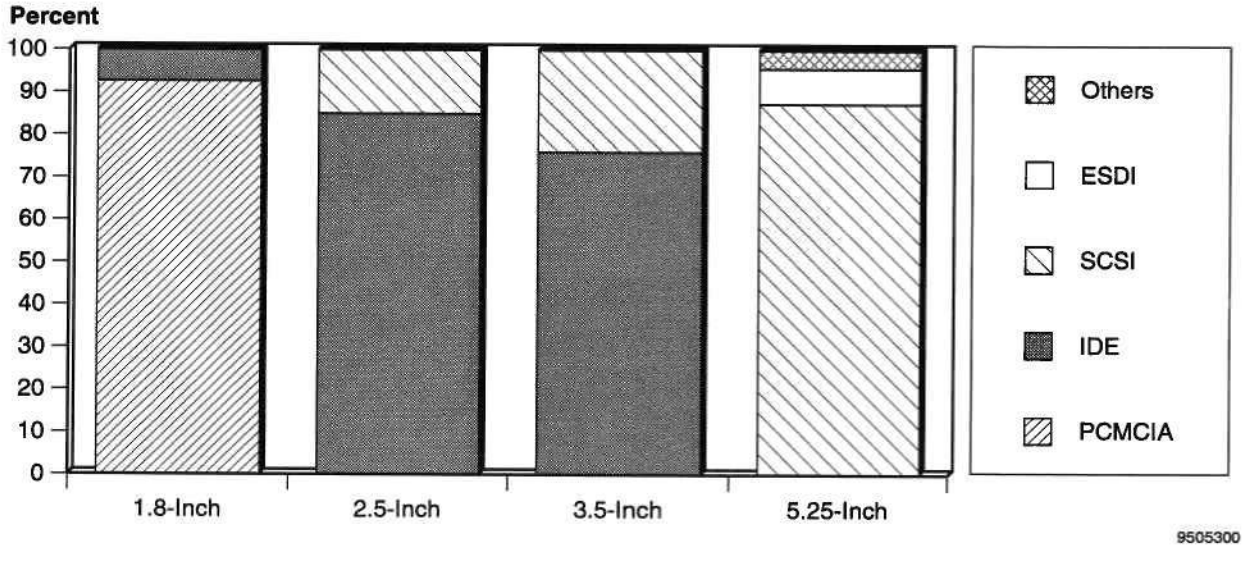
Overview

The popularity of the AT-attached disk drive with IDE or Enhanced IDE interfaces is being maintained as the desktop products move into the gigabyte-capacity range. SCSI continues to be the interface of choice for disk array subsystems and, generally, for products with high-performance characteristics. Figure 6-1 shows the split among interfaces on the various diameter disk products sold in 1994.

Figure 6-2 illustrates Dataquest's projected interface split between IDE and SCSI (parallel or serial) in the 3.5-inch form factor disk drives, and Figure 6-3 concentrates on 2.5- and 3.5-inch disk drives with capacities over 1GB and the segmentation of parallel and serial interfaces.

In the middle of 1995, SSA appears to have a definite lead on FC/AL for the device interface of choice. IBM is the inventor and key proponent of SSA, but also had considerable input into the Fibre Channel specifications. Hewlett-Packard, Quantum and Seagate are the most vocal advocates of FC/AL, with apparently a large following of system makers that would love to have production quantities of disk drives for new, high-performance array products. Conner, IBM and Micropolis are the drive makers that have announced SSA products, and IBM is, in fact, shipping production models. IBM is also designing SSA-interfaced disk drives into some of its midrange and high-end array products.

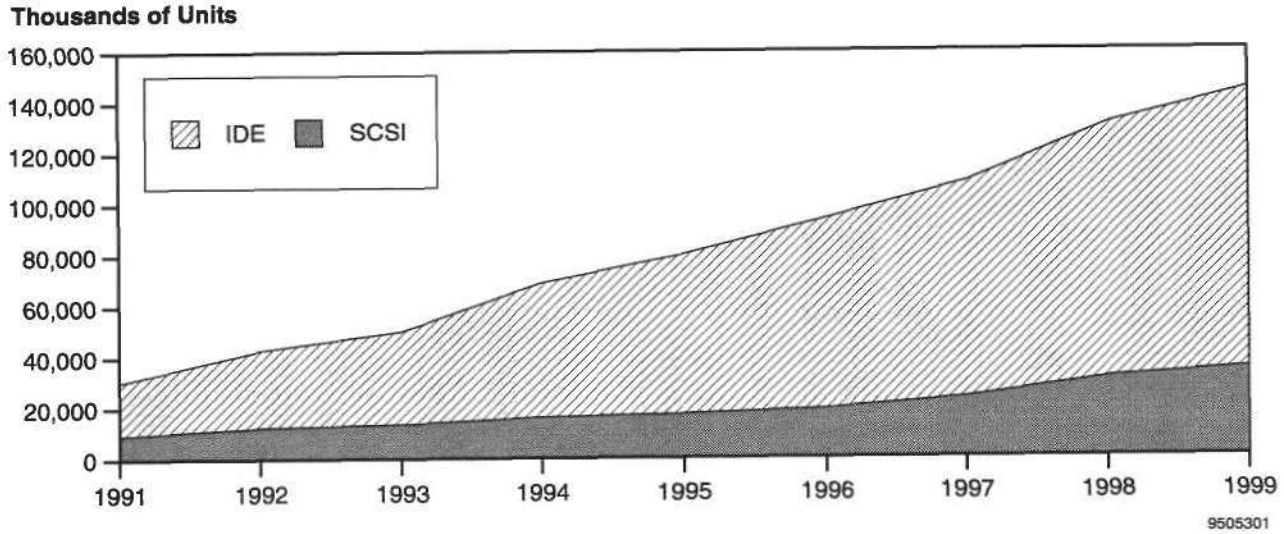
Figure 6-1
Interface Share by RDD Form Factor



Source: Dataquest (October 1995 Estimates)

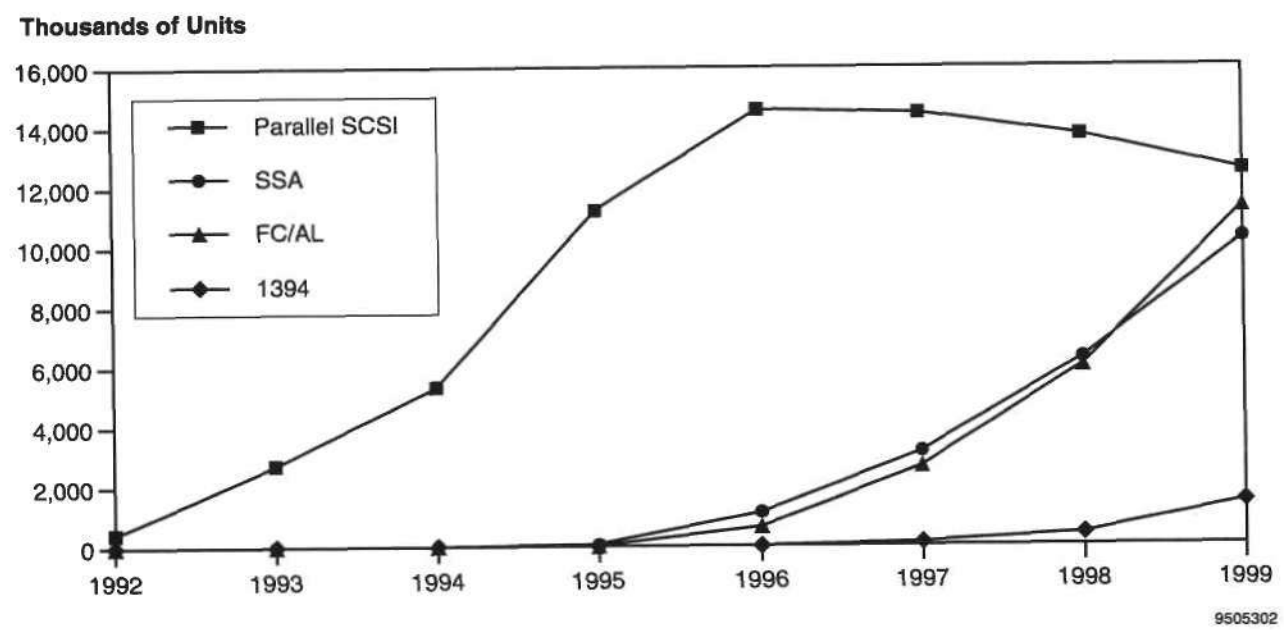
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Figure 6-2
RDD Interface Worldwide Split Forecast for 3.5-inch Drives



Source: Dataquest (October 1995 Estimates)

Figure 6-3
RDD SCSI Interface Worldwide Split Between Parallel and Serial Versions



Source: Dataquest (October 1995 Estimates)

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SSA is the lowest-cost implementation of serial SCSI products, with interface parts available from IBM and VLSI. FC/AL interfaces are still expensive, but have been tuned downward in performance to make the interface chips easier to manufacture. Timing and cost are the decision criteria being used now to evaluate these competing interfaces. In 1997, there will be sufficient products available so that each can be judged on its own merit by performance and cost.

The Dataquest forecast for serial SCSI interfaced disk drives indicates SSA leadership, but FC/AL could take over in 1999. Actually, many changes could happen in that time, including a melding of the two interfaces into one powerful standard that all can use without arguing relative merits (much like the VHS and Beta wars of the last decade).

In summary, the serial interface battles are far from over, and it is difficult to project the long-term winners. The SSA interface continues to show that it will be more widely available at lower prices than the FC/AL interface disk drives. FC/AL, however, appears able to boast a larger following of system vendors that have selected it over SSA.

IDE/EIDE

The IDE interface was defined as part of the PC AT architecture in 1987. It is aptly named Integrated Device Electronics (IDE), but is also known as ATA or AT Attachment. The IDE interface replaced a de facto standard defined by rigid disk drive manufacturer Seagate known as ST-506. IDE provides a low-cost storage solution for PCs because it requires a controller only in the device rather than in both the device and the host PC. Only an IDE interface, rather than a full controller, is required on the host side, which keeps silicon costs at a minimum. The low cost for IDE has made it almost a universal feature for PCs, with over 80 percent penetration. Integration of the IDE interface into popular core logic chipsets will push the penetration rate for IDE/EIDE closer to 100 percent.

IDE controllers are best suited for single-user systems such as desktop or mobile PCs. The original IDE standard allows only two devices to be connected on a single IDE channel. Few desktop PCs require more than two rigid disk drives, but this is one limitation of the IDE specification. Other limitations have become more significant as disk sizes and file sizes have increased over the past decade. IDE drives have a maximum size of 528MB and file transfer rates were in the range of 2 MB/sec to 3 MB/sec. Another drawback of IDE is simply that only rigid disk drives could use the interface. Other interfaces such as SCSI allow a variety of devices to be attached, such as tape drives, scanners and other peripherals.

These limitations have driven the industry to create a new standard that addresses these issues. Several versions of the new standard have emerged. Western Digital has named one specification Enhanced IDE, and this has widespread use in the PC world. Seagate has named a similar specification ATA-2. The principal difference between these two standards is peak transfer speed. Current EIDE controllers may not support transfer rates greater than 11.1 MB/sec. ATA-2 devices support two transfer modes (PIO mode 4 and DMA mode 2) that transfer data at a peak rate of 16.6 MB/sec. End users do not need to worry about their Enhanced IDE host interface recognizing their ATA-2 disk drive; it will, but the peak transfer rate will be 11.1 MB/sec. For this document, the term Enhanced IDE or EIDE is used to describe EIDE and ATA-2 collectively.

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Enhanced IDE addresses many of the limitations of the original IDE specification. The EIDE specification recognizes disk drives as large as 8.3GB and provides two independent channels supporting two devices each, for a maximum of four devices. The speed issue has been addressed by new programmed input/output (PIO) modes as well as DMA modes. These new modes provide a maximum transfer rate of 11.1 MB/sec for PIO mode 3 and 16.6 MB/sec for PIO mode 4, but DMA modes will replace PIO modes for performance reasons. Dataquest does not expect any PIO modes to be developed beyond the 16.6 MB/sec mode 4. Instead, developers will focus on DMA modes. Two DMA modes have already been defined: Mode 1 multiword, which has a transfer rate of 13.3 MB/sec; and Mode 2 multiword, with a rate of 16.6 MB/sec.

Enhanced IDE has additional issues that are being addressed but are not yet finalized. At this time, two EIDE devices on a single channel must take turns. In fact, the issue is larger than just taking turns because when a request is submitted to one drive, that drive maintains control of the channel until it delivers the data. Access times for 3.5-inch rigid disk drives are typically 10ms to 15ms, so the channel is tied up unnecessarily for that time. Work is being done to define an overlapped I/O feature that will allow a second request to be made before the first request has received data. SCSI controllers already support this type of multitasking. For example, a request is made to drive No. 1 on channel No. 1 and, while it is searching for the data (about 10ms to 15ms), a second request is made to drive No. 2 on the same channel. When the drives are ready to transfer the data, they will issue an interrupt, and whichever drive issues the interrupt request first will get to transfer its data first. This feature will increase the overall performance by making the channel available if it is not currently being used to carry instructions or data.

Another issue that will challenge EIDE in the near future is maximum transfer rate. Parallel SCSI has transfer rates of 20 MB/sec, with plans for 40 MB/sec. EIDE does not need to match those rates but does need to grow beyond the current 16.6 MB/sec maximum. Development work is being done on new DMA modes, with rates expected to be between 22 MB/sec and 33 MB/sec.

One last issue that is not being addressed is cable length. EIDE cables have a maximum length of 18 inches and are designed to be an inside-the-box solution. Dataquest is not aware of any plans to expand the specification for longer cabling options to make external EIDE devices feasible.

SCSI

SCSI has long been the high-performance disk interface for desktop computers. The SCSI specification uses a parallel interface that is 8-bit-wide. Transfer rates started at 5 MB/sec, but new versions of parallel SCSI offer higher performance. SCSI controllers have been standard equipment in workstations and Apple Macintosh computers, but acceptance has been less widespread for x86-based PCs.

SCSI controllers have moderate acceptance for PCs because of the additional cost of implementing SCSI as compared to EIDE. SCSI requires a controller on the host PC side as well as in the SCSI peripheral. A SCSI controller card for a PC is several times the cost of an EIDE interface card because the additional controller chip is required. However, performance and expansion requirements have caused OEMs to add SCSI controller to many high-end desktop PCs as well as servers. Until the adoption of Enhanced IDE, SCSI controllers were the most convenient way to use large disk drives (larger than 528MB) or add other devices such as optical drives (including CD-ROM drives) or tape backup units, as well as to provide a high-speed interface to external peripherals.

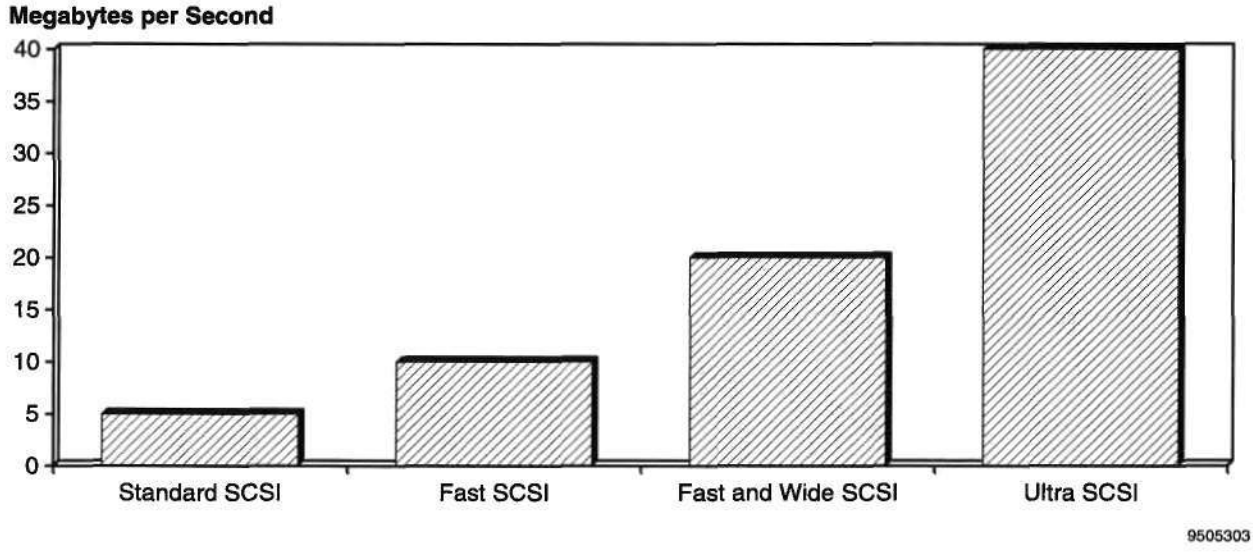
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New SCSI protocol versions have been named numerically and with descriptive terms. SCSI-2 and SCSI-3 represent command set enhancements, while terms like "fast" and "wide" represent a doubling of the clock rate and a doubling of the interface width respectively. The original cable specification for SCSI uses a 50-conductor cable with an 8-bit parallel interface for data transfer. The "wide" versions of SCSI use either 68-conductor or 80-conductor cables and have a 16-bit interface for data transfer. The latest version is known as ultra-SCSI, which is the fastest version of SCSI to be finalized. An additional specification known as ultra-SCSI-2 is on the drawing board and could double the transfer rate of ultra-SCSI.

Versatility is one of the SCSI family's notable features. SCSI interfaces are found on a variety of peripherals such as disk drives, tape drives and scanners because they provide a high-performance I/O standard for both internal and external peripherals. A standard SCSI chain can accept up to seven devices attached to a single host controller. This is one major advantage of SCSI over EIDE because EIDE is limited to four internal devices. The SCSI cabling specification allows cable lengths from 1.5 m up to 6.0 m, depending on transfer speed. There is an inverse relationship between maximum transfer rate and cable length, with the higher transfer rates requiring shorter cables. However, even the 1.5 m cable length is over three times as long as the 18-inch limit for EIDE. Figure 6-4 shows parallel SCSI transfer rates.

The biggest hurdles for SCSI to overcome are the cost of implementation and the cabling complexity. EIDE is a lower-cost solution and meets the requirements of the typical desktop PC user. SCSI will retain some share of the market because of its ability to connect external peripherals and its current performance advantage, but it is unlikely to become a standard feature in a typical PC. Standard SCSI will lose market share to the serial SCSI architectures as the serial versions ramp through the rest of this decade.

Figure 6-4
Parallel SCSI Transfer Rates



Source: Dataquest (October 1995)

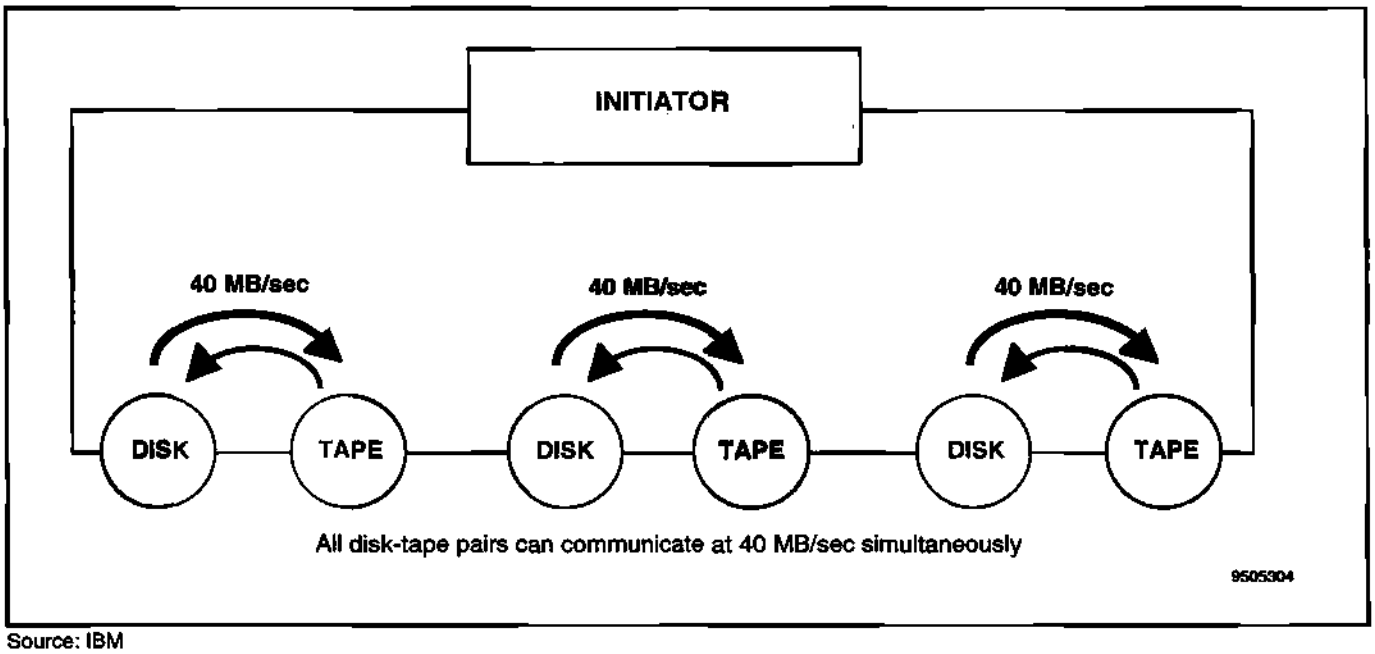
Serial Storage Architecture

SSA is a high-performance specification created and championed by IBM. SSA uses the SCSI-2 command set but provides higher performance and other benefits with a new cabling scheme. The cabling is actually four-wire cable, which provides four independent communications paths. Each path is capable of operating at 20 MB/sec bandwidth, so an SSA node has total bandwidth of 80 MB/sec.

SSA addresses many of the cabling problems associated with parallel SCSI. Parallel SCSI cables are wide (between 50 and 80 conductors) and not only can be difficult to route but may also block air flow in an enclosure. SSA cabling (four conductors) is much smaller and so does not have the same problems. Also, cabling for SSA is point-to-point and can configured in strings or loops. A loop configuration allows packets to be routed either way around the loop, so a single cable failure does not isolate any device on the loop. Faulty cables are easy to locate regardless of the configuration because a transmission error will identify specifically which section of cable (that is, between which two nodes) caused the problem.

Spatial reuse is an additional feature of the point-to-point nature of SSA. Data packets travel from node to node rather than being broadcast to all of the peripherals simultaneously. This allows effective data rates much greater than 80 MB/sec. For example, imagine a configuration that features pairs of peripherals, with a tape drive and a rigid disk drive in each pair. If the cabling is routed as shown in Figure 6-5, then each of these pairs could transfer data at 40 MB/sec simultaneously. A configuration with three such pairs would actually be transferring 120 MB/sec (40 MB/sec times three pairs).

Figure 6-5
Example of Spatial Reuse with SSA Interfaces



Source: IBM

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1394 (also known as FireWire)

The IEEE 1394 specification is a high-speed serial bus that uses SCSI commands but defines a new cabling scheme. It was designed to be a universal I/O solution to connect a variety of devices with simple cabling and an overall low cost. The performance road map for 1394 places it firmly in the middle of its competitors. It is faster than parallel SCSI, but not as fast as the other serial SCSI specifications. 1394 will be adopted for applications where its mix of features make it attractive rather than competing on speed alone.

One feature distinguishing 1394 from the other serial SCSI standards is isochronous support, which allows guaranteed bandwidth. This feature makes 1394 well suited to applications that require real-time data, for example, playing motion video clips. Each frame of data must arrive at the frame buffer in time to be displayed. If some data is delayed, then the image quality of the displayed motion video clip will be compromised by incomplete or missing frames. Some applications particularly well suited for 1394 are consumer audiovisual equipment such as digital video cameras and videodisk players, as well as business applications such as multimedia authoring or video editing.

Several consumer electronics companies have endorsed 1394 as the preferred interface for many consumer devices, including digital VCRs, camcorders and set-top boxes. Sony has already demonstrated products with the 1394 interface. Also, Apple Computer has endorsed 1394 as an I/O standard for connecting a variety of peripherals to desktop computers.

Fibre Channel-Arbitrated Loop

Fibre Channel-Arbitrated Loop (FC/AL) is a serial peripheral interface standard. It is a subset of the Fibre Channel specification that defines an entire network architecture. The FC/AL subset was defined because full Fibre Channel compatibility is too expensive to implement in a peripheral device. FC/AL allows peripherals to use many of the features of Fibre Channel, particularly its high data rate, without adding unnecessary cost. FC/AL supports data rates up to 100 MB/sec and is the fastest standard interface available for rigid disk drives. Unfortunately, it is also the most expensive.

FC/AL is a serial SCSI interface, like its competitors SSA and 1394. The SCSI commands and protocols are used, but the cables and hardware are different. Up to 126 devices can be attached to a single FC/AL interface connection. Cabling can be configured as a single or a double loop. The advantage of the double loop is a doubling of bandwidth to 200 MB/sec and greater fault tolerance. FC/AL provides other advantages for disk arrays, including array-specific commands and XOR logic built into the disk drives. No special hardware is required on the host controller for RAID 5 because of those built-in features. This increases the array performance by reducing the workload of the host controller. FC/AL also lets the user define the ratio of data disks to parity disks in the array to balance cost of implementation versus speed of error recovery.

FC/AL is the preferred interface for users who require maximum bandwidth and are willing to pay a higher price. FC/AL disk drives will be very popular with companies using Fibre Channel as their network protocol because the disk interface comes at no additional cost, but the mainstream market will find the cost of FC/AL drives to be high. FC/AL will continue to serve the high-end market, but is unlikely to gain significant market share in lower-performance markets through the remainder of the 1990s. Table 6-1 compares RDD interface features.

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Table 6-1
Comparison of Basic Features for RDD Interfaces

	EIDE	SCSI	Wide SCSI	SSA	1394	FC/AL
Relative Cost	Low	Medium	Medium	Medium	Medium	High
Transfer Rate (MB/Sec)	11.1	10.0	20.0	80.0	50.0	100.0
Approximate Silicon Cost—Host Side ($)	3-5	8-11	10-15	Over 20 today, 5-15 future	Over 25 today, 5-10 future	Over 80 today, less in future
Relative Cabling Cost	Low	High	High	Low	Low	Low
Maximum Cable Length (Copper)	18 in.	6 m	6 m	20 m, device to device	10 m	30 m, device to device
Number of Conductors in Cable	40	50	68 or 80	4	6	Varies
Number of Devices per Interface	4	7	15	126	63	126
Hot Pluggable	No	Not standard	Not standard	Yes	Yes	Yes
Supports External Devices	No	Yes	Yes	Yes	Yes	Yes
Flexible Cable Configuration	No	No	No	Yes	Yes	Yes

Source: Dataquest (October 1995)

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Chapter 7
Semiconductors in Rigid Disk Drives

The major semiconductor devices in a rigid disk drive can be broken into the following categories: preamplifiers, read-channel ICs, motor controllers, servo controllers, peripherals controllers, and memory devices. The market for semiconductors in rigid disk drives is really a semicustom market. Semiconductor vendors develop core products as standard devices, but frequently end up creating a unique (although similar) part for each major customer. The design effort for the core product is leveraged for each customer, but production is customer-specific. A discussion of market trends and technologies follows for each of these categories. Figure 7-1 shows a simple block diagram for a rigid disk drive.

Preamplifiers

A preamplifier is necessary in a rigid disk drive because the electrical signal from the head is comparatively small. Such a small signal cannot reliably be carried outside of the disk enclosure because of electrical interference. The read signal is amplified by the preamp to minimize the effects of interference as the signal travels along a copper trace to the read-channel IC. Preamps are bipolar parts and are typically priced at $1.50. The merchant market for preamps is smaller in terms of units than that for the other semiconductor devices because many drive OEMs prefer captive solutions to merchant ones. These parts must be matched to the type of read/write head in the disk drive. A preamp for an MR head will not work with other types such as an inductive head.

Read-Channel ICs

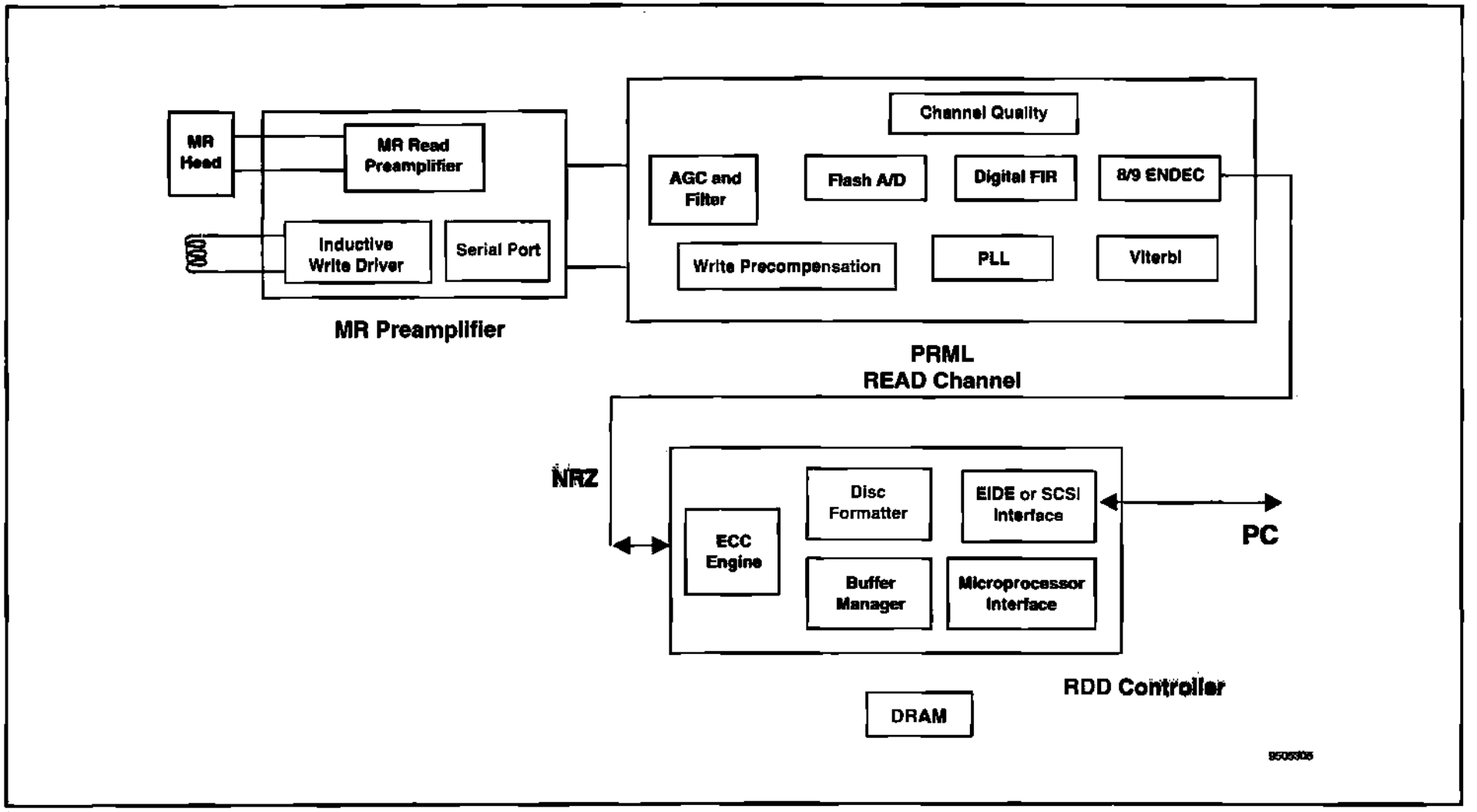
Once the signal from the disk drive head has been amplified, it requires additional processing before going to the disk controller. The first major step is identifying the peaks and valleys that represent encoded data. The goal is to reproduce the signal written to the disk. This conversion may be done using analog properties such as hysteresis, or the signal may be digitized before processing. The next step is to prepare the data stream for the disk controller. This process is called decoding and essentially separates the user data from the control and error correction data. The two data streams (user and error correction) are then passed to the disk controller.

Read-channel performance is a limiting factor in overall hard disk performance. The data rate for the read channel determines how quickly data can be read from the disk itself. Read-channel data rates for mainstream disk drives are 80 Mbit/s to 120 Mbit/s, with the high-end parts at 160 Mbit/s. These rates will rise to 200 Mbit/s in 1996 and are expected to reach 240 Mbit/s in 1997. These rates are specified in terms of user data rather than the data stream coming from the head. The data rate is a function of the maximum clock speed as well as the encoding scheme. Because the data stored on the disk is a combination of user data as well as error control data, the user data rate is always less than the data rate from the platter through the head assembly.

Common encoding schemes result in a 2/3 ratio of user data to written data, but new methods are producing an improved ratio of 8/9. In each case, the maximum clock speed multiplied by the ratio equals the user data rate. For example, a read channel operating at 180 MHz can handle user data rates of 120 Mbit/s with a 2/3 encoding scheme or 160 Mbit/s with an 8/9 encoding scheme. Obviously, the 8/9 encoding scheme is a more efficient use of the channel because it carries more user data at the same clock speed. Faster read-channel ICs are needed to improve the performance of disk drives, but these devices are pushing process technology limits for speed and manufacturability. Single

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Figure 7-1
Block Diagram for a Rigid Disk Drive



Source: GEC Plessey

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chip peak-detect solutions are bipolar or BiCMOS parts. If the peak-detect functions are divided between two chips, then one is bipolar/BiCMOS and the other is CMOS. Most companies use BiCMOS processes for their PRML read-channel products, but others use CMOS or a mix of the two. Dataquest expects these products to be offered in both CMOS and BiCMOS through the end of this decade.

Two types of read-channel technology are predominant: peak detect and PRML. Peak detect read channels are commonly matched with thin-film heads and rely on analog peak detection to convert the signal from the preamp into the encoded data stream. PRML relies on digital signal processing (DSP) techniques rather than analog techniques. PRML read channels are commonly associated with MR heads but are used with thin-film heads also. PRML read channels are higher performance than peak detect but are also more expensive. As areal density continues to increase, along with motor speed and performance expectations for disk drives, PRML will become the dominant type of read channel. PRML is shipping in almost all disk drives from IBM as well as most drives from Quantum. Other manufacturers are still designing and manufacturing drives with peak detect for cost reasons as well as offering PRML-based drives.

Motor Controllers

Disk drives require motor controllers to drive the spindle motor for the rotating platters. These motor controllers have not changed radically since the early Winchester drives, even though the average rpm has increased significantly. This trend will change as speeds approach 10,000 rpm. High-end drives operate at 7,200 rpm and use ball bearings. However, demand for greater performance continues to push drive OEMs to design products with higher rpm. Dataquest expects drive OEMs to change their motor designs from ball bearings to fluid bearings to reach 10,000 rpm. This change will impact motor controller ICs because fluid bearings require nonlinear compensation. Another change that has affected the motor controller market for disk drives is a trend toward using digital signal processors in 1.8-inch drives instead of traditional disk controllers. For the smaller form factors, some OEMs are using a DSP for the overall disk controller as well as the motor and servo controllers. In these cases, the motor controller is replaced by a motor driver and the control functions are performed wholly by the DSP.

The rotational speed affects drive performance in two ways: raw data rate and seek time. The raw data rate is equal to the linear bit density multiplied by the linear speed of the platter under the head. This rate is limited by a number of factors, including the quality of the magnetic media, the rpm, and the read-channel speed. For this example, assume that the linear bit density is maximized, but the read channel is operating at 50 percent of capacity. If the rpm is doubled, then the raw data rate will be doubled without requiring higher-quality media.

Another way that rpm can affect drive performance is access time. Access time is the sum of seek time (the time it takes to position the head over the proper track) plus latency (the time it takes for the beginning of the proper sector to pass under the head). A typical latency is equal to the time for one-half rotation (just over 4ms for a 7,200-rpm drive), because the proper sector will never be more than a single rotation away once the proper track has been found.

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Servo Controllers

Servo controllers are used to position the head assembly over the media in rigid disk drives. The speed of the servo controller impacts the seek time of the disk drive inversely: a higher-speed servo results in a lower seek time. As mentioned, access time is the sum of seek time plus latency. As track densities increase, more precision is required from the servo controller. Today, track densities are limited by the quality of the motor bearings as well as servo precision. The design shift toward fluid bearings as motor speeds increase may impact the servo controller market. Another trend that impacts this market is the shift toward DSP solutions for the smaller drives. Like motor controllers, servo controllers can be replaced by more simple servo drivers if a DSP is used for the disk controller.

Memory Devices

Memory devices are used in rigid disk drives for two functions: holding software and buffering data between the disk and the host interface. Software necessary for the disk drive to operate must be contained in the drive itself. OEMs have conventionally used EPROM to hold the drive software, but the trend is toward flash memory instead of EPROM. The disk drive PCB in appendix B's Figure B-1 shows two 1M flash memories soldered to the card.

The amount of buffer memory installed in drives today varies widely from 32KB SRAM to a full MB of DRAM. A drive that has SRAM for the buffer will most likely have either 32KB or 64KB with a 25ns access time. Buffer sizes larger than 64KB are almost certainly DRAM rather than SRAM. Typical DRAM buffers are either 128KB or 256KB with 70ns access times. As the PC market drives memory manufacturers to produce larger memory devices, some disk drive OEMs are concerned about availability of lower-density memory devices. A shortage of low-density memory devices could increase the average buffer size faster than consumers demand for performance reasons. Dataquest expects the total cost of the buffer memories to increase in disk drives as the average buffer size increases faster than memory prices decline.

Disk Drive Controllers

Disk drive controllers handle a variety of functions that have not been detailed. These functions are primarily communication with the host interface, data buffer control, serializing/deserializing data for the read channel, error correction, hardware defect management, translation of requests into commands for the various disk subsystems (motor, servo, and read-channel), and providing the interface to the subsystems. Actions such as formatting a disk and translating a logical block address into a physical block address are also handled by the disk drive controller.

Several types of disk drive controller interfaces were described in detail in chapter 5. These controllers are not cross-compatible but, other than the interface to the host, they have much functionality in common. The host interface logic can be considered a functional block within the controller. Many semiconductor vendors leverage their controller design efforts by producing controllers for more than one interface. This does not mean that a single device supports more than one interface. It simply means that two products that support different interfaces can be very similar except for the interface logic.

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Some drive OEMs are using DSP solutions instead of standard controllers. This technique is more expensive than using standard controllers, but allows the motor and servo controllers to be replaced with driver ICs. It is most popular for the 1.8-inch drives because of space requirements. Dataquest expects that DSP solutions will continue to be more popular for 1.8-inch drives than for larger form factors.

Table 7-1 (overleaf) shows a product matrix of several semiconductor vendors and the major devices they supply to the rigid disk drive industry.

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Table 7-1
Product Matrix for Semiconductors in RDDs

	Adaptec	Allegro	AMD	Analog Devices	AT&T Microelectronics	Cirrus Logic	GEC Plessey	Hitachi	IMP
Read Channel									
Preamplifier							✔	✔	✔
PD				✔	✔	✔	✔	✔	✔
PRML				✔	✔	✔	✔	✔	
Controller									
IDE/EIDE	✔					✔			
Parallel SCSI	✔					✔			
SSA									
1394	✔								
Fibre Channel									
Microcontrollers/ASICs			✔		✔		✔	✔	
Servo Control		✔		✔	✔	✔	✔	✔	
Motor Control		✔		✔		✔	✔	✔	

	Intel	Micro Linear	Motorola	National Semiconductor	Q Logic	SGS-Thomson	SSI	Symbios	Texas Instruments
Read Channel									
Preamplifier		✔		✔	✔		✔		✔
PD		✔		✔	✔	✔	✔		✔
PRML				✔	✔	✔	✔		✔
Controller									
IDE/EIDE					✔	✔	✔	✔	
Parallel SCSI					✔	✔	✔	✔	✔
SSA									
1394								✔	✔
Fibre Channel					✔			✔	
Microcontrollers/ASICs	✔		✔						✔
Servo Control		✔	✔	✔	✔	✔	✔		✔
Motor Control		✔	✔	✔	✔	✔	✔		✔

Source: Dataquest (October 1995 Estimates)

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Chapter 8

Semiconductor Market Forecast for Disk Drives

Table 8-1 shows unit shipment, average selling price, and revenue statistics and forecasts from 1990 to 1999 for disk drives with 2.5-inch and smaller form factors.

Table 8-2 provides unit shipments, ASP, and revenue statistics and forecasts from 1990 to 1999 for disk drives with 3.5-inch or larger form factors.

Table 8-3 provides statistics and forecasts for semiconductor revenue and content by size of disk drive and product category.

Figure 8-1 displays semiconductor market revenue for rigid disk drives by form factor. Figure 8-2 displays semiconductor market revenue for rigid disk drives by product category.

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Table 8-1
Worldwide 2.5-inch and Smaller Rigid Disk Drive Market

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1990-1994	CAGR (%) 1995-1999
New Shipments (K)	813.60	3,382.20	5,223.50	5,557.70	8,437.40	11,235.00	15,803.00	21,496.00	28,760.00	39,540.00	79.5	37.0
ASP Factory ($K)	0.26	0.24	0.20	0.26	0.24	0.24	0.19	0.16	0.15	0.16	-2.1	-9.1
Revenue Factory ($M)	212.40	817.81	1,050.08	1,447.10	2,026.17	2,652.11	3,009.75	3,520.82	4,387.80	6,361.00	75.7	24.4
ASP End User ($K)	0.78	0.56	0.70	0.51	0.53	0.50	0.40	0.33	0.29	0.32	-9.3	-10.6
Revenue End User ($M)	635.20	1,877.32	3,678.33	2,842.57	4,449.73	5,593.98	6,284.05	7,182.58	8,469.00	12,579.20	62.7	22.5
Retirements (K)	0	0	25	814	2,590	1,260	1,485	4,222	6,627	10,982	NA	71.8
End Installed Base (K)	839	4,221	9,419	14,163	20,011	29,986	44,304	61,578	83,712	112,269	121.0	39.1
Average Megabytes per Drive	22.46	42.56	78.24	157.50	270.23	471.49	709.26	918.46	1,312.90	1,412.15	86.2	31.6

NA = not applicable
Source: Dataquest (October 1995 Estimates)

Table 8-2
Worldwide 3.5-inch and Larger Rigid Disk Drive Market

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1990-1994	CAGR (%) 1995-1999
New Shipments (K)	29,233.38	29,122.68	39,019.26	45,952.10	60,892.20	68,948.40	74,951.20	89,042.00	106,709.20	116,904.00	20.1	14.1
ASP Factory ($K)	0.62	0.64	0.46	0.36	0.25	0.19	0.20	0.18	0.17	0.15	-20.4	-5.4
Revenue Factory ($M)	18,169.89	18,665.49	17,974.79	16,673.82	15,192.56	13,234.80	14,790.88	15,955.00	18,182.52	17,999.80	-4.4	8.0
ASP End User ($K)	1.34	1.52	0.80	0.56	0.33	0.28	0.27	0.26	0.23	0.20	-29.6	-8.2
Revenue End User ($M)	39,150.77	44,368.37	31,273.97	25,944.09	19,998.05	19,166.47	20,211.40	23,396.70	25,005.26	23,071.00	-15.5	4.7
Retirements (K)	2,321	6,327	9,076	14,264	21,399	30,646	33,562	40,833	46,469	60,099	74.3	18.3
End Installed Base (K)	89,091	111,888	141,832	173,520	213,013	248,980	291,259	339,468	399,708	456,343	24.3	16.4
Average Megabytes per Drive	114.59	161.38	200.70	335.51	518.64	803.11	1,339.71	1,736.76	2,270.84	3,161.74	45.9	40.9

Source: Dataquest (October 1995 Estimates)

SAMM-EU-FR-9502

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Table 8-3
Worldwide Rigid Disk Drive Semiconductor Market (Millions of Dollars)

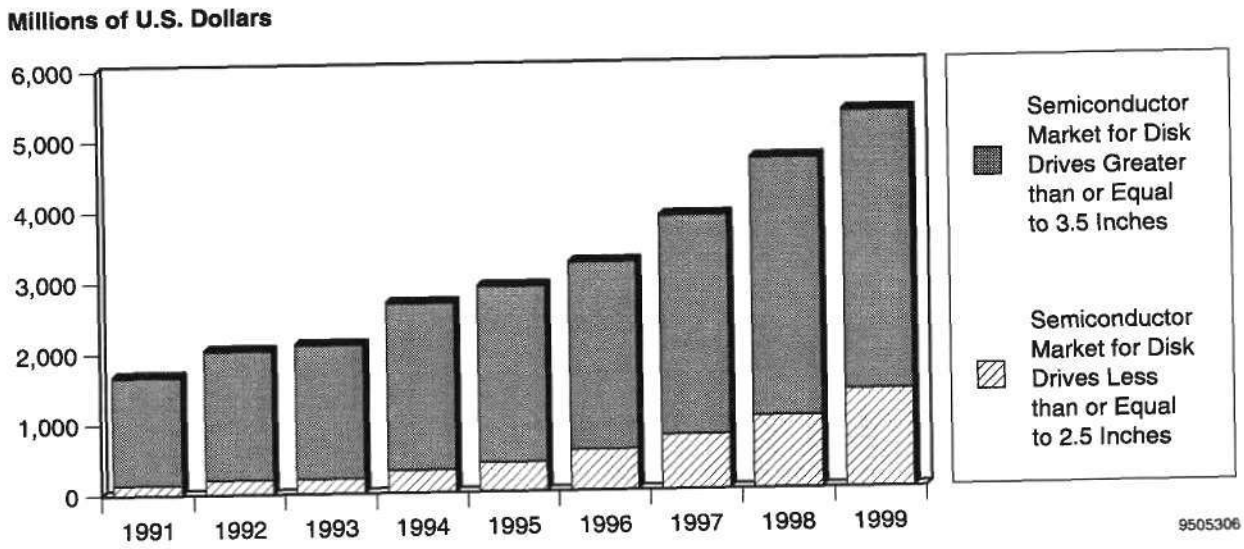
	1991	1992	1993	1994	1995	1996	1997	1998	1999	CAGR (%) 1994-1999
Semiconductor Content ≤2.5 inches ($)	44.00	41.30	39.25	38.52	37.51	36.86	36.26	35.70	35.20	-1.8
Semiconductor Market ≤2.5 inches ($M)	149	216	218	325	421	582	779	1,027	1,392	33.8
Semiconductor Content ≥3.5 inches ($)	52.40	46.73	41.16	38.72	36.01	35.36	34.76	34.20	33.70	-2.7
Semiconductor Market ≥3.5 inches ($M)	1,526	1,823	1,891	2,357	2,483	2,650	3,095	3,650	3,939	10.8
Semiconductor Content All RDD ($)	51.53	46.09	41.02	38.69	36.22	35.62	35.05	34.52	34.08	-2.5
Semiconductor Market All RDD ($M)	1,675	2,039	2,110	2,682	2,904	3,233	3,874	4,677	5,331	14.7
Memory ($M)	261	313	317	428	519	632	825	1,078	1,322	25.3
Analog ($M)	592	694	674	824	802	889	1,062	1,275	1,443	11.9
Microcontroller ($M)	223	279	301	395	435	471	547	640	708	12.4
ASIC/ASSP ($M)	563	709	773	981	1,086	1,171	1,357	1,583	1,743	12.2
Standard Logic ($M)	24	29	29	32	36	41	49	59	68	16.1
Discrete ($M)	12	15	16	22	25	29	34	42	48	16.4

Source: Dataquest (October 1995 Estimates)

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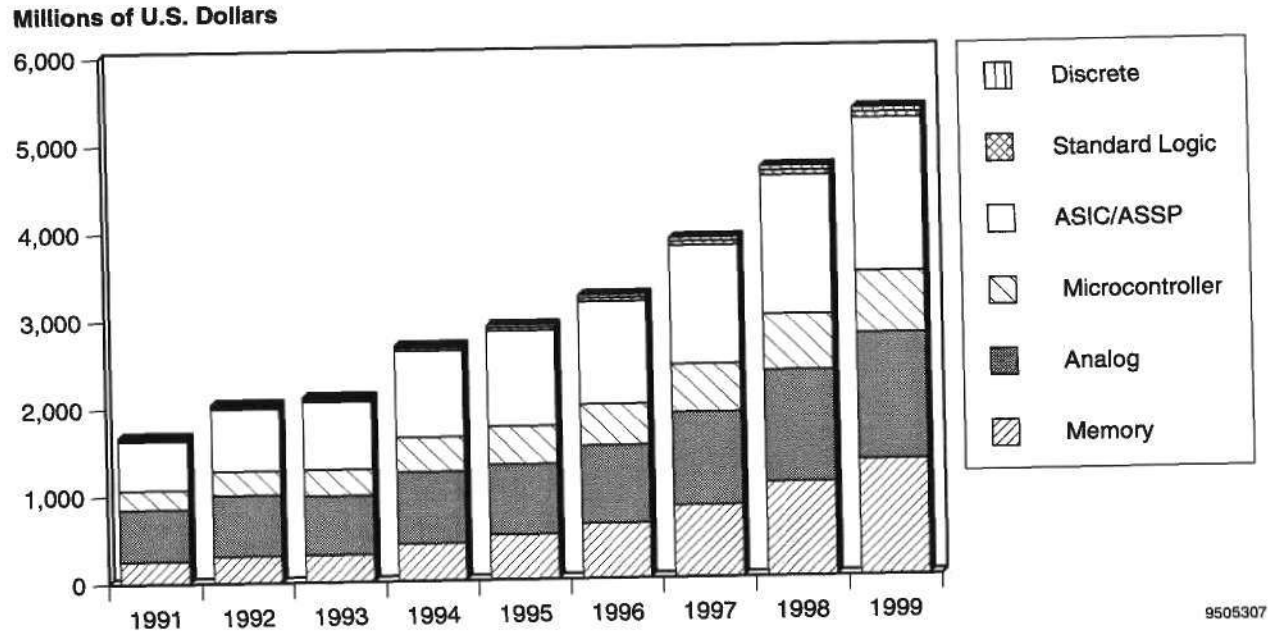
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Figure 8-1
Worldwide Semiconductor Market for RDDs by Size



Source: Dataquest (October 1995 Estimates)

Figure 8-2
Worldwide Semiconductor Market for RDDs by Product Category



Source: Dataquest (October 1995 Estimates)

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Chapter 9
Dataquest Perspective

The market for semiconductors in rigid disk drives can be considered a pseudocustom market. Semiconductor devices for rigid disk drives are generally high-volume, customer-tailored designs. This does not mean that the entire industry is ASIC-driven because the level of customization for each account does not require an ASIC level of redesign and optimization. However, each design does generally require a new set of masks for production because customers demand varying amounts of memory as well as slight variations in other features. There are standard products available that are not customer-specific, but these are generally lower-performance and less expensive parts. Leading-edge products are designed in cooperation with the drive OEMs because no one wants to throw a party without guests (that is, customers). The relationships between the large OEMs and their suppliers appear to be "virtual" vertical integration with long-term cooperation.

Semiconductor vendors are advised to use the cooperative nature of these relationships. Semiconductor performance and costs are critical elements of disk drive performance and cost. Without continued development in semiconductors as well as heads and media, drive OEMs will not be able to sustain the 60 percent growth rate in areal density that the industry has exhibited over the past few years. Cooperation between semiconductor vendors and OEMs will result in better disk drives as the semiconductor vendors supply IC design expertise, process technology, and fab capacity and OEMs provide integration and assembly expertise.

Additionally, the drive OEM market is consolidating. Quantum purchased Digital Equipment Corporation's drive operations, and Seagate has purchased Conner Peripherals. Fewer OEMs means fewer design-win opportunities for semiconductor vendors. Keeping a healthy relationship, fuelled by continued process and device improvements, will be essential for semiconductor vendors to grow unit shipments and revenue. In other words, tend that garden and it will bear fruit.

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Appendix A
Current RDD Product Specifications

Table A-1 provides specifications for rigid disk drives 5.25 inches and smaller that are known to be shipping today.

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Table A-1
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Areal Technology	2.5-inch	A175	175	1	2	13	3,600	74,000	3,920	290	175	3.875	AT/IDE	0.49	2	150,000	Glass media
Areal Technology	2.5-inch	A270	270	1	2	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.5	1.9	250,000	Glass media
Areal Technology	2.5-inch	A340	340	3	6	13	3,600	76,000	2,800	213	113		AT/IDE	0.75	4	150,000	Glass media
Areal Technology	2.5-inch	A345	350	2	4	13	3,600	73,000	4,029	294	175	3.875	AT/IDE	0.5	2.15	150,000	Glass media
Areal Technology	2.5-inch	A525	525	4	8	13	3,600	76,000	2,800	213	131		AT/IDE	0.75	4	150,000	Glass media
Areal Technology	2.5-inch	A520	526	3	6	13	3,600	74,000	3,920	290	175	3.875	AT/IDE	0.75	2.375	150,000	Glass media
Areal Technology	2.5-inch	A540	540	2	4	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.5	1.9	250,000	Glass media
Areal Technology	2.5-inch	A700	702	4	8	13	3,600	74,000	3,920	290	176	3.875	AT/IDE	0.75	2.375	150,000	Glass media
Areal Technology	2.5-inch	A810	810	3	6	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.75	1.9	250,000	Glass media
Areal Technology	2.5-inch	A1080	1,080	4	8	13	4,500	97,000	4,600	446	270	6.5	Fast ATA-2	0.75	1.9	250,000	Glass media
Calluna	1.8-inch	Callunacard 260	260	2	4	16	4,500				130	4.84	PCMCIA-III	0.41	2.2		
Conner	2.5-inch	CFN 170	170	2	4	12	4,500	58,230	2,611	152	85	3.5	IDE/SCSI2	0.77	1.4	150,000	
Conner	2.5-inch	CFN 250	250	3	6	12	4,500	58,230	2,611	152	83	3.5	IDE/SCSI2	0.77	1.4	150,000	
Conner	2.5-inch	CFN 340A	340	3	6	13	4,000	65,564	3,004	197	113	4	IDE	0.77	0.9	150,000	
Conner	2.5-inch	CFL 350A	350	2	4	12	3,750	70,600	4,110	290	175	4	IDE	0.50	0.75	300,000	Kiwi
Conner	2.5-inch	CFL 420A	422	2	4	12	3,600	80,000	4,200	336	211	4.125	IDE	0.50	1.3	300,000	Kiwi
Conner	3.5-inch	CFS 210A	213.4	1	2	14	3,600	58,566	2,774	162	213	4	IDE	1.00	5.7	250,000	
Conner	3.5-inch	CFS 270A	270	1	2	15	3,400	68,000	2,988	203	270	1.3	IDE	1.00	4.5	250,000	Cabo
Conner	3.5-inch	CFS 425A	425	1	2	15	3,600	75,000	3,840	288	425	1.3	IDE	1.00	5.7	250,000	Cabo
Conner	3.5-inch	CFA 425	426	1	2	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	
Conner	3.5-inch	CFS 420A	426.8	2	4	14	3,600	58,566	2,774	162	213	4	IDE	1.00	5.7	250,000	
Conner	3.5-inch	CFA 540	540	2	4	12	4,500	62,500	2,805	175	270	5.75	IDE/SCSI2	1.00	5	300,000	Steamboat
Conner	3.5-inch	CFS 540A	540	2	4	15	3,600	70,000	2,990	209	270	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFS 541A	540	1	2	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFS 638A	635	2	3	14	3,600	93,000	4,100	381	423	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFA 810	810	3	6	12	4,500	65,000	3,245	211	270	5.75	IDE/SCSI2	1.00	11.8	300,000	
Conner	3.5-inch	CFS 850A	850	2	4	15	3,600	75,000	3,833	287	425	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFA 850	852	2	4	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	Steamboat
Conner	3.5-inch	CFP 1060	1,060	4	8	9	5,400	65,131	3,147	205	265	6.875	SCSI2 F/W	1.00	14.3	500,000	

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Conner	3.5-inch	CFP 1080	1,080	3	6	11	5,400	64,000	3,833	245	360	6.925	SCSI2 F/W	1.00	5.6	500,000	Antigua
Conner	3.5-inch	CFS 1081A	1,080	2	4	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFA 1080	1,080	4	8	10.5	4,500	65,000	3,245	211	270	5.75	IDE/SCSI2	1.00	12.8	300,000	Barbados
Conner	3.5-inch	CFS 1275A	1,278	3	6	15	3,600	75,000	3,833	287	426	1.3	IDE	1.00	5.6	250,000	Cabo
Conner	3.5-inch	CFA 1275	1,278	3	6	12	4,500	77,350	3,833	296	426	7.55	IDE/SCSI2	1.00	5.3	300,000	Steamboat
Conner	3.5-inch	CFS 1621A	1,620	3	6	14	3,600	93,000	4,100	381	540	1.3	EIDE	1.00	5.7	300,000	Cabo
Conner	3.5-inch	CFP 2107	2,110	5	10	8.5	7,200	78,000	4,010	313	422	10.925	SCSI2 F/W	1.00	10	1,000,000	
Conner	3.5-inch	CFP 2120	2,120	8	16	9.5	5,400	64,980	3,147	204	265	6.875	SCSI2 F/W	1.63	17.1	500,000	
Conner	3.5-inch	CFP 2105	2,147	5	10	8.5	5,400	74,000	3,980	295	429	9.1375	SCSI2 F/W	1.00	7.6	1,000,000	
Conner	3.5-inch	CFP 4207	4,220	10	20	9	7,200	78,000	4,055	316	422	10.925	SCSI2 F/W	1.60	14.3	1,000,000	SSA available
Conner	3.5-inch	Aruba	4,320	4	8		7,200			810	1,080		SCSI2 F/W	1.00			MR heads, PRML
Conner	3.5-inch	Aruba	5,400	5	10		7,200			810	1,080		SCSI2 F/W	1.00			MR heads, PRML
Conner	3.5-inch	Aruba	8,640	8	16		7,200			810	1,080		SCSI2 F/W	1.60			MR heads, PRML
Conner	3.5-inch	Aruba	10,800	10	20		7,200			810	1,080		SCSI2 F/W	1.60			MR heads, PRML
Fujitsu	2.5-inch	M2704S	353	2	4	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	2.5-inch	M2705S	442	3	5	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	2.5-inch	M2706S, Hornet 5	532	3	6	12	5,400	78,000	4,300	335	177		IDE OR SCSI2	0.67		300,000	MR heads, PRML channel
Fujitsu	3.5-inch	M2681SA	264	2	3	14	4,500				176	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2622T	326.7	4	7	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2682SA	353	2	4	14	4,500				177	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2623T	420.1	5	9	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2624T	513.5	6	11	12	4,400				93		IDE	1.63		200,000	MIG heads, std. channel
Fujitsu	3.5-inch	M2684SA	532	3	6	14	4,500				177	4.68	SCSI2	1.00		250,000	MIG heads, std. channel
Fujitsu	3.5-inch	M160x	540	2	3	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M160x	720	2	4	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M160x	1,080	3	6	10	5,400				360	7.8	IDE OR SCSI2 F/W	1.00		500,000	Allegro 2
Fujitsu	3.5-inch	M2927	1,130	4	7	9.6	5,400	75,535	3,553	268	323	6.8	SCSI2 F/W	1.00		500,000	MR heads, PRML channel

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Fujitsu	3.5-inch	M2903	2,110	7	13	9.6	5,400	75,536	3,553	268	325	6.8	SCSI2 F/W	1.63		500,000	MR heads, PR4ML channel
Fujitsu	3.5-inch	M2915	2,170	8	15	8.9	7,200	71,627	3,553	254	289	8	SCSI2 F/W	1.63		500,000	MR heads, PR4ML channel
Fujitsu	3.5-inch	M2909	3,100	10	19	9.6	5,400	75,500	3,550	268	326	6.8	SCSI2 F/W	1.63		500,000	MR heads, PR4ML channel
Fujitsu	3.5-inch	M160x	4,400	10	19	10	7,200	102,400	3,758	385	463	11.3	SCSI2 F/W	1.63		500,000	Allegro 2, MR heads, PR4ML
Fujitsu	5.25-in	M2654	2,055	12	21	11.5	5,400	50,200	1,840	92	196		SCSI2 F	3.25		500,000	2, 4, 8, or 16MB cache options
Hewlett-Packard	3.5-inch	C3323A	1,050	4	7	9.5	5,400	69,200	3,223	223	300	6	SCSI2 F/W	1.00	10	500,000	
Hewlett-Packard	3.5-inch	C2490A	2,100	10	18	8.9	6,400	58,500	2,840	166	233	6	SCSI2 F/W	1.63	15.8	500,000	
Hewlett-Packard	3.5-inch	C3325A	2,170	5	9	9.5	5,400	92,000	4,000	368	482	8	SCSI2 F/W	1.00	9.2	800,000	PRML channel
Hewlett-Packard	3.5-inch	C3330A	2,175	3	5	9.2	7,200	135,000	5,660	764	870	15	SCSI2 F/W	1.00	11.7	1,200,000	MR heads, PRML
Hewlett-Packard	3.5-inch	C3331A	4,350	5	10	9.2	7,200	135,000	5,660	764	870	15	SCSI2 F/W	1.00	11.7	1,200,000	MR heads, PRML
Hitachi	2.5-inch	DK222A-27	270	1	2	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.50	2	300,000	Glass media
Hitachi	2.5-inch	DK221A-34	340	2	4	12.6	4,464	83,000	3,500	291	170	5.9	ATA/IDE	0.50	2	300,000	
Hitachi	2.5-inch	DK221A-51	510	3	6	12.6	4,464	83,000	3,500	291	170	5.9	ATA/IDE	0.75	2	300,000	
Hitachi	2.5-inch	DK221C-51	510	3	6	12.6	4,464	83,000	3,500	291	170	5.9	SCSI2F	0.75	2	300,000	
Hitachi	2.5-inch	DK222A-54	540	2	4	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.50	2	300,000	Glass media
Hitachi	2.5-inch	Preview	720	2	4	12	4,464				360	6.1	EIDE	0.50	2	300,000	MR hands, PRML, glass
Hitachi	2.5-inch	DK212A-81	810	3	6	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.75	2	300,000	Glass media
Hitachi	2.5-inch	DK212A-10	1,080	4	8	12	4,464	99,000	4,500	446	270	6.1	EIDE	0.75	2	300,000	Glass media
Hitachi	3.5-inch	DK326C-6	601	3	4	9.8	6,300	63,500	3,600	229	301	7	SCSI2 F	1.00		400,000	
Hitachi	3.5-inch	DK325C-6WD	601	3	4	9.8	6,300	63,500	3,600	229	301	7	SCSI2 W	1.00		400,000	
Hitachi	3.5-inch	DK326C-10WD	1,052	4	7	9.8	6,300	63,500	3,600	229	301	7	SCSI2 W	1.00		400,000	
Hitachi	3.5-inch	DK328C-10	1,052	2	3	9.8	5,800	120,000	5,400	648	701	11	SCSI2 F/W	1.00	2	800,000	MR heads, peak detect, embedded servo
Hitachi	3.5-inch	DK326C-10	1,052	4	7	9.8	6,300	63,500	3,600	229	301	7	SCSI2 F	1.00		400,000	
Hitachi	3.5-inch	Preview	2,100	3	5	9.8	7,200				840	11	SCSI2 F/W	1.00	2	800,000	MR heads, PRML, embedded servo
Hitachi	3.5-inch	DK328C-21	2,100	3	5	9.8	5,800	120,000	5,400	648	840	11	SCSI2 F/W	1.00	2	800,000	MR heads, peak detect, embedded servo
Hitachi	3.5-inch	DK328C-43	4,300	5	10	9.8	5,800	120,000	5,400	648	860	11	SCSI2 F/W	1.00	4	800,000	MR heads, peak detect, embedded servo

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Hitachi	3.5-inch	Preview	4,300	5	10	9.8	7,200				860	11	SCSI2 F/W	1.00	2	800,000	MR heads, PRML, embedded servo
IBM	2.5-inch	DHAA-2270	270	1	2	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAS-2270	270	1	2	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2360 Bolero	360	1	2	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DHAA-2405	405	2	3	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAS-2405	405	2	3	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2540 Bolero	540	2	3	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DHAS-2540	540	2	4	14	3,800	93,100	5,300	493	270	9	SCSI2F	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DHAA-2540	540	2	4	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DBOA-2720 Bolero	720	2	4	13	4,000	101,400	6,350	644	360	4.9375	ATA-2	0.50	2.3	300,000	MR heads
IBM	2.5-inch	DVAA-2810	810	3	6	14	3,800	93,100	5,300	493	270	9	ATA/IDE	0.67	2.8	300,000	MR heads, PRML channel
IBM	2.5-inch	DPRA-20810 Presto	810	2	4	12	4,900	110,300	6,350	700	405	7.125	ATA-2 and SCSI2F	0.67	2.6	300,000	MR heads, Travelstar XP
IBM	2.5-inch	DPRA-21215 Presto	1,215	3	6	12	4,900	110,300	6,350	700	405	7.125	ATA-2 and SCSI2F	0.67	2.6	300,000	MR heads, Travelstar XP
IBM	3.5-inch	DSAS-3270	281	1	2	12	4,500	83,200	4,300	358	281	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3270	281	1	2	12	4,500	83,200	4,300	358	281	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAS-3360	365	1	2	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3360	365	1	2	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DPEA-30540 Pegasus	540	1	2	10.5	5,400	85,600	5,340	457	540	6.8875	ATA/SCSI2	1.00	6.3	500,000	MR heads, Deskstar XP
IBM	3.5-inch	DALA-3540 Aladdin	540	1	2	12	4,500	82,600	5,340	441	540	6.0875	ATA/SCSI2	1.00	5.2	350,000	MR heads, Deskstar
IBM	3.5-inch	DSAS-3540	548	2	3	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA3540	548	2	3	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAS-3720	730	2	4	12	4,500	83,200	4,300	358	365	5.56	SCSI2F	1.00	4.8	300,000	MR heads, PRML channel
IBM	3.5-inch	DSAA-3720	730	2	4	12	4,500	83,200	4,300	358	365	5.56	ATA/IDE	1.00	4.8	300,000	MR heads, PRML channel

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
IBM	3.5-inch	0662A	1,052	3	6	8.5	5,400	78,200	4,077	319	351	6	ATA/IDE	1.00		500,000	MR heads, PRML channel
IBM	3.5-inch	0662	1,052	3	6	8.5	5,400	86,900	4,077	354	351	5	PIO, DMA	1.00		500,000	MR heads, PRML channel
IBM	3.5-inch	DFHS-31080	1,080	2	4	6.9	7,200	125,000	4,352	544	540	12.6	SCSI2, F/W	1.00	9.1	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-31080	1,080	2	4	8	5,400	128,900	4,351	561	540	12.2	SCSI2, F/W	1.00	9.4	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DPEA-31080 Pegasus	1,080	2	4	10.5	5,400	85,600	5,340	457	540	6.8875	ATA/SCSI2	1.00	6.7	500,000	MR heads
IBM	3.5-inch	DJAA-31210 Jaffar	1,210	2	3	12	4,500	99,000	6,700	663	807	7.7625	ATA/SCSI2	1.00	3.9	350,000	MR heads, Deskstar
IBM	3.5-inch	DJAA-31700 Jaffar	1,700	2	4	12	4,500	99,000	6,700	663	850	7.7625	ATA/SCSI2	1.00	3.9	350,000	MR heads, Deskstar
IBM	3.5-inch	0664 Allicat	2,014	8	16	9.2	5,400	61,913	3,168	260	252		SCSI2, F/W	1.60	12.7	750,000	MR heads, PRDF channel
IBM	3.5-inch	DFMS-32160	2,325	4	8	7.5	5,400	133,000	4,362	580	581	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFHS-32160	2,255	4	8	7.5	7,200	133,000	4,362	580	564	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFMS-32600	2,657	4	8	7.5	5,400	133,000	4,352	579	664	12.6	SCSI2, F/W	1.00	9	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DFHS-34320	4,512	8	16	8	7,200	125,000	4,352	544	564	12.6	SCSI2, F/W	1.63	15.5	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-34320	4,320	7	13	8	5,400	133,000	4,352	579	665	12.6	SCSI2, F/W	1.63	11	1,000,000	MR heads, PRML channel
IBM	3.5-inch	Ultrastar AV	5,106	8	16	8	5,400	133,000	4,352	579	638	7.6	SCSI2, F/W	1.63	11.2	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DFMS-35250	5,318	8	16	8	5,400	133,000	4,352	579	665	12.6	SCSI2, F/W	1.63	11.2	1,000,000	MR heads, PRML channel
IBM	3.5-inch	DCHS-38700 Scorpion HP	8,700	9	18	8.9	7,200	133,000	5,966	793	967	14.2	SCSI2, F/W	1.63	17.5	1,000,000	MR heads, PRML channel, SSA
IBM	3.5-inch	DCMS-310800 Scorpion HC	10,800	10	20	8.9	5,400	133,000	5,966	793	1,080	14.2	SCSI2, F/W	1.63	14	1,000,000	MR heads, PRML channel, SSA
Integral Peripherals	1.8-inch	Viper 105	105.4	2	4	15	4,500	70,000	2,840	199	53	3	PCMCIA-III	0.41	1.5	250,000	
Integral Peripherals	1.8-inch	Viper 170	170.8	2	4	12	4,500	84,000	3,800	319	85	3.5	PCMCIA-III	0.41	1.5	250,000	
Integral Peripherals	1.8-inch	Viper 260	260.7	2	4	12	4,500	112,350	4,300	483	130	6	PCMCIA-III	0.41	2.2	250,000	IBM media, PRML
Integral Peripherals	1.8-inch	Viper 340	340.6	2	4	12	4,500	123,600	5,100	630	170	6	PCMCIA-III	0.41	2.1	250,000	IBM media, PRML
Integral Peripherals	2.5-inch	Platinum 720	720	3	5	12	4,200	104,550	5,100	533	288	8	ATA-2	0.50	2	250,000	IBM media PRML

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Integral Peripherals	2.5-inch	Platinum 1010	1,010	3	6	12	4,200	123,000	5,100	627	337	8	ATA-2	0.50	2	250,000	IBM media PRML
Maxtor	1.8-inch	MobileMax Lite 85	85	1	2	16	4,464	69,600	3,606	251	85	3.18	PCMCIA-II	0.20	1.65	300,000	Glass media, 3.3V, Type II
Maxtor	1.8-inch	MobileMax 105	105	2	4	19	4,464	58,000	2,727	158	53	2.425	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax Lite 121	121	1	2	16	4,464	86,500	4,110	356	121	3.18	PCMCIA-II	0.20	1.65	300,000	Glass media, 3.3V, Type II
Maxtor	1.8-inch	MobileMax 131	131	2	4	19	4,464	58,000	3,332	193	66	2.425	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax 171	171	2	4	16	4,464	67,500	3,555	240	86	3.1875	PCMCIA-III	0.41	1.65	300,000	Glass media
Maxtor	1.8-inch	MobileMax 262	262	2	4	16	4,464	67,500	3,555	240	131	4	PCMCIA-III	0.41	1.65	300,000	Glass media, proximity recording
Maxtor	2.5-inch	250837	837	3	5	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	2.5-inch	251005	1,005	3	6	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	2.5-inch	251340	1,340	4	8	14	4,464	92,200	5,080	468	335	11.1	EIDE	0.50	1.7	300,000	Proximity recording
Maxtor	3.5-inch	7135AV	135	1	1	14	3,551	64,100	3,100	199	270	4.75	IDE	1.00	4.07	300,000	
Maxtor	3.5-inch	7270AV	270	1	2	12	3,551	64,100	3,100	199	270	11.1	EIDE	1.00	3.9	300,000	
Maxtor	3.5-inch	7420AV	422	2	3	14	3,551	64,100	3,100	199	281	4.75	IDE	1.00	4.28	300,000	
Maxtor	3.5-inch	7425AV	426	1	2	12	3,551	73,870	3,900	288	426	5.36	EIDE	1.00	4.07	300,000	
Maxtor	3.5-inch	7540AV	540	2	4	14	3,551	64,100	3,100	199	270	4.75	IDE	1.00	4.28	300,000	
Maxtor	3.5-inch	7541A	541	1	2	12	4,480	92,130	4,232	390	541	8.1	EIDE	1.00	4.25	300,000	Proximity recording
Maxtor	3.5-inch	7546	546	2	4	12	4,500	68,500	3,050	209	273	5.6	IDE and SCSI2	1.00	3.7	300,000	
Maxtor	3.5-inch	7850AV	853	2	4	12	3,551	73,870	3,900	288	427	5.36	EIDE	1.00	4.07	300,000	
Maxtor	3.5-inch	71050A	1,050	3	5	12	4,500	78,400	4,030	316	420	6.19	IDE and SCSI2	1.00	5.6	300,000	
Maxtor	3.5-inch	71084AP	1,084	2	4	12	4,480	92,130	4,232	390	542	8.1	EIDE	1.00	4.25	300,000	Proximity recording
Maxtor	3.5-inch	71260A	1,260	3	6	12	4,500	78,400	4,030	316	420	6.19	IDE & SCSI2	1.00	5.6	300,000	
Maxtor	3.5-inch	71626AP	1,626	3	6	12	4,480	92,130	4,232	390	542	8.1	EIDE	1.00	4.25	300,000	Proximity recording
Micropolis	3.5-inch	4110	1,052	5	9	8.5	5,400				234	5.875	SCSI2 F	1.00	8.5	500,000	
Micropolis	3.5-inch	2210	1,056	5	9	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	2210AV	1,056	5	9	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	4110A	1,057	5	9	8.5	5,400				235	5.875	IDE	1.00	8.25	500,000	
Micropolis	3.5-inch	2217AV	1,765	8	15	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	2217	1,765	8	15	10	5,400				235	5.8125	SCSI2 F	1.63	12	300,000	
Micropolis	3.5-inch	4221	2,140	5	9	8.9	7,200			320	476	10.125	SCSI2 F/W	1.00	10.25	1,000,000	Taurus
Micropolis	3.5-inch	3131	3,150	10	19	8	7,200				332	8.375	SCSI2 F/W	1.63	14	1,000,000	
Micropolis	3.5-inch	3243	4,290	10	19	8.9	7,200			320	452	10	SCSI2 F/W	1.63	14	1,000,000	Capricorn
Micropolis	5.25-inch	1991	9,100	14	27	12	5,400				674	9.625	SCSI2 F/W	3.25		1,000,000	

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
MiniStor Peripherals	1.8-inch	130A	130	2	4	15	4,464	76,500	3,200	245	65	3.225	PCMCIA-II	0.41	1.5	250,000	
MiniStor Peripherals	1.8-inch	260A	260	2	4	15	4,464	76,500	3,200	245	130	3.225	PCMCIA-II	0.41	1.5	250,000	Data compressed by Stac
MiniStor Peripherals	2.5-inch	M340	340	2	4	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.50	2	250,000	
MiniStor Peripherals	2.5-inch	M510	510	3	6	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.75	2	250,000	
MiniStor Peripherals	2.5-inch	M680	680	4	8	12.6	4,464	80,200	3,620	290	170	4.875	ATA/IDE	0.75	2	250,000	
NEC	2.5-inch	D2713	352	2	4	14.5	4,000	74,700	3,600	268.92	176	4.4	IDE	0.5		300,000	
NEC	3.5-inch	D3713	345	2	4	12	4,090	56,000	2,500	140	172.5	3	IDE/SCSI	1.00	4.8	250,000	
NEC	3.5-inch	D3723	365	1	2	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3823	365	1	2	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3724	426	1	2	14	4,090	85,500	3,800	325	426	7.2	ATA	1.00	4	300,000	PRML
NEC	3.5-inch	D3743	540	1	2	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3843	540	1	2	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3717	540	2	4	12	4,500	63,871	3,100	198	270	6	IDE/SCSI2	1.00	4.8	250,000	TF heads
NEC	3.5-inch	D3725	730	2	4	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	TF heads
NEC	3.5-inch	D3825	730	2	4	11	4,090	71,000	3,800	269.8	365	6	IDE	1.00		300,000	
NEC	3.5-inch	D3726	853	2	4	14	4,090	85,500	3,800	325	426	7.2	ATA	1.00	4	300,000	TF heads, PRML
NEC	3.5-inch	D3845	1,080	2	4	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3745	1,080	2	4	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3727	1,083	3	6	11	4,090	71,000	3,800	269.8	361	6	IDE	1.00		300,000	TF heads
NEC	3.5-inch	D3847	1,620	3	6	10	4,500	100,000	4,000	400	540		SCSI2	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3747	1,620	3	6	10	4,500	100,000	4,000	400	540		ATA	1.00		300,000	TF heads, PRML
NEC	3.5-inch	D3896	2,160	5	9	9	7,200	78,000	4,070	317.46	480		SCSI2	1.00		800,000	TF heads
Quantum	2.5-inch	GLS 85	85	1	2	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.49	2	350,000	
Quantum	2.5-inch	Daytona 127	127	1	2	17	4,500	71,600	3,100	222	127	4	IDE OR SCSI2	0.50	2.2	350,000	
Quantum	2.5-inch	GLS 127	127	2	3	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.67	2	350,000	
Quantum	2.5-inch	GLS 170	170	2	4	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.67	2	350,000	
Quantum	2.5-inch	Daytona 256	256	2	4	17	4,500	71,600	3,100	222	128	4	IDE OR SCSI2	0.50	2.2	350,000	
Quantum	2.5-inch	GLS 256	256	3	6	17	3,600	57,812	2,529	146	85	2.875	IDE OR SCSI2	0.75	2	350,000	
Quantum	2.5-inch	Daytona 341	341	3	6	17	4,500	71,600	3,100	222	114	4	IDE OR SCSI2	0.75	2.3	350,000	
Quantum	2.5-inch	Daytona 514	514	4	8	17	4,500	71,600	3,100	222	129	4	IDE OR SCSI2	0.75	2.3	350,000	
Quantum	2.5-inch	Europa 540	540	2	4	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.49	2.5	350,000	MR heads, PRML
Quantum	2.5-inch	Europa 810	810	3	6	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.74	2.5	350,000	MR heads, PRML
Quantum	2.5-inch	Europa 1080	1,080	4	8	14	3,800	96,373	5,300	511	270	4.875	ATA-2	0.74	2.5	350,000	MR heads, PRML
Quantum	3.5-inch	LPS 127	127	1	2	14	3,600	48,865	2,670	130	127	3.5	IDE OR SCSI2	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 170	170	1	2	14	3,600	48,865	2,670	130	170	3.5	IDE OR SCSI2	1.00	4.6	300,000	

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Quantum	3.5-inch	Maverick 270S	270	1	2	14	3,600	60,204	2,950	178	270	4.51	SCSI	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 270	270	1	2	12	4,500	62,600	2,875	180	270	5.75	IDE OR SCSI2	1.00	5.2	300,000	
Quantum	3.5-inch	Maverick 270AT	270	1	2	14	3,600	60,204	2,950	178	270	4.51	IDE	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 340	340	2	4	12	3,600	49,273	2,670	132	170	3.5	IDE OR SCSI2	1.00	4.3	300,000	
Quantum	3.5-inch	Lightning 365S	365	1	2	11	4,500	63,515	3,794	241	365	5.9	SCSI	1.00	5.7	300,000	
Quantum	3.5-inch	Lightning 365A	365	1	2	11	4,500	63,515	3,794	241	365	5.9	IDE	1.00	5.7	300,000	
Quantum	3.5-inch	Trailblazer	425	1	2	14	4,500	74,258	3,794	282	425	6.7125	Fast ATA, SCSI2	1.00	4.5	300,000	MIG heads
Quantum	3.5-inch	Lightning 540A	540	2	3	11	4,500	63,515	3,794	241	360	5.9	IDE	1.00	6.3	300,000	
Quantum	3.5-inch	Lightning 540S	540	2	3	11	4,500	63,515	3,794	241	360	5.9	SCSI	1.00	6.3	300,000	
Quantum	3.5-inch	Maverick 540AT	540	2	4	14	3,600	60,204	2,950	178	270	4.51	IDE	1.00	4.6	300,000	
Quantum	3.5-inch	LPS 540	540	2	4	12	4,500	62,600	2,875	180	270	5.75	IDE OR SCSI2	1.00	5.9	300,000	
Quantum	3.5-inch	Maverick 540S	540	2	4	14	3,600	60,204	2,950	178	270	4.51	SCSI	1.00	4.6	300,000	
Quantum	3.5-inch	Fireball	545	1	2	12	5,400	92,982	4,200	391	545	10.5	Fast ATA, SCSI3	1.00	5	500,000	
Quantum	3.5-inch	Capella 3055	551	2	4	8.5	5,400	57,996	3,256	189	276	6.5	SCSI2 F/W	1.00	6	700,000	
Quantum	3.5-inch	Lightning 730A	730	2	4	11	4,500	63,515	3,794	241	365	5.9	IDE	1.00	6.3	300,000	
Quantum	3.5-inch	Lightning 730S	730	2	4	11	4,500	63,515	3,794	241	365	5.9	SCSI	1.00	6.3	300,000	
Quantum	3.5-inch	Trailblazer	850	2	4	14	4,500	74,258	3,794	282	425	6.7125	Fast ATA, SCSI2	1.00	4.5	300,000	MIG heads
Quantum	3.5-inch	Atlas XP31070	1,075	3	5	8	7,200	72,490	3,858	280	430	8.5	SCSI2 F/W	1.00	11	800,000	
Quantum	3.5-inch	Empire 1080	1,080	4	8	9.5	5,400	61,300	3,014	185	270	6	SCSI3 F/W	1.00	7.5	500,000	
Quantum	3.5-inch	Fireball	1,090	2	4	12	5,400	92,982	4,200	391	545	10.5	Fast ATA, SCSI3	1.00	5.5	500,000	
Quantum	3.5-inch	Capella 31110	1,108	2	4	8.5	5,400	92,000	4,350	400	554	6.9	SCSI2 F/W	1.00	7	800,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire 1400	1,400	4	8	9.5	5,400	80,000	3,150	252	350	8	SCSI3 F/W	1.00	10.5	500,000	PRML channel
Quantum	3.5-inch	Empire 2100	2,100	6	12	9.5	5,400	80,000	3,150	252	350	8	SCSI3 F/W	1.63	12.5	500,000	PRML channel
Quantum	3.5-inch	Grand Prix XP32140	2,140	5	10	8.6	7,200	79,600	4,000	318	428	9.7	SCSI3 F/W	1.63	10	800,000	PRML channel
Quantum	3.5-inch	Atlas XP32150	2,150	5	10	8	7,200	72,490	3,858	280	430	8.5	SCSI2 F/W	1.00	10	800,000	
Quantum	3.5-inch	Atlas II XP32181	2,180	3	5	7.8	7,200	106,000	6,000	636	872	13.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire II VP32181	2,180	3	5	8.9	5,400	98,000	5,701	559	872	11.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, PRML channel
Quantum	3.5-inch	Capella 32210	2,216	4	8	8.5	5,400	92,000	4,350	400	554	6.9	SCSI2 F/W	1.00	7	800,000	MR heads, ASABET chipset
Quantum	3.5-inch	Grand Prix XP34280	4,280	10	20	8.6	7,200	79,600	4,000	318	428	9.7	SCSI3 F/W	1.63	14	800,000	PRML channel
Quantum	3.5-inch	Atlas XP34300	4,300	10	20	8	7,200	72,284	3,858	279	430	8.5	SCSI2 F/W	1.63	14	800,000	
Quantum	3.5-inch	Atlas II XP34361	4,360	5	10	7.8	7,200	106,000	6,000	636	872	13.25	ULTRASCSI3 F/W	1.00	10.7	1,000,000	MR heads, ASABET chipset
Quantum	3.5-inch	Empire II VP34360	4,360	5	10	8.9	5,400	98,000	5,701	559	872	11.25	ULTRASCSI3 F/W	1.00	9	1,000,000	MR heads, PRML channel

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Quantum	3.5-inch	Empire II VP39100	9,100	10	20	8.9	5,400	98,000	6,200	608	910	11.25	ULTRASCSI3 F/W	1.63	14	1,000,000	MR heads, PRML channel
Quantum	3.5-inch	Atlas II XP39100	9,100	10	20	7.8	7,200	111,000	6,000	666	910	13.875	ULTRASCSI3 F/W	1.63	14.6	1,000,000	MR heads, ASABET chipset
Samsung	3.5-inch	SHD-30280A	280.5	1	2	12	3,600	69,132	3,125	216	281	4.7625	AT/IDE	1.00	4.2	250,000	
Samsung	3.5-inch	SHD-30420A	420	2	3	12	3,600	69,132	3,125	216	280	4.7625	AT/IDE	1.00	4.2	250,000	
Samsung	3.5-inch	PLS-30540A	547	2	3	11	4,500	70,000	4,100	287	365	4.7625	AT/IDE	1.00	4.2	300,000	
Samsung	3.5-inch	SHD-30560A	561	2	4	12	3,600	69,132	3,125	216	281	4.7625	AT/IDE	1.00	4.2	250,000	
Samsung	3.5-inch	PLS-30850A/S	850	2	4	11	4,500	70,000	4,300	301	425	4.7625	AT/SCSI	1.00	4.2	300,000	
Samsung	3.5-inch	TDR-31080A	1,080	2	4	9	5,400	85,380	4,504	385	540		EIDE	1.00	10.7	500,000	
Samsung	3.5-inch	PLS-31100A/S	1,270	3	6	11	4,500	70,000	4,100	287	423	4.7625	AT/SCSI	1.00	4.2	300,000	
Seagate	2.5-inch	ST9150AG Marathon	131.2	1	2	16	3,980	59,124	2,760	163	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9240AG Marathon	210.4	2	3	16	3,980	59,124	3,282	194	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9300AG Marathon	262.1	2	4	16	3,980	59,124	3,282	194	131	3.6875	AT/IDE	0.50	1.65	300,000	
Seagate	2.5-inch	ST9385AG	340	3	6	16	3,980	60,000	3,300	198	113	3.4625	AT/IDE	0.75	1.9	300,000	
Seagate	2.5-inch	ST9420AG Marathon	420.8	2	4	16	4,500	90,000	3,807	343	210	5.5	ATA-2	0.50	1.9	300,000	Glass media and PRML
Seagate	2.5-inch	ST9550AG	455	4	8	16	3,980	53,000	2,400	127	114	3.4625	AT/IDE	0 75	1.9	300,000	
Seagate	2.5-inch	ST9655AG	524	4	8	16	3,980	72,100	3,227	233	131	3.525	AT/IDE	0 75	1.9	300,000	
Seagate	2.5-inch	ST9816AG Marathon	810.7	4	8	16	4,500	90,000	3,807	343	203	5.5	ATA-2	0.75	2.1	300,000	Glass media and PRML
Seagate	3.5-inch	ST3250A Medalist XE	214	1	2	14	3,811	53,000	2,400	127	214	4	AT/IDE	1.00	3.4	300,000	Fast ATA
Seagate	3.5-inch	ST3295A Medalist XE	272	1	2	14	3,811	53,000	3,100	164	272	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST3391A Medalist XE	341	2	4	13	3,811	53,000	3,100	164	171	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST3491A Medalist XE	428	2	4	14	3,811	53,000	3,100	164	214	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST5660N Decathlon 545	545	2	4	12	4,500	68,000	3,309	225	273	5.25	SCSI2 F	0.75	5.5	300,000	
Seagate	3.5-inch	ST5540A Decathlon 545	545	1	2	11	5,400	73,344	4,923	361	545	8	ATA-2	0.75	5	300,000	Fast ATA-2
Seagate	3.5-inch	ST3660A Medalist XE	545	2	4	14	3,811	53,000	3,100	164	273	4	AT/IDE	1.00	4.4	300,000	Fast ATA
Seagate	3.5-inch	ST5660A Decathlon 545	545	2	4	12	4,500	68,000	3,309	225	273	5.25	ATA-2	0.75	5.5	300,000	Fast ATA
Seagate	3.5-inch	ST3780A	722	2	4	12	4,500	70,101	4,250	298	361	5.875	AT/IDE	1.00	6	300,000	Fast ATA
Seagate	3.5-inch	ST5850N Decathlon 850	854.7	2	4	11	5,400	68,000	3,309	225	427	7.70625	ATA-2	0.75	5.5	300,000	Fast ATA-2

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Seagate	3.5-inch	ST31061 Hawk 2XL	1,050	2	4	9	5,411	87,000	4,800	418	525	8.75	SCSI2 F/W	1.00	6.5	500,000	PRML, ASAII
Seagate	3.5-inch	ST31230N Hawk 2LP	1,050	3	5	9	5,400	78,000	4,200	328	420	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST51080A Decathlon 1080	1,080	2	4	11	5,400	73,344	4,923	361	540	8	ATA-2	0.75	5	300,000	Fast ATA-2
Seagate	3.5-inch	ST51080N Decathlon 1080	1,080	2	4	11	5,400	73,344	4,923	361	540	8	SCSI2	0.75	5	300,000	
Seagate	3.5-inch	ST31220A Medalist	1,083	3	6	12	4,500	70,101	4,250	298	361	5.875	AT/IDE	1.00	6	300,000	Fast ATA
Seagate	3.5-inch	ST31640A Medalist	1,625	3	6	10	5,400	80,000	4,500	360	542	8.375	AT/IDE	1.00	7.7	300,000	Fast ATA
Seagate	3.5-inch	ST31930N	1,700	4	7	9	5,400	78,000	4,200	328	486	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST12450W	1,780	10	19	8	7,200	53,000	3,100	164	187	14.125	SCSI2 F/W	1.63	24	500,000	2-head parallel, 20MB/sec
Seagate	3.5-inch	ST32430N Hawk 2LP	2,140	5	9	9	5,400	78,000	4,200	328	476	7.75	SCSI2 F	1.00	20.4	800,000	
Seagate	3.5-inch	ST32151 Hawk 2XL	2,147	4	8	9	5,411	87,000	4,800	418	537	8.75	SCSI2 F/W	1.00	6.5	500,000	PRML, ASAII
Seagate	3.5-inch	ST32550N 'Cuda 2LP	2,147	6	11	8	7,200	72,680	4,048	294	390	8.775	SCSI2 F/W	1.00	20.4	800,000	
Seagate	3.5-inch	Barracuda 4LP	2,150	3	6	8	7,200	120,000	5,500	660	717	15	ULTRASCSI3 F/W	1.00	11	1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	3.5-inch	ST32140A Medalist	2,167	4	8	10	5,400	80,000	4,500	360	542	8.375	AT/IDE	1.00	7.7	300,000	Fast ATA
Seagate	3.5-inch	ST15150N 'Cuda	4,100	11	21	8	7,200	52,000	4,000	208	390	8.9375	SCSI2 F	1.63	24	500,000	
Seagate	3.5-inch	ST15230N Hawk	4,294	10	19	9	5,400	52,000	4,000	208	452	8	SCSI2 F/W	1.63	24	800,000	
Seagate	3.5-inch	ST15150FC 'Cuda	4,294	11	21	8	7,200	52,000	4,000	208	409	9	FC-AL	1.63	24	800,000	FC/AL available
Seagate	3.5-inch	Barracuda 4LP	4,350	5	10	8	7,200	120,000	5,500	660	870	15	ULTRASCSI3 F/W	1.00	11	1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	3.5-inch	Barracuda 8	8,700	10	20	8	7,200	120,000	5,500	660	870	15	ULTRASCSI3 F/W	1.63		1,000,000	MR, PRML, embedded servo, FC/AL
Seagate	5.25-inch	ST410800N Elite 9	9,080	14	27	11	5,400	71,000	4,000	284	673	8.125	SCSI2 F	3.25	30	500,000	
Toshiba	2.5-inch	MK-1422FCV	86	1	2	15	3,600				86	2.2	AT/IDE	0.50	1.8	150,000	Glass media
Toshiba	2.5-inch	MK-1522FCV	126	1	2	15	3,600				126	3.6125	AT/IDE	0.50	3	150,000	Glass media
Toshiba	2.5-inch	MK-1624FCV	213	2	4	13	4,000				107	3.9	AT/IDE	0.50	2.7	150,000	Glass media
Toshiba	2.5-inch	MK-1724FCV	262	2	4	13	4,000			0	131	3.875	AT/IDE	0.50	2.7	150,000	Glass media
Toshiba	2.5-inch	MK-2124FC	130	2	4	17	3,200			0	65	2.0375	AT/IDE	0.50	1.8	150,000	Glass media
Toshiba	2.5-inch	MK-2224FC	213	2	4	12	4,000			0	107	3.95	AT/IDE	0.75	3.3	150,000	Glass media
Toshiba	2.5-inch	MK-2224FB	213	2	4	12	4,000			0	107	3.95	SCSI2 F	0.75	3.6	150,000	Glass media
Toshiba	2.5-inch	MK-2326FC	340	3	6	12	4,200			0	113	3.7	AT/IDE	0.75	2.9	150,000	Glass media
Toshiba	2.5-inch	MK-2326FB	340	3	6	12	4,200			0	113	3.7	SCSI2 F	0.75	3	150,000	Glass media
Toshiba	2.5-inch	MK-1624FCV	352	2	4	13	4,200			0	176	5.46875	ATA-2	0.50	2.5	300,000	Glass media

(Continued)

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Table A-1 (Continued)
Specifications of Currently Available 5.25-inch and Below Disk Drives

Product	Class	Model No.	Capacity (MB)	Disks	Heads	Seek (ms)	RPM	BPI	TPI	Areal Density (Mb/ sq. in.)	Platter Capacity (MB)	Int. Data Max. (MBsec)	Interface	Height (Inches)	Power Max. (W)	MTBF (Hrs.)	Notes
Toshiba	2.5-inch	MK-2428FC	524	4	8	12	4,000			245	131	3.95	AT/IDE	0.75	3.6	150,000	Glass media
Toshiba	2.5-inch	MK-2428FB	524	4	8	12	4,000			245	131	3.95	SCSI2 F	0.75	3	150,000	Glass media
Toshiba	2.5-inch	MK-2526FB	528	4	6	13	4,200			0	176	3.95	SCSI2 F	0.75	3.6	300,000	Glass media, ATA/ IDE also available
Toshiba	2.5-inch	MK-1924FCV	540	2	4	13	4,200			0	270		Fast ATA-2	0.50	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2528FB	704	4	8	13	4,200			0	176	3.95	SCSI2 F	0.75	3.8	300,000	Glass media, ATA/ IDE also available
Toshiba	2.5-inch	MK-2628FCV	810	4	8	13	4,200			0	203	5.375	Fast ATA-2	0.75	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-1926F	815	3	6	13	4,200			0	272	5.6125	Fast ATA-2/ SCSI2	0.50	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2728FC	1,080	4	8	13	4,200			0	270	5.375	Fast ATA-2	0.75	1	300,000	Glass media, SCSI available
Toshiba	2.5-inch	MK-2720FC	1,350	5	10	13	4,200			0	270	5.6125	Fast ATA-2/ SCSI2	0.75	1.4	300,000	Glass media, SCSI available
Western Digital	3.5-inch	WDAC1270	270.4	1	2	11	4,500	61,000	3,300	201	270		AT/IDE	1.00	3.6	250,000	Enhanced IDE, MIG heads
Western Digital	3.5-inch	WDAC1365	365.4	1	2	10	4,500				365	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC1425	426.8	1	2	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC2540	540.8	2	4	11	4,500	61,000	3,300	201	270		AT/IDE	1.00	3.6	250,000	Enhanced IDE, MIG heads
Western Digital	3.5-inch	WDAC2700	730.7	2	4	12	4,495	68,100	4,000	272	365		AT/IDE	1.00	3.25	250,000	Enhanced IDE
Western Digital	3.5-inch	WDAC2700	730.9	2	4	10	4,500				365	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE, Sturgeon
Western Digital	3.5-inch	WDAC2850	853.6	2	4	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31000	1,096	3	6	12	4,495	68,100	4,000	272	365		AT/IDE	1.00	3.25	250,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31200	1,280	3	6	10	4,500				427	5.26	EIDE	1.00	8.1	300,000	Enhanced IDE
Western Digital	3.5-inch	WDAC31600	1,625	3	6	9	5,200				542	9.625	EIDE	1.00	4.3	300,000	Enhanced IDE, Tri-Pad head+U28s, PRML

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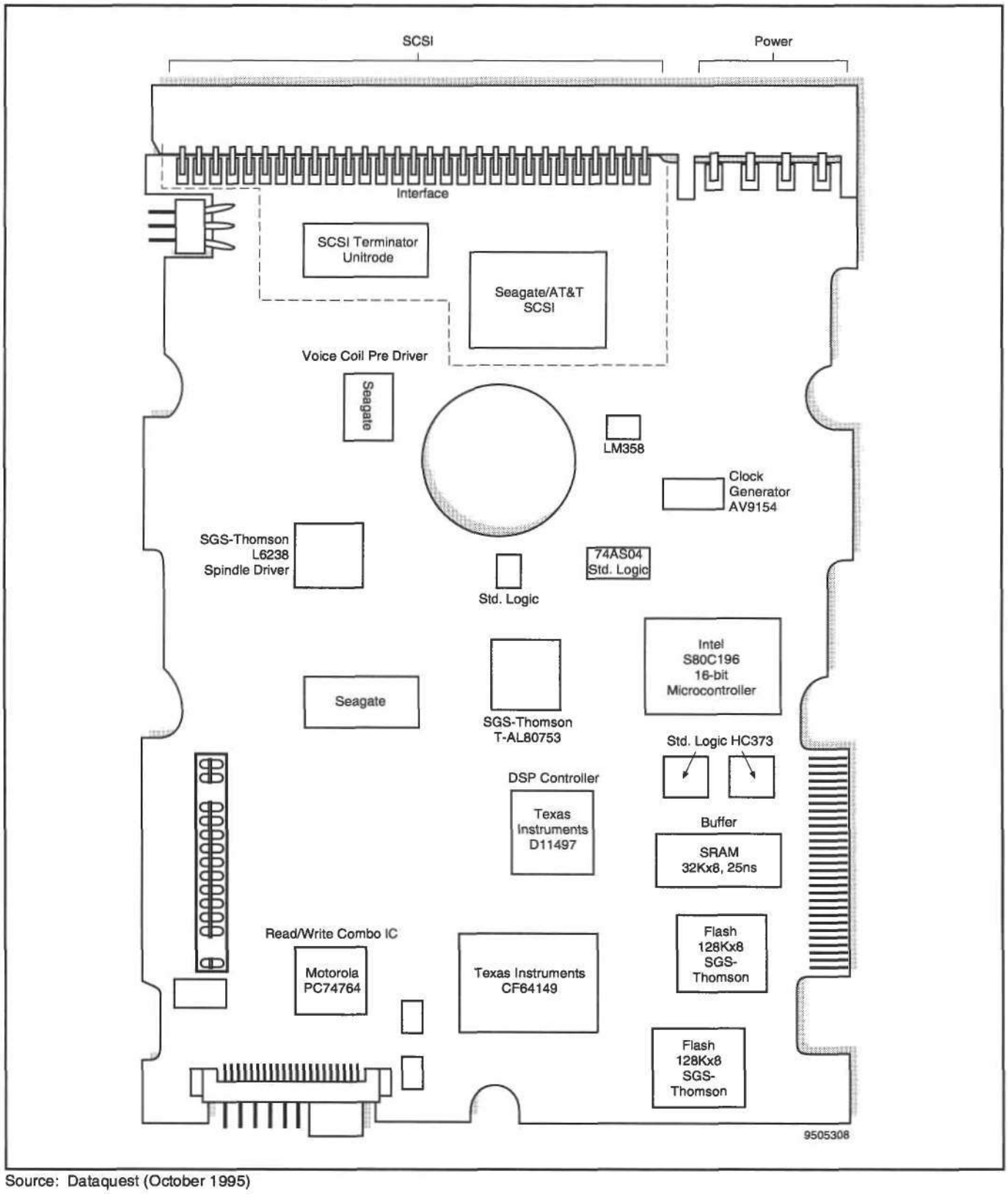
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Appendix B
RDD Board Graphic

Figure B-1 shows a printed circuit board from a Seagate rigid disk drive.

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Figure B-1
PCB for a 540MB, 3.5-inch Rigid Disk Drive



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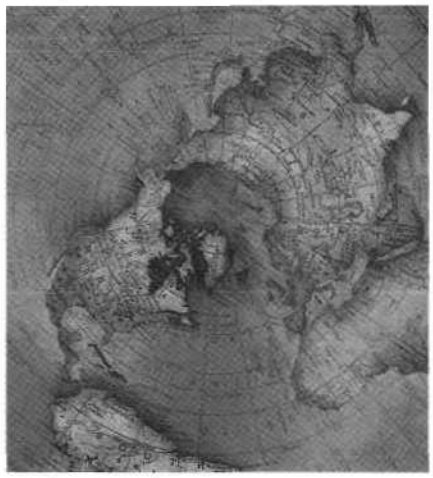
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Emerging Automotive Electronics Applications



Focus Report

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Chapter 1
Executive Summary and Introduction

Executive Summary

The market for automotive electronics is now set for further growth as global issues begin to place even more emphasis on strict exhaust emission regulations for both petrol and diesel engines becoming enforceable over the next few years. Developments of advanced driver information and traffic control systems will keep this strong momentum into the new millennium.

Historically, powertrain electronics and safety electronics have been the growth drivers in this market segment. Dataquest estimates that growth in automotive electronics is reaching maturity for powertrain electronics, which now accounts for nearly 50 percent of the worldwide automotive electronics market. Safety applications such as antilock braking systems (ABS) and airbags have also emerged and will continue to grow into the next decade as factory installations and aftermarket opportunities increase.

Fresh new impetus for further growth is anticipated to come from newly emerging communications applications for road transport/traffic and vehicle systems. The European Union (EU) and the European automobile manufacturers have committed more than $1 billion in the PROMETHEUS research program, which aims to halve the EU's 50,000 road deaths a year by the year 2010 through greater use of in-car electronic information systems and other technological developments.

The new "smart" cars for the next decade will be intelligent cars that can:

- Illuminate long distances in the dark with infrared and ultraviolet headlights
- Cruise intelligently by automatically keeping pace with the vehicle in front
- Know exactly where they are, using satellite navigation
- Summon emergency services to the exact location of a breakdown or accident with or without any driver action

This report explores the implications of this future strategy for cars of the future—so-called "smart cars"—for the electronic components industry and provides an insight to developments in this area. The report identifies 25 newly emerging electronic applications for the intelligent cars of the future and identifies the opportunities for future electronics growth in this fast-growing market segment.

Introduction

Automotive electronics is a rather fragmented semiconductor application market, but all the automotive electronics systems will eventually become integrated. This integration will occur as multiplexing technology advances to allow each of the subsystems to be interconnected. Thus, it is conceivable that automobile electronics will become one of the top five global electronics markets for semiconductor and passive electronic components. As a single system application, the personal computer aside, automotive electronics is forecast to be one of the single most important "engines" for semiconductor components in the next century. Worldwide, the average semiconductor content of a vehicle is now estimated to be in excess of $100.

By the year 2000 average semiconductor content per vehicle will be nearly $200. Worldwide automotive semiconductor consumption in 1994 amounted to

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$5 billion. By 2000, the demand for semiconductors by cars and commercial vehicles is expected to at least double, exceeding nearly $10 billion.

Electronic applications in the car (specifically integrated circuits) first appeared in commercial volumes during the 1960s as voltage regulators for alternators and also ignition control. During the 1970s the world fuel crisis led to the introduction of electronic control for fuel injection and carburettor engines. The 1980s brought legislation in the United States for electronic engine control systems to curb engine exhaust pollution. By the 1990s electronics in the car was widespread in various automotive applications from engine management, air conditioning, dashboard, security systems, vehicle tracking devices, and safety applications such as airbags and ABS, and driver navigation systems for route planning and traffic information.

In the 1980s and 1990s, environmental factors were driving electronic penetration in cars. Recently (the late 1980s and early 1990s), electronics was used as a product differentiator among car manufacturers, and the use of electronics has now advanced past that stage, ushering in a new era where vehicle emission legislation and safety regulations account for growth. Nowadays, these metrics are taken for granted, and electronics is being used to improve vehicle safety and optimize vehicle functionality.

Current research indicates that electronics and vehicle electrics account for nearly 12 percent of the total cost of a midrange car; by 2005 this cost is forecast to exceed 25 percent of the cost of a new car. New factors are beginning to drive the use of electronics in cars. Virtual market forces (aside from legislation and regulation) are now emerging as, for example, insurance companies begin to mandate the use of electronics to enhance car security.

By the end of the decade social, political and economic factors enforced by governments, and the entire fleet transportation industry, will begin to drive the use of electronics in cars. The millions of dollars spent on research and development for the transportation industry will also be expected to yield dividends for the commercial sector. At the end of 1994, the European Commission was publicly censured by automotive manufacturers for failing to honor its financial and strategic planning obligations under the joint industry and EU precompetitive research program.

We have partitioned each emerging technology development in the report into three main sections:

- **Advanced driver information and communication systems (chapter 6):** This looks at all the areas of development that contribute to increased driver awareness for road safety and road conditions.
- **Powertrain electronics (chapter 7):** Covers all aspects in motor vehicles that affect the physical design of powertrain or motion aspects of the vehicle and include engine management, suspension control and vehicle handling.
- **Body control electronics (chapter 8):** Deals with the entire electronics infrastructure from door body control, windows, central locking, lights, wipers and security systems.

Please note that in the tables showing worldwide penetration of electronic systems, penetration rates are shown as a proportion of annual car production volumes in each world region.

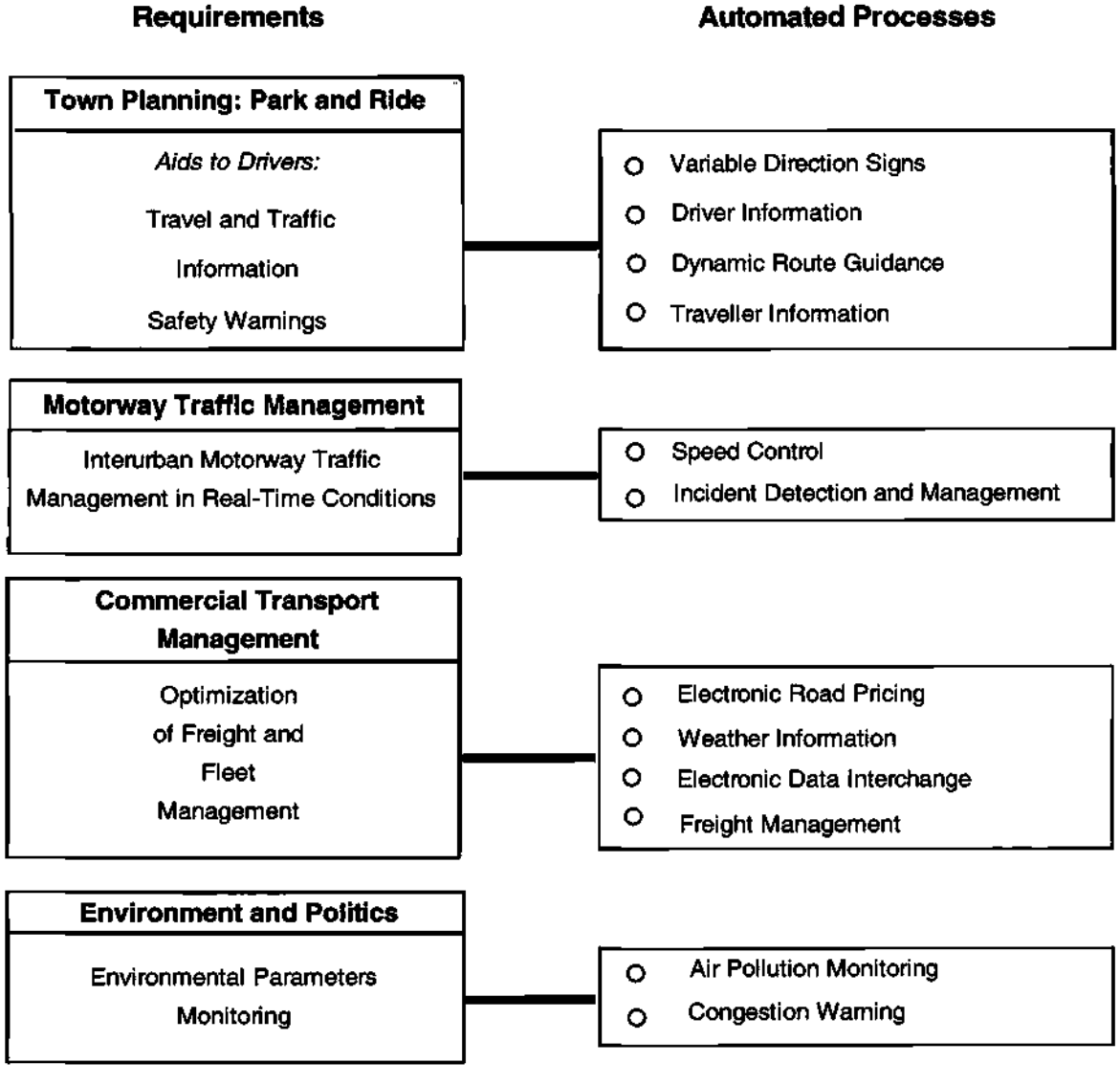
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Chapter 2
Factors Driving Demand for Emerging Automotive Electronics Applications

Because the automotive industry is a global industry, certain regional factors have a very strong impact on the global markets. Legislation, safety, security, and environmental issues have recently impacted automotive electronics applications in cars. Europe, the United States and Japan are the three major car producing regions worldwide. Any future changes affecting this industry are mostly influenced by the issues and decisions of these major regions.

Emerging electronic automotive applications will be influenced by a combination of factors as car manufacturers, governments and communities actively respond to curbing the rate of vehicle traffic congestion and the effect of global air pollution in major world cities. Figure 2-1 summarizes new areas for development towards the year 2000 and beyond. These plans are expected to result in increases in demand for electronics in automobiles.

Figure 2-1
Advanced Road Telematics: Emerging Applications from New Perspectives



Source: Dataquest (April 1995)

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In a regionally structured initiative, the major automotive markets worldwide—namely the United States, Europe and Japan—have each formed research coordinating organizations aimed at achieving the above objectives. In the United States, the entire concept is referred to as IVHS (Intelligent Vehicle Highway Systems), and in Japan it is known as ARTS (Advanced Road Transport Telematics), while in Europe it is commonly referred to as RTI (Road Transport Informatics).

IVHS America is a coordinating organization set up by the federal government to pursue and advance the development of research programs, pilot trials and pre-competitive cooperative product development of infrastructure systems for road transport telematics. Participants of IVHS America are government agencies, companies allied to the automotive industry, and the information technology industries in the United States.

ARTS is the Japanese initiative which aims to coordinate a number of national and governmental research projects involving companies in the automotive industry (both manufacturers and suppliers) to achieve goals similar to the IVHS America initiative.

RTI is the active program in Europe to realize advanced road traffic systems under way across Europe. It coordinates, through a number of European Commission research projects, pre-competitive cooperative research among competitor companies, car manufacturers and government agencies.

Telematics refers to the merging of communications and computing technology making it possible for traffic information to become more widely accessible by motorists. Telematics is a central infrastructural requirement of the global IVHS efforts and will itself require yet more investment in certain infrastructure areas before implementation. Worldwide, the target date of 2010 set by IVHS America and Europe's PROMETHEUS program is steering the industry toward achieving these goals.

This report identifies future opportunities for automotive electronic penetration in vehicles that will make the European initiative achieve the 2010 objective. It also identifies the potential new semiconductor markets that will be generated as a result of this objective for the global automotive market.

Most microelectronics applications in cars improve the control or efficiency of existing mechanical systems. Consequently, the use of electronics is often perceived as additional cost. Nowadays, electronics addresses more than control and efficiency. It provides more accurate monitoring of the various parts of a car. From ignition, engine, transmission, through to braking control—start to stop—electronics are used to maintain optimal performance. Microcontrollers (MCUs) are used to control, monitor and process analog signals from the mechanical operations of the car. Thus, most automotive systems have a microcontroller, voltage regulator, analog interface and an I/O driver interface.

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Chapter 3
What Future for Microelectronics in the Car?

Future car microelectronics will be toward replacing some mechanical systems and permitting further integration of electronics and mechanics. Independent surveys of the automotive industry show that nearly 90 percent of all electrical faults that occur in vehicles are due to the connector. Therefore, in at least 90 percent of all electronic fault cases, the system itself is not responsible for failure.

Several companies have advanced research in system connectors. Specifically in Europe, BMW is among those which have advanced car electronic connector technology, and its patents are now being licensed to several German and European car manufacturers. But there is still more development ahead for integrated systems such as mechatronics.

A second area of equal importance and market potential for development is the use of silicon sensors. The automotive industry is now approaching certain requirements that can no longer rely on existing technology. Where existing technologies can meet these requirements, they are often too costly to implement and design-in.

Specifically for airbag applications, micromachined accelerometer sensors are required to further reduce the risk of false airbag trigger. In meeting the US legislation for side impact protection, most manufacturers are seeking newer but lower-cost silicon sensors that predict crash impact. A combination of radar and optical sensors could be used for side impact detection but the limitations here are false airbag triggering, as some vehicle collision is avoided even after getting as close as two millimeters.

Mechatronics is the concept of integrating electronics and mechanical parts to form a completely integrated system. Antilock braking systems are a prime example of mechatronics, where brake plungers and electronic sensors are designed into mechanical components for controlling vehicle braking.

Many areas still remain to be resolved as car electronics (and car electrics to a lesser extent) is a relatively young technology in search of many solutions from the semiconductor industry. Furthermore, some of the technologies required for automotive application are not readily available as costs are still too high for automotive engineers to design-in such components. In the sensors area, for example, suppliers of military electronic systems that found their markets extinguished at the end of the cold war have attempted to diverge into the automotive segment. Here, new processes and technology are required to meet the automotive needs. The volume application potential for silicon sensors for automotive applications is very substantial.

Much still needs to be resolved as car electronics is a relatively new technology in search of many solutions from the semiconductor industry. New developments in the semiconductor industry itself present many automotive opportunities, and examples include integrated IC connectors, electronic packaging, wiring, multiplexing, and semiconductor technology for applications such as smart power, radiofrequency (RF), millimeter-wave sensors, piezoelectric sensors, and newer but cheaper accelerometer sensors.

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Chapter 4
Worldwide Automotive Electronic Markets

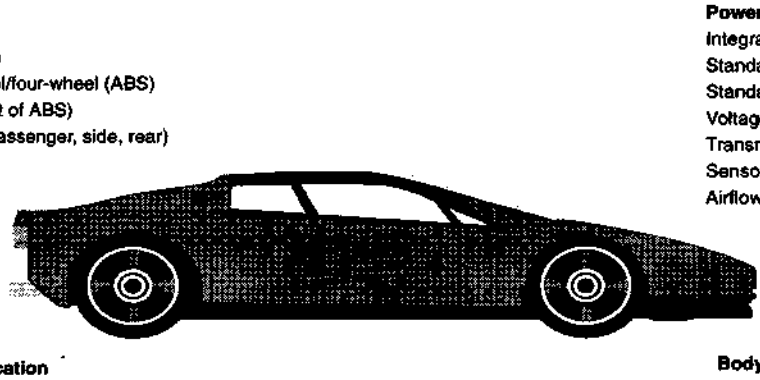
Figure 4-1 shows the current electronic systems that are available for automotive applications. Many of these systems are available as aftermarket systems that are not installed at the factory by the vehicle manufacturer. This report focuses on the new emerging applications (see Figure 5-2 in the next chapter). To bring the volume applications of these systems into perspective, Table 4-1 gives our current forecast for worldwide car production.

Europe is the leading manufacturer of cars worldwide, accounting for almost 35 percent of global car production. This pattern will likely change as the big emerging markets (BEMs) of Asia, Central and Eastern Europe and Latin America begin to take shape. The final formation of car production demographics beyond the year 2000 is still quite uncertain as car ownership has a very strong correlation with economic gross domestic product (GDP). However, China represents the single car market with the largest potential and is likely to become an important producing country beyond 2000. Other important BEMs include Eastern Europe and Latin America, although it is widely acknowledged that Eastern Europe holds more prospects than the Latin American markets.

Dataquest believes that the major car manufacturers will continue to control car production globally and will retain the relationships of established suppliers rather than extending their supplier relationships with more suppliers. Already, automotive component procurement is being actively trimmed by most manufacturers in a drive to further cut manufacturing costs. Some car manufacturers are forming joint procurement groups to procure components with their competitors to drive down system costs.

Japanese car production is forecast to slow towards the year 2000 and will probably decline as production shifts away from Japan to Europe begin to gain momentum towards the end of the decade. US car production will continue a healthy growth as favorable currency exchange rates continue to make US cars competitive in the global markets. European car production will soar towards the year 2000 as Eastern European manufacturing begins to ramp up and Japanese transplant manufacturing activities enter their final phase of production volume expansion.

Figure 4-1
Automotive Electronics—Standard Features and Options



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Source: Dataquest (April 1995)

Table 4-1
Worldwide Car Production Forecast
(Millions of Units)

Region	1993	1998	2000
North America	7.34	8.33	8.65
Light Trucks	5.83	7.47	7.80
Europe	11.33	11.84	13.53
Japan	8.50	9.29	10.29
Light Trucks	0.96	1.20	1.35
Asia/Pacific–ROW	3.97	5.15	7.24
Total Cars	31.14	34.61	39.71
Total*	37.93	43.28	48.86

* Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

Manufacturers from the Asia/Pacific region are expanding capacity and beginning to establish manufacturing sites outside their region. The region is dominated by the Korean vehicle manufacturers but there is also a sprinkling of minor car manufacturers serving countries in this region. The newest car manufacturing company is electronics conglomerate Samsung of Korea, which is working with Nissan Motors of Japan to start manufacturing cars.

Penetration of car electronics across all regions is forecast to grow rapidly toward the year 2000. The automotive industry in the 1990s is achieving goals of reducing car development cycles from five years to three years on average, and this is now rapidly approaching two years. Moreover, the automotive industry is experiencing some very radical market trends that will stimulate increased electronics penetration.

The latest trend shows that traditional market demographics of small, medium-size and large car markets are moving to include more exotic vehicles. The new demography includes performance sport cars (ranging from high-performance roadsters to hatchback convertibles), four-wheel drive (4WD) vehicles (high-end, midrange and low-end versions), and multipurpose vehicles (MPVs). Nowadays, the new vehicles are all fitted with standard electronic systems such as ABS, airbags, engine management controls, power windows/sunroof/roof (convertibles), central door locking, alarm systems and immobilizers, and RDS (Radio Data Systems) stereo radiocassette systems. On a worldwide basis about 100 new car models are introduced on the market each year. Each new car model announced ultimately increases the numbers of controllers, sensors, electric motors, actuators and general electronics in cars.

Automotive Electronics Systems Market Trends

- About 100 new or redesigned vehicles are introduced worldwide each year. An estimated 60 percent of these involve new electronics. Assuming 6 modules or subsystems per vehicle, there are 350 to 400 new design-win opportunities each year.
- A new class of controls for integrated engine and transmission management is emerging in the powertrain area. A trend toward 32-bit microcontroller-based integrated modules is being stimulated by efficiencies needed for even stricter and tighter emission controls and fuel consumption requirements.

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- Electronic-intensive antilock brakes and airbag controls continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (legislation in Europe) to be used in high-end and midrange cars.
- Driver-side airbags are becoming standard equipment on almost every vehicle. Passenger-side airbag versions have now entered the market, and rear passenger airbags (rear-seat and door/side impact) airbags are emerging as an option. Strictly speaking, side impact is being driven by legislation in the United States for side impact protection by 1998. Three versions are emerging: those installed in the door, seat and car frame pillars.
- Europe is leading the world in the development of side impact airbags. Volvo was first to come to market with side impact, quickly followed by Saab and BMW. Porsche, Mercedes and Jaguar are planning introduction later this year for 1996 models. The European standard for side impact airbags is more rigorous than the US standard: the European standard is based on deflection and force, while the US standard is based on acceleration.
- Electronic suspension and steering are now beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Head-up displays (HUDs) appear to be moving from just indicating speed to an entire list of dashboard, road information and communications displays oriented toward keeping the driver's eyes on the road.
- Keyless and remote entry, and light timers are proving popular options in an ever security-conscious world.
- Personalization features such as memory seats, memory mirror and radio settings are now popular on high-end models, with future models extending personalized settings to include engine management, glove compartment locks and fuel usage depending on driver code.
- Entertainment systems continue to be cassette-based today, with CD-based systems emerging at a modest rate. New digital compact cassette (DCC) and Mini-Disc (MD) systems have begun to find their way into 1994/1995 vehicles. Intelligent/distributed speaker systems (surround sound) are becoming more common.
- Digital audio systems and technology for car radio is still developing rapidly with RDS now being introduced in the United States, and Japan likely to follow. RDS alerts the driver to traffic reports and will display radio station format and call letters. Digital audio broadcasting (DAB) for car radios is also set to emerge by the end of the century.
- To satisfy the California Air Resources Board (CARB) requirement for a common diagnostics interface, SAE J1850 multiplexing protocol has been adopted in the United States. This interface is heading toward serving the communication link between modules. Europe is settling on a standard called ISO 9141 and other proprietary standards like Intel's and Bosch's CAN, and the French VAN standard.
- Electric vehicles are being developed by global manufacturers to satisfy California's requirement for a 2 percent requirement on all vehicles sold in that state by 1998 (10 percent by 2003). Several manufacturers have chosen a minivan test platform. The most critical challenges are creating cost-effective battery technology and fast-charge batteries. Nickel metal hydride seems to be the leader at the moment. Electric vehicles currently cost about 50 percent more than the petrol versions. Battery life averages about three years; it costs the consumer $3,000 to replace them. Hybrid approaches are being considered including advanced flywheel technology.

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- Navigation systems based on dead-reckoning technology and the Global Positioning by Satellite System (GPS) are becoming very popular in Japan and are now emerging as standard options in the United States and Europe. General Motors has introduced a $2,000 system that uses a PCMCIA format card for the map database and a Motorola-based 68EC020 processor for GPS and dead-reckoning processing (made by Zexel and Rockwell). BMW has chosen the Philips CARIN navigation system with dead-reckoning, GPS and audio annunciation—it also doubles as an in-car television set.
- With the pressure on environmental cleanliness and fuel efficiency, diesel car sales are now on a rapid and steady growth curve. New diesel engine technology is allowing electronic diesel engine management systems to proliferate, achieving performances matching petrol cars and increasing fuel efficiency of traditional diesel engines. Diesel engines are also benefiting from the use of electronic engine control systems that help reduce the emission of harmful exhaust particulates.

World Automotive Electronics Production

Worldwide factory revenues of automotive electronic equipment production reached nearly $36 billion during 1994 (Table 4-2). The fastest-growing regions continued to be North America and Europe, with some growth also measured in the Asia/Pacific region specifically in Singapore and Korea.

During 1994, key market growth indicators from a global perspective include:

- **Powertrain electronics**: Engine management systems and diesel engine management systems
- **Safety and convenience electronics**: Airbags and ABS
- **Body control**: Multiplex door wiring and car security systems
- **Security systems**: Immobilizers and car alarms
- **In-car entertainment**: CD players and navigation systems

Dataquest forecasts that first-generation systems for driver information systems such as integrated car navigation and traffic information systems will begin to appear on the market from 1988 onwards. The market for these systems are forecast to begin to take off when infrastructure systems become available. Table 4-3 shows our worldwide forecast for automotive electronic production by end-application segment.

Table 4-2
Worldwide Automotive Electronics Production by Region, Factory Revenues
(Millions of Dollars)

Region	1993	1994	1998	2000
North America*	9,458	11,311	15,022	16,824
Europe	8,558	9,953	15,763	17,313
Japan*	11,519	11,843	14,099	15,981
Asia/Pacific–ROW	2,676	2,922	4,596	6,994
Total*	32,211	36,029	47,480	57,112

* Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

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Table 4-3
Worldwide Automotive Electronic Production by End-Application Segment, Factory Revenues
(Millions of Dollars)

Segment	1993	1994	1998	2000
Entertainment	5,871	6,191	8,452	9,652
Body Control	3,077	3,495	5,532	6,594
Driver Information	5,464	5,893	7,584	9,068
Powertrain	10,607	11,929	16,425	18,541
Safety and Convenience	7,193	8,521	11,486	13,257
Total	32,211	36,029	49,480	57,112

Source: Dataquest (April 1995 Estimates)

We have projected a conservative forecast for the overall automotive electronics market to reach more than $57 billion by the year 2000. Powertrain electronics and safety and convenience electronics are forecast to dominate as requirements for increased security functions and tighter regulations governing emissions take off. A number of factors such as legislation, pressure from insurance companies and, ultimately, demand for further electronics could push up the demand for automotive electronics even more.

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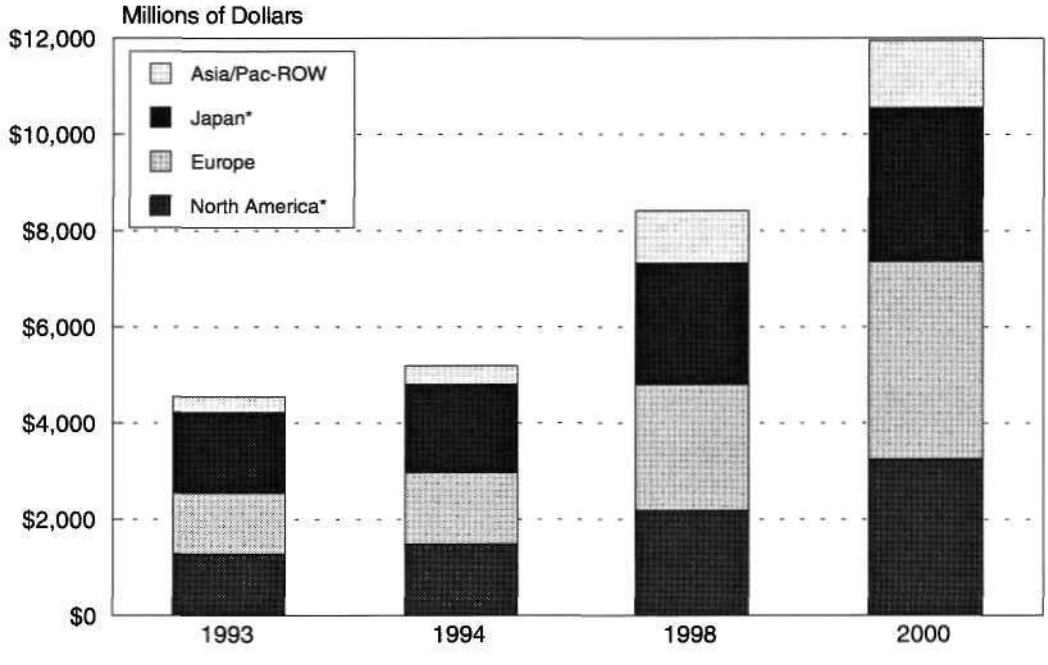
Chapter 5
Worldwide Automotive Semiconductor Markets

Dataquest estimates that the worldwide semiconductor market for automotive applications reached $5.2 billion in 1994. By the year 2000, worldwide semiconductor demand for automotive applications is forecast to reach nearly $10.2 billion (Figure 5-1). By that time, the fastest-growing regional market for automotive semiconductor components will be the Asia/Pacific region. However, as a result of global component procurement, just-in-time deliveries, and flexible but shorter cyclical R&D requirements for local automotive production, Dataquest forecasts that by 2000, Europe will account for 40 percent of the worldwide semiconductor consumption, and Japan and the United States will account for 24 percent and 32 percent respectively.

In North America the factors driving growth are tighter emission controls with more sophisticated engine control units being developed as well as safety applications like airbags to meet side impact protection legislation in the United States from 1997.

European automotive semiconductor growth has been spurred by growth in electronic engine immobilizer systems and car security systems, in addition to airbags, ABS and engine control units. Diesel engine management systems are also taking off in Europe—already nearly 25 percent of cars sold in Europe are diesel engine cars. Towards the year 2000, we anticipate that digital audio broadcast receivers will begin to appear in car radios and driving stability guidance systems (an extension of ABS and traction control).

Figure 5-1
Preliminary Worldwide Automotive Semiconductor Markets by Region Forecast



* Includes light trucks (pickups, 4WD sport-utility vehicles, and minivans)
Source: Dataquest (April 1995 Estimates)

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Table 5-1
Preliminary Worldwide Automotive Semiconductor Markets by End-Application Segment
(Millions of US Dollars)

Segment	1993	1994	1998	2000
Entertainment	681	727	1,262	1,793
Body Control	545	519	842	1,195
Driver Information	363	416	505	956
Powertrain	2,044	2,389	3,871	5,258
Safety and Convenience	909	1,143	1,936	2,749
Total	4,543	5,194	8,416	11,950

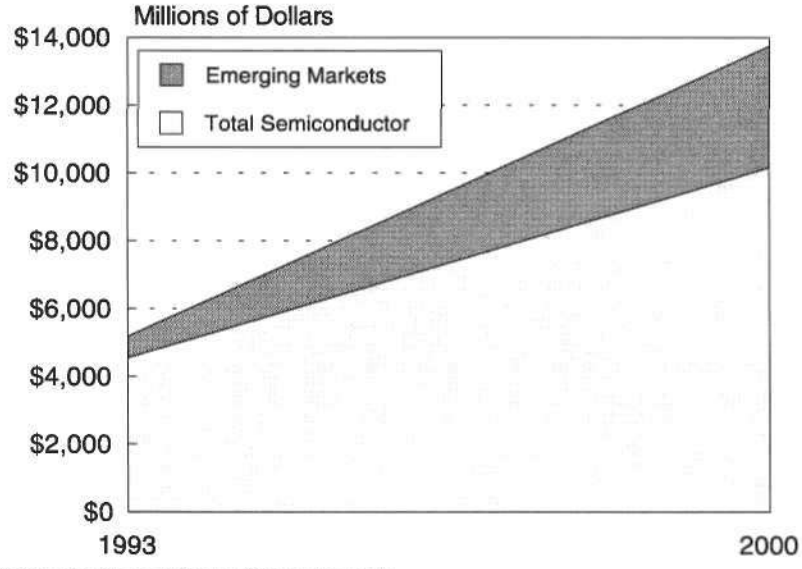
Source: Dataquest (April 1995 Estimates)

The Japanese automotive segment is driven by the entertainment and driver information systems markets. Car navigation systems are proving very popular in Japan and are forecast to maintain this growth momentum toward 2000, by which time many Japanese car manufacturers will be fitting these systems into cars at the factory.

Growth in the Asia/Pacific region is coming from demand by Korean car manufacturers such as Hyundai, Kia and Daewoo, and Malaysian car manufacturer Proton, which are ramping up manufacturing capacity to match demand coming from both Western and Eastern European countries. This means that they now have to meet the emission control legislation in these markets and therefore fit more engine management systems and catalytic converters to their cars.

Overall, by end-application market segment (see Table 5-1), powertrain electronics represents nearly 50 percent of the automotive semiconductor total available market (TAM). Safety and convenience applications now account for nearly 25 percent of the automotive semiconductor market. The remainder of the market is mostly in-car entertainment electronics.

Figure 5-2
Contribution to Worldwide Automotive Semiconductor Growth by Emerging Applications



Source: Dataquest (April 1995 Estimates)

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Emerging applications highlighted in this report are mostly driver entertainment, powertrain and body control electronics. This could add an additional 10 to 50 percent of semiconductor business to the worldwide automotive segment alone. This report identifies the additional electronics business potential for emerging automotive applications shown in the top layer of Dataquest's forecast for worldwide automotive semiconductor markets in Figure 5-2.

Product Trends of Existing Automotive Electronic Systems in the Car

Cost sensitivity in automotive electronics affects product trends of existing systems. Car electronic systems are continually being upgraded, improved and refined. In many non-safety or non-legislated application areas, the automotive industry itself cannot justify development costs. Often, economies of scale in other related electronics markets, such as communications and consumer electronics, drive down technology costs before they appear in the car. Figure 5-3 illustrates the systems included in the so-called "smart car" of the future.

In the driver entertainment area, new technologies have enhanced car stereo systems as developments in audio technology have migrated from the home into cars. Examples are compact disc players, digital audio tapes (DAT)—albeit not very successful to date—digital compact cassettes, Mini-Discs, and in the near future, digital audio broadcasting. The evolution of in-car entertainment continues with the pace of development in consumer entertainment markets.

Other factors such as environmental pressures continue to affect development in areas such as ignition and engine control systems: fuel shortages of the 1970s led to the introduction of fuel injection engines and electronic injection control systems. Environmental pressure has resulted in the growth in the sales of diesel cars, and now more electronic development is being applied to meet new tighter emission control regulations aimed at reducing dirty and harmful particulates from diesel exhaust emission.

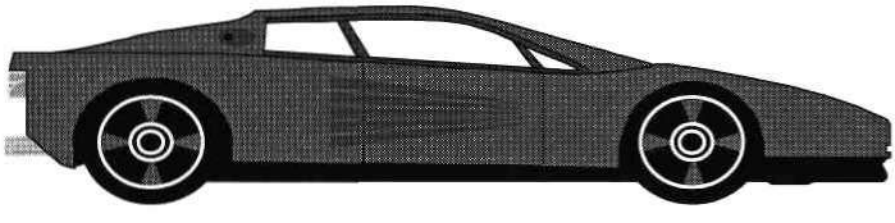
Additionally, heightened driver awareness has stimulated demand and growth in automotive safety applications such as antilock braking systems, antiskid, traction control and airbags. Each new era in the car electronics evolution is creating further demand for electronics, and in some cases newer electronic systems and technology are being sought.

Figure 5-3
Emerging Automotive Applications—Future Systems

Advanced Driver Information and Communication Systems
- Keyless entry
- Vehicle identification
- Speech recognition/synthesis
- Navigation systems
- Global Positioning Systems
- GSM and wireless digital communications (data)
- Head-up displays
- Near obstacle detection

Body Control Electronics
- Tyre pressure monitors
- Multiplex systems
- Car computers
- Noise cancellation
- Accident data recorders

Powertrain Electronics
- TCS/traction control
- Electronic power steering
- Active suspension
- Adaptive suspension
- Intelligent cruise control
- Electronic transmission
- Electronic clutch
- Electronic brakes
- Diesel engine management
- Collision avoidance
- Driving stability control



Source: Dataquest (April 1995)

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As an example, in the current airbag phase, where legislation for side impact protection and full frontal protection is required in the United States from 1998, car manufacturers are seeking newer collision detector sensors at low cost to sense side impact collision. Electronic solutions for the automotive business seem to be endless, restrained only by costs.

However, the automotive industry has one major constraint, and that is the customers. It is often customer needs that dictate the level of electronic sophistication the cars have—in the end the customer has to pay for all the car electronics.

The Automotive Environment

The automotive environment is often described as very harsh with most electronics expected to reach the level of military specifications for semiconductor device qualification. Compared with other electronic devices, this is a valid perception. The following are some of the factors that have to be tolerated when designing-in semiconductor devices for automotive applications:

- Dust-proof
- Electromagnetic compatibility (EMC)
- Humidity (including sudden changes in humidity from air conditioners)
- Oil and fuel resistant
- Shock and vibration resistant
- Short-circuit-proof
- Surge voltage resistant
- Temperature resistant (possible low temperatures of -50°C.)
- Voltage changes
- Waterproof
- Proof against polarity reversal

As a guide, Table 5-3 provides some basic conditions that are currently applicable as conditions for electronic components in automotive applications.

Minimum operating temperatures for most of these systems are set by regional automotive electronics bodies like the Society of Automotive Engineers (SAE) in the United States, JASO in Japan, and in Europe by the various national governments' transport department. But most car manufacturers generally tend to apply the extreme limits of specification for electronic systems in order to qualify for exports to all countries.

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Table 5-3
Semiconductor Device Temperature Thresholds for Automotive Applications

Location		Maximum Temperature (°C)
Chassis	Overall vehicle chassis	85
	Near heat sources	121
	Oil chassis	175
Body	Outside	121
Engine Compartment	Engine walls	140
	Engine surfaces	150
	Choke surface	205
	Starter cable (near exhaust pipes)	205
	Exhaust manifold	650
Passenger Compartment	Floor surface	85
	Real parcel shelf	107
	Instrument panel (surface)	113
	Instrument Panel (general)	85
Boot/Trunk		85

Source: Dataquest (April 1995)

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Chapter 6
Advanced Driver Information and Communication Systems

Driver Information in the Technology Evolution Process

For many years driver information systems have graduated from crude generations of roadside signs through to advanced, electronically controlled active matrix roadside information boards. Roadside information networks have advanced to a stage where most developed countries now have a computerized information control room that displays relevant traffic information on specific road routes. This infrastructure development has occurred mostly over the last decade.

Along with roadside information boards are car radios, which have also undergone quite substantial advances in technology. Microelectronics has developed the car radio to provide more information than what is audible. Text-based information is also transmitted to modern car radios using the RDS channel on FM analog radios.

Communication systems in the car have also advanced with the introduction of cellular telephony, which is now making a further advancement from analog cellular communication systems to digital cellular communications. These developments have occurred largely as a result of a market need for mobile communication systems. The introduction of digital telephony offers a new dimension to road users as it is now possible to transmit data (in addition to voice) over the digital networks by using a relatively simple data interface.

Global Positioning by Satellite Systems have also emerged as a viable technology for automotive applications. The applications for GPS in the automotive segment range from car navigation, security (vehicle movement tracking), through to very accurate clock-timing precision.

Dataquest predicts that car radios will become the hub for future driver information systems that will incorporate digital cellular communications, navigation and route guidance systems, and digital audio broadcast. The car radio is currently going through a technology evolution that will change the way these systems are used in the future, and this chapter looks at parallel developments in driver information systems that will shape future in-car driver information systems.

This chapter covers the following emerging technology areas that will have roles to play in future driver information systems:

- Keyless entry
- Vehicle identification
- Speech recognition—audio, entry, carphones, navigation
- Global Positioning Systems—alternative identification/location
- Navigation systems
- GSM/wireless communications
- Digital audio broadcast: car radio/cassettes (versus RDS/TMC/EON)
- Head-up displays
- Near-obstacle detection (NODs)/blind-spot camera/mirrors

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Keyless Entry

What Is Keyless Entry?

Keyless entry at its lowest specification allows door locks to be locked or unlocked without using the traditional car key. The most common implementation uses a remote control key-fob or "plip." More sophisticated models will have intelligent functions that may automatically lock doors once the engine is started (for security or safety purposes).

Current applications use infrared remote controls with trends toward integrating technology. The RF technology holds a unique code which is transmitted to a receiver that controls the engine management system (EMS). The codes activate either the fuel pump relays, or the EMS itself.

Keyless Entry Features

Keyless entry improves existing car security and safety as it also possible to configure the system to switch on or off, inside/courtesy lights, alarms and immobilizers, and quickens entry into the car by the driver (especially in dark places). RF adds additional security to EMS. The level of security required to combat vandals, joy riders, car theft, and higher insurance premiums are currently best addressed using electronics. Future keyless entry systems will use more sophisticated software to increase electronic security. Further integration of the modulator/demodulator unit into the engine management system, for example, will expand the application possibilities of keyless entry.

Table 6-1 shows the anticipated level of demand in each major world region. Although Europe is the largest car producing region, keyless entry systems have been slower to reach the market compared with the North American region. Japan has the second-highest penetration rates for keyless entry systems because of the volume of exports to other world regions where these systems are sold or installed by respective regional car dealers through aftermarket channels.

Table 6-1
Worldwide Automotive Market Penetration of Keyless Entry Systems

Region	1993	1998	2000
Europe	10%	65%	80%
Japan	15%	75%	97%
North America	15%	30%	40%
Asia/Pacific-ROW	5%	15%	30%
Total	12%	50%	64%

Source: Dataquest (April 1995 Estimates)

Future Keyless Entry Applications

Wireless communication itself as an enabling technology will in future allow linkage of engine management, transmission and braking system for immobilization. Future RF keys could offer more processing power on-chip to increase the security level by implementing rolling codes or ciphering on-chip, thus permitting new application capabilities for keyless entry (wireless) offering customized keys for each family member that will, for example, automatically reset:

- Driver seat/mirror to memory position
- Restrict driver speed (depending on preset key priorities)

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- Restrict the distance travelled (mileage), or fuel usage (for garage mechanics)
- Restrict access to boot or glove compartment
- Reset driver preferences for preset-radio, CD, and so on

Current EU vehicle type approval is for door lock, antitheft steering column lock and transmission. Although there is no regulation in place for keyless entry, it will become mandated for EU vehicle type approval when it becomes fully implemented as a high-security door lock.

The major supplier companies of ignition keys, car alarms, engine management and engine immobilizers will continue to work toward the development of keyless entry systems. Major original equipment manufacturers (OEMs) active in this area are shown in Table 6-2.

Table 6-2
Major OEMs of Keyless Entry Systems

Company	Country
AB Electronics	United Kingdom
Ford Electronics	United Kingdom
GM-Delco	Kokomo, Indiana, USA
Kiekert	Germany
Kokusan	Japan
Lucas	United Kingdom
Magneti-Marelli	Italy
Nippondenso	Japan
Omron	Japan
Valeo	France

Source: Dataquest (April 1995)

Because these systems are addressing the mass production car markets, all the major volume car manufacturers are evaluating keys that enhance vehicle security. A further addition to keyless entry is RF transponder keys. Ford of Europe pioneered this application in Europe by introducing Texas Instruments' TIRIS RF key across the entire entry-level car range, resulting in new insurance ratings for the Fiesta and Escort models. Other major end-user market customers include the following:

- BMW
- Chrysler
- Delco Electronics
- Ford
- GM (Adam Opel/Vauxhall)
- Honda
- Jaguar
- Mercedes-Benz
- Mitsubishi
- Nissan
- Porsche

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- PSA Group (Peugeot/Citroën)
- Renault
- Subaru
- Toyota

Vehicle Identification

What Is Vehicle Identification?

Current EU vehicle type approval regulations for vehicle identification specify serial Vehicle Identification Numbers (VIN) to be etched into a vehicle identification plate that is affixed onto the car body and the car engine.

Global efforts to develop world standards for smart cars and highways using computers, wireless communications and electronic traffic control systems have resulted in a need for electronic vehicle identification. Research and development are being coordinated in the United States through the IVHS program, in Europe through the EU's PROMETHEUS program, and in Japan through the government's Info-Mobility projects.

Although there may be no world standards for vehicle identification, the various research efforts being undertaken will develop common standards to address the main aspects of electronic vehicle identification. The generic feature for all these systems requires wireless vehicle identification systems that may be designed around radiofrequency identification (RF/ID): radar, infrared, or digital cellular communication technologies.

RF/ID is a method of electronically tracking items using embedded tags or transponders, stationary or mobile readers, data input devices and system software. In low-frequency passive systems, usually 30 kHz to 500 kHz, a reader transmits a signal to an embedded or attached tag, charging the transponder and sending back a signal identifying the tagged item's unique code.

Low-frequency devices work best at a range of a few feet or less and transmit at 20 miles per hour. High-frequency systems, in the 900 MHz to 2.5 GHz range, are capable of transmitting a greater amount of information over a wider geographic area. High-frequency devices can be used at distances of 250 feet and at speeds of more than 150 miles per hour. In Europe some systems have been developed to operate within the 5.8-GHz range specifically for road-tolling applications.

Vehicle Identification Features

Electronic vehicle identification improves existing vehicle security and traffic/vehicle monitoring/control. It offers the capability of transmitting vehicle identification for specific applications such as prepaid road-tolling systems.

Current proposals for prepaid road-tolling systems are mostly smart card–based so that older cars can benefit. However, future systems may use an integrated car identification system that will hold the car owner's details. This could offer some added benefits for car security when the "intelligent highway" concept becomes a reality. For example, access to future transaction services (such as booking car parking spaces) may be accessed more easily electronically as VIN effectively provides a user address.

Other features driving future growth for vehicle identification include:

- Road tolling (debiting/crediting transactions)

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- Ability to restrict access of certain vehicle categories to road lanes
- Control and monitor road access
- Pre-booking parking space at destination
- Fleet transport movement control and antitheft applications

Future Car Identification Applications

With an electronic vehicle identification system linked to cruise control and collision avoidance systems, it is possible that cars travelling to the same destination could be chained together in a train. Such a combination is believed to control traffic speed and ease traffic flow, potentially making road traffic conditions safer. This concept is known as cooperative driving in the EU PROMETHEUS program. Future development starts in 1995 for what is known as medium-range pre-information systems that will involve cooperative driving, autonomous intelligent cruise control and automatic emergency calling. Table 6-3 gives Dataquest's forecast for these systems.

Table 6-3
Worldwide Automotive Market Penetration of Electronic Car Identification Systems

Region	1993	1998	2000
Europe	0%	8%	12%
Japan	0%	6%	15%
North America	0%	10%	20%
Asia/Pacific-ROW	0%	3%	5%
Total	0%	7%	14%

Source: Dataquest (April 1995 Estimates)

Already, pilot trials are being conducted to develop this concept in a pre-competitive research environment. Although there are no real major supplier companies for car identification systems because the protocols and standards have not yet been established in Europe or the United States, Table 6-4 lists car manufacturing companies which are involved in this research and similar projects in the United States and Japan, as well as other major participants which are suppliers, subcontract manufacturers, or partners to vehicle manufacturers and that have participated in the PROMETHEUS program.

Table 6-4
Companies Involved in the European PROMETHEUS Program

Car Manufacturers		Other Participating Companies
BMW	Mitsubishi	Celsius Technology
Chrysler	Nissan	DAIS
Daimler-Benz	Opel	Dräxlmaier
Fiat	Porsche	GEC-Marconi
Ford	PSA (Peugeot-Citroën)	HUSAT
General Motors	Renault	IBR
Honda	Saab	Leica
Jaguar	Toyota	Lucas
MAN	Volvo	Matra CAP
Mazda		Pilkington
		Robert Bosch
		Siemens Automotive
		TEMIC (Telefunken)
		Thomson

Source: Dataquest (April 1995)

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Speech Recognition/Synthesizers

What Is Speech Recognition/Synthesis?

Speech recognition and speech synthesis use digital signal processing (DSP) techniques. Speech recognition uses DSP to filter analog signals into meaningful digital signals. Speech synthesis uses DSP to process digital signals to produce speech.

Existing solutions for speech recognition require large amounts of memory: EPROM and DRAM mostly (for software), and this makes the whole concept rather expensive for car applications. Software is a key component of speech recognition technology and until artificial intelligence software is developed further, then large volumes of memory capacity will remain associated with this application.

Volume applications for this technology have been pursued for nearly 20 years now. The primary objective is to develop an aural user interface that bypasses graphical user interfaces (GUIs). Currently, some limited applications exist, for access to program applications, especially for car telephones and other access applications such as door entry and car navigation systems. The use for this technology in these applications largely consists of voice-enabling or command functions. Speech recognition is mainly used to complement or replace other interface technologies.

Speech Recognition/Synthesizer Features

Current in-car applications use speech recognition as command- or voice-enabled functions mostly for carphone applications:

- Frequently used telephone numbers are stored in memory with a speech command assigned to dial them.
- It allows for absolute hands-free operation of car telephones or other in-car peripherals.
- It enhances driver safety by enabling voice-activated command input for non-safety-critical functions in car peripherals systems such as car radios, in-car phone/fax machines, and navigation systems.

The main problem areas for this kind of technology are analog noise cancellation for speech in a noisy environment.

Future car applications will require high-performance microphones to cancel out noise in the speech/command environment. Approaches to this technology for automotive applications require substantial amounts of processing capability, which makes it a very expensive solution.

To become successful in volume market applications, it must offer enhancements to existing technologies, or newly emerging applications to drive its use in the car. The main attractions for speech recognition in the car are a host of possible hands-free applications, allowing the driver to restrict hand use to other safety-critical areas such as steering and gear change. At its best, speech recognition offers the capability of "interactive-communication" with other car systems such as radio, traffic information networks and other such applications. Initially, this will not be suitable for safety-critical applications until the technology achieves higher standards of reliability.

First-generation speech synthesis systems have already been used in cars, but the concept of speech recognition is yet to appear in cars. To realize maximum appreciation of these technologies, newer systems will have to be interactive, combining both speech recognition and synthesis.

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Table 6-5
Worldwide Automotive Market Penetration of Speech Recognition Systems

Region	1993	1998	2000
Europe	0%	2%	10%
Japan	1%	2%	10%
North America	0%	3%	15%
Asia/Pacific–ROW	0%	0%	5%
Total	0%	2%	10%

Source: Dataquest (April 1995 Estimates)

Against further implementation of this technology in the car is some very negative press reception, which is killing use of the systems even before they are designed into new cars. Most press reports describe the application as too "gimmicky" and impractical. European press coverage of earlier audio warning systems based on electronic speech synthesis (that constantly gave "doors open" warnings when they became faulty), discouraged early adopters, and blemished any prospect for this technology in the car when, for example, it was first introduced in the 1980s by Rover. As a result, speech recognition has not been massively successful. Table 6-5 details current and forecast penetration of the technology worldwide.

Emerging speech recognition systems will be for interactive car radio, navigation systems and other driver information systems.

Companies producing speech recognition/synthesis hardware and software are as follows:

- Hardware
  - AT&T Microelectronics
  - Clarion
  - Ford
  - Fujitsu-TEN
  - General Motors
  - Hughes Network Systems
  - NEC
  - Nippondenso
  - Nokia
  - Oki
  - Sanyo
  - Sharp
  - Toshiba
  - Voice Control Systems, Inc.
- Software
  - Lernout & Hauspie Speech Products, Belgium
  - Ricoh, Japan
  - Voice Control Systems, Dallas, Texas

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Future Speech Recognition Applications

Some state-of-the-art car navigation systems developed in Japan already offer speech synthesis. It is currently more accepted in Japan because of poor road signs and severe traffic conditions in the urban areas. In Europe, market acceptance of speech recognition is poor. The failure of existing systems to reproduce accurate and human voice responses makes the whole concept appear even more gimmicky. Early systems handle non-safety-critical applications such as windows, mirrors, seats, central locking and heating and air-conditioning control.

Secondary wireless application areas for speech recognition and interactive communication for automatic voice-activated hotel or restaurant reservations and other navigational aids may add value in other world regions for gradual market acceptance.

The proposed European standard for Traffic Message Channel protocol (for RDS-TMC) Alert-C offers a very structured digital language that has been developed to allow simple traffic information to be coded and transmitted to radio receivers equipped with a TMC decoder. The feature permits a user to receive traffic information in text form but in all the major European languages (English, French, German, Italian and Spanish). This structure could also be easily formatted for speech synthesis in the car allowing audio interpretation of the code for any language. It is likely that the European Alert-C protocol may be adopted on a worldwide basis, to become a world standard as GSM is beginning to prove.

RDS-TMC provides other benefits through the car radio such as:

- Up-to-date traffic information from automatic traffic data collection and automated message paths
- Capability to be selective in information retrieval by criteria (for example, according to route)
- Constantly transmitted without interruption

Other applications in the car could include audible early warning systems such as low fuel, obstacle detection, and audio vehicle diagnostics. The enabling technologies for car applications are not yet widely available. Computer software houses and telecommunications companies are among the forerunners exploring this technology and its use, but the automotive industry itself may borrow from such vertical industries once applications become available.

Global Positioning Systems

What Is GPS?

The Global Positioning System (GPS) is one product of the cold war that could prove lucrative. Developed by the US Department of Defense (DoD) as a strategic defense need, the Global Positioning System is a space-based satellite radio navigation system that provides a continuous source of three-dimensional positioning, velocity and time. The GPS infrastructure consists of a "constellation" of 24 low earth orbiting (LEO) satellites (including 3 operative "spares") orbiting in a predetermined configuration at an altitude of approximately 10,900 nautical miles above earth.

A GPS receiver relies on the principle of triangulation to calculate its set of location coordinates, by measuring accurately its distance from 4 satellites that are in view (using a digital signal processor and a microprocessor). This is accomplished by measuring precisely the time taken for a radio transmission to travel from a GPS satellite to the GPS receiver. A receiver uses an internal database

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(called an Almanac), stored in a PROM chip, to look up the exact 3-D coordinates at a particular time of any of the 21 satellites in space. Thus, the GPS receiver relies on highly accurate time information provided by each satellite, and high degrees of computation in each GPS receiver.

GPS Features

A GPS provides longitude, latitude and altitude information (making it possible to calculate location anywhere in the world) while a navigation system provides more than just position information, but also route guidance and direction information.

Global Positioning Systems offer immense capabilities for navigation systems with their accurate location tracking systems. The accuracy of the location systems also make them very suitable for vehicle tracking applications, and they are therefore designed into fleet control systems and car security systems.

Consumer receivers cost as little as $500, but even that figure is dropping dramatically. If they are integrated into other types of system like navigation or security systems, then system prices, depending on features, range from $1,500 to $6,000. Car manufacturers expect that by the year 2010, virtually every vehicle will be tracked using an embedded GPS engine. About one-third of the world's established GPS hardware (engines) and software is made in California by such companies as Magnavox, Magellan Systems, Ashtech, Trimble Navigation, ESRI and Rockwell International. Other manufacturers include the following:

- Ashtech
- Navstar (a Peek Company)
- Garmin
- New Japan Radio Company (JRC)
- GEC-Plessey Semiconductors
- NovAtel Communications
- Koden
- Sony
- Motorola
- Socket Communications Inc.

GPS applications in the car are mostly to aid dynamic driver navigation systems which use dead-reckoning. Although they have seen successful introduction on the Japanese aftermarket for nearly four years now, car manufacturers have only recently begun to offer them as an option. In Japan Honda, Toyota, Mazda, Mitsubishi and Nissan are now offering GPS navigation systems with their top-of-the-range car models; while in the United States General Motors is leading with OEM installations of its Guidestar navigation system developed with Hughes Electronics; and in Europe BMW, Mercedes and Jaguar (Ford) are emerging as pioneers for OEM installations of navigation and traffic information systems.

Dataquest believes that GPS navigation systems will begin to take off from the year 2000 onwards (see Table 6-6). To date, the Japanese lead in aftermarket installation and car factory installations of GPS navigation systems. GPS navigation markets in Europe and the United States are only just beginning.

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Table 6-6
Worldwide Automotive Market Penetration of Global Positioning Systems

Region	1993	1998	2000
Europe	0%	20%	30%
Japan	2%	40%	50%
North America	0%	8%	15%
Asia/Pacific–ROW	0%	6%	10%
Total	1%	20%	27%

Source: Dataquest (April 1995 Estimates)

Suppliers of the systems are as follows:

- GPS-based car navigation systems:
  - Aisin (Japan)
  - Peek (United Kingdom)
  - Alpine (Japan)
  - Philips Car Systems (Germany)
  - Clarion (Japan)
  - Pioneer (Japan)
  - Delco (USA)
  - Robert Bosch/Blaupunkt (Germany)
  - Ford (USA)
  - Sagem (France)
  - Fujitsu-Ten (Japan)
  - Sanyo (Japan)
  - Gilardini/Fiat (Italy)
  - Siemens (Germany)
  - JVC (Japan)
  - Sony (Japan)
  - Kenwood (Japan)
  - Sumitomo Electric (Japan)
  - Mannesmann/VDO (Germany)
  - Toshiba (Japan)
  - Motorola (USA)
  - Xanavi (Japan)
  - Nippondenso (Japan)
  - Zexel (Japan)
  - Panasonic (Japan)

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- Major digital map suppliers:
  - Etak Technologies (News Corporation International subsidiary)
  - Road Scholar Inc. (PC map software company)
  - Robert Bosch (Germany)
  - European Geographic Technologies (EGT)
  - Personal Travel Technologies Inc. (with locations of hotels, restaurants and so on)
  - Zenrin (Japan)

Navigation Systems

What Is a Navigation System?

Several different navigation systems are available for automotive use. They typically range from variants incorporating a liquid crystal display (LCD) which may be graphic, text or alphanumeric, Azimuth sensors (for measuring coordinates), distance-travelled sensors, GPS, CD-ROM maps, FM radio data systems/traffic message channel (RDS-TMC) and GSM (Global System for Mobile Communications) voice/data telephony capability.

For most car navigation systems, the driver will key in the destination, with the system then guiding the driver to the selected destination. The methods of calculating and planning routes differ by type of navigation system. However, most electronic navigation systems embrace the basic method of finding your way to any destination using GPS and digital maps. State-of-the-art navigation systems in a car need to meet certain requirements:

- Ability to operate in a mobile environment
- Continuous operation mode for the duration of the journey
- Fast, clear and concise display of information
- Provide "real-time" information
- Rationalize new roads/changes in road-direction flow

Navigation System Features

Earlier car navigation systems were simply electronic compasses. Navigation systems have advanced through map-based route guidance systems incorporating cathode ray tube (CRT) visual display units (VDUs) to intelligent dynamic navigation systems using satellites, LCDs and digital CD-ROM maps. Some of the differentiating features among the several emerging platforms for car navigation systems are as follows:

- Gyroscopes/dead-reckoning/compass
- Global positioning satellites
- CD-ROM map-based navigation
- Traffic information processing
- UHF radio/GSM telephony

Car navigation systems fall into three main categories—autonomous route guidance, interactive route guidance, and traffic information. Autonomous route guidance systems use a GPS receiver, CD-ROM and on-board computer, and sometimes an electronic compass and/or wheel distance sensors are used. These systems provide on-board route guidance to the driver without any use of real-time traffic information.

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Interactive route guidance systems provide route planning information by receiving traffic information from FM-RDS stations or via GSM data communication channels. RDS information is received from the in-built radio. This traffic information is processed by the on-board computer to provide the most efficient route guidance for the selected destination. They may also use roadside beacons to communicate with the vehicle's on-board navigation system to receive traffic information in city centers.

Traffic information systems are real-time systems like the United Kingdom's "Trafficmaster," which provides traffic information collected using infrared beacons to detect vehicle speed (traffic flow) on motorways. The Trafficmaster also provides text information about traffic incidents and could be used as a radio pager. These systems give traffic information but with very limited navigation information.

Emerging application trends will incorporate the following:

- Audio: Car radio RDS-TMC (character LCDs)
- Visual: Information boards (in-car navigation systems—LCD VDU)
- Semi-interactive intelligent systems (DAB)
- Bidirectional and interactive communications and off-board digital maps (GSM)

Car navigation systems have existed for many years now, but the market for these systems has been very slow to develop (see the current and forecast penetration in Table 6-7), as these systems have taken longer to reach the development phase that exists today. In the early days, gyroscope positioning was the only available system to aid driver navigation and these devices had some major drawbacks in accuracy.

CD-ROM maps were developed for use in second-generation systems, but these too were not entirely adequate. At the end of the cold war, global positioning technology became available and a combination of these three technologies is now widely acknowledged as offering the most reliable navigation techniques available for car navigation systems.

It is clear that navigation systems still have quite some way to go; for example, next-generation systems may not include CD-ROM maps as an integral part of the system. Digital mobile communication technologies will allow electronic maps to be transmitted to cars in the future.

Table 6-7
Worldwide Automotive Market Penetration of Vehicle Navigation Systems

Region	1993	1998	2000
Europe	0%	3%	7%
Japan	2%	20%	40%
North America	0%	3%	5%
Asia/Pacific–ROW	0%	1%	5%
Total	1%	7%	13%

Source: Dataquest (April 1995 Estimates)

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Another product development trend is that most manufacturers of car navigation systems are the major car radio manufacturers. It is somewhat inevitable that navigation systems will become integrated with car radio. This will produce a more versatile driver information system with multimedia capability in the car.

Suppliers of car navigation systems include the following:

- Aisin (Japan)
- Panasonic (Japan)
- Alpine (Japan)
- Pagamatron (France)
- Clarion (Japan)
- Philips Car Systems (Germany)
- Delco (USA)
- Pioneer (Japan)
- Ford (USA)
- Robert Bosch/Blaupunkt (Germany)
- Fujitsu-Ten (Japan)
- Sagem (France)
- Gilardini/Fiat (Italy)
- Sanyo (Japan)
- JVC (Japan)
- Siemens (Germany)
- Kenwood (Japan)
- Sony (Japan)
- Mannesmann/VDO (Germany)
- Sumitomo Electric (Japan)
- Mazda (Japan)
- Toshiba (Japan)
- Motorola (USA)
- Toyota (Japan)
- Nippondenso (Japan)
- Xanavi (Japan)
- Nissan (Japan)
- Zexel (Japan)

GSM

What Is GSM?

Global System for Mobile Communications (GSM), initially developed as a pan-European digital cellular telecommunications network, is fast becoming the world standard for digital cellular communications.The primary application of GSM in cars will be data-driven applications that fit into the advanced

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road transport telematics program. GSM offers bidirectional communication, while the FM radio RDS/TMC only offers one-way communication.

Future Applications and Features of GSM

As part of the EU SOCRATES program, research funding was made available to participants for exploring ways of utilizing GSM for a pan-European traffic information infrastructure. There are four projects developing SOCRATES: the Kernel project which coordinates the research and development; and pilot trials in three countries—London in the United Kingdom (APPLE pilot project), Frankfurt in Germany (RHAPIT pilot project), and Gothenburg in Sweden (TANGO pilot project). Major participating companies in SOCRATES projects are as follows:

- Adam Opel
- Philips Car Systems
- British Telecommunications plc (BT)
- Philips Kommunications Industrie AG
- CelsiusTech Systems
- RAC Enterprises
- Daimler-Benz
- Renault
- DeTeMobil
- Robert Bosch
- European Geographic Technologies
- Rover Group
- Expertel
- Saab Automobile
- Ford Motor Company
- Saab Mecel
- France Telecom Grands Comptes
- SEMA Group Telecom
- GEC Marconi Transport Systems
- Telecom Securicor Cellular Radio
- Hessisches Landesampt für Stassenbau
- Telefónica
- Heusch Boesefeldt
- Telia Mobitel
- Kjessler and Mannerstraler
- Traffic Research Institute
- Lockheed IMS (UK) Ltd
- Volvo Technological Department
- London Transport

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Compared to analog cellular, GSM offers a superior spectrum efficiency which allows for speech clarity, provides improved communication security and eliminates some of the fading problems associated with analog cellular telephony. Initially developed for voice communication applications, GSM technology is rapidly beginning to provide a medium for data transmission. It is this capability that opens up new areas for automotive applications.

For driver information—road transport, traffic and navigation—purposes, GSM offers the capability to deliver data at 9 Kbit/s which allows for immense flexibility for real-time information delivery. The most significant feature of GSM in automotive applications is the ability to provide bidirectional data exchange for off-board information processing. Precise position information could be sent via digital cellular communications, linked with an on-board GPS.

In future automotive applications, GSM will offer high-speed/high-density bidirectional data transfer capabilities; for example, GSM could be used in the following areas:

- **Digital road maps**: To deliver, digitally, electronic maps to subscribers of a GSM system which will be temporarily stored for use with a car navigation system. This is especially valuable as freshly updated maps could be provided instantly without risk of being outdated.
- **Road tolling (cashless transaction processing)**: To provide data interchange for electronic cashless transactions for prepaid road tolling debiting. It could also be used to facilitate traffic control and information by utilizing data from such electronic tolling plazas or from roadside transponder networks.
- **Market information services**: GSM could be used for electronically paging customized traffic information which is tailored to suit prespecified routes (such as tourism, trade, brief news and diagnosis).
- **Security and emergency calling**: Automatic SOS calls giving the location of the vehicle with the use of a GPS navigation system to police, fire, ambulance or recovery services.
- **Traffic management (park and ride)**: Automatic booking and reservation of public car parking spaces in advance of reaching the destination. This feature extends to allow GSM for automatic reservations in other commercial applications like restaurants, cinemas, theatres and other such applications.

Although at this time, government ministers have not yet approved GSM as an application for advanced telematics infrastructure, several car manufacturers and subsystem manufacturers have developed systems for this industry. OEMs of hardware include the following:

- Robert Bosch/Blaupunkt
- Nokia
- Dancall
- Oki
- Ericsson
- Orbitel
- Hagenuk/Cetelco
- Panasonic
- Matra-AEG
- Sony

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- Mitsubishi
- Siemens
- Motorola
- Mannesmann/VDO
- NEC

Dataquest believes that navigation systems incorporating GSM will offer an abridged version of GSM technology offering just data communication. Car systems will have the option of integrating both data and voice at the customer's request. Automotive manufacturers will be looking at integrating these systems in the interior compartment design of future cars. Table 6-8 gives Dataquest's projections for penetration of these systems.

Table 6-8
Worldwide Automotive Market Penetration of Digital Mobile Communication Systems

Region	1993	1998	2000
Europe	0%	10%	15%
Japan	3%	5%	10%
North America	0%	1%	5%
Asia/Pacific–ROW	0%	0%	1%
Total	1%	5%	9%

Source: Dataquest (April 1995 Estimates)

Digital Audio Broadcasting

What Is DAB?

Digital audio broadcasting (DAB) is the result of the seven-year Eureka project EU 147 (costing $110 million) to develop the standards for digital terrestrial radio. Digital audio broadcasting involves the newest audio broadcasting technology developed to replace existing analog broadcasting systems. Analog information (usually speech or music) is digitized and transmitted in digital format. The result is that it offers digital CD-like sound quality from radio broadcasts that is superior to the best FM radio can offer. Test transmissions are already broadcast in France, Germany, Italy, the Netherlands, Sweden and the United Kingdom. Fully operational pilot trials and tests will begin from the second half of 1995 in several countries including most EU member states, and outside Europe in Canada and Australia.

DAB Features

DAB is especially suited to vehicle radio applications because it eliminates the noise problems associated with analog radio signals and offers constant, excellent reception quality. Distortion of FM radio signals caused by multipath propagation and other physical conditions are avoided by using a transmission method known as coded orthogonal frequency-division multiplex (COFDM). DAB also allows the transmission of data such as music/speech identification, program type identification, station name and other such text data that could be transmitted with audio broadcasts.

Future DAB Applications in the Car

Largely because DAB (unlike GSM) is not a bidirectional communication medium, in the future, powerful data channels will allow specific information to be transmitted to closed user groups, opening up the possibility of "data

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broadcasts" and conditional access services alongside audio broadcasts. Examples of data broadcasting services for DAB include:

- Traffic message channel (character text-based)
- Paging systems
- Stock market news
- Real-time electronic maps for car navigation systems
- Weather information

Although the DAB market is not yet developed for commercial use (see Table 6-9 for current and forecast penetration), Dataquest believes that Germany will lead the world with its introduction. Nearly 40 percent of the Western European car radio market is in Germany, and car radio manufacturers will begin to switch production to DAB systems when the service becomes commercially available in Germany from 1997. The nearest single European car radio country market is less than 15 percent of the European market.

Table 6-9
Worldwide Automotive Market Penetration of DAB Car Radios

Region	1993	1998	2000
Europe	0%	3%	5%
Japan	0%	0%	5%
North America	0%	1%	3%
Asia/Pacific–ROW	0%	0%	0%
Total	0%	1%	4%

Source: Dataquest (April 1995 Estimates)

First-to-market OEMs of DAB radios include the following:

- Becker
- Philips
- Clarion
- Robert Bosch (Blaupunkt)
- Delco
- Sony
- Grundig
- Thomson Consumer Electronics

Many of these OEMs currently have prototype test receivers available—which are too bulky for car dashboards. By September 1995 (in time for the Berlin IFA-*International Funkausstellung Berlin, 1995*), these manufacturers are expected to bring some prototype models to market, although the cost of these systems at that time will not be attractive for OEM factory installations. Market development for car DAB systems will take place when car manufacturers sign up for volume allocations that will bring component prices down.

Typically, it takes two years in a car manufacturer's design cycle for dashboard applications to appear on the market. With the introduction of DAB to the volume German market planned for 1997, we do not expect to see DAB car radios become factory-fitted until after 1998. Initial systems will likely be sold through aftermarket channels after the fourth quarter of 1996, although these

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will be insignificant volumes. We expect to see DAB volumes begin to have some slight effect on the semiconductor market by the year 2000. Since DAB will be simulcast with existing FM for at least 15 years, it will not be until around 2010 that the market will begin to take off.

Dataquest believes that these first systems will be hybrid systems capable of receiving both digital audio broadcast and analog broadcasts; thus, some hybrid radios will remain on the market for many years before the switch to full coverage of DAB takes place.

Head-Up Displays

What Is Head-Up Display?

For a number of reasons ranging from reduced night visibility through to dashboard instrument clutter, solutions are being sought to prevent momentary lowering of driver alertness. Head-up displays (HUDs) are seen as a technology to present essential information in the driver's field of view. Developments for future in-car applications have been borrowed from aircraft and military systems to improve road safety. HUDs use a display projector built into the car dashboard which projects images onto specially constructed windscreens. The special windscreen construction (using glass optics and projection techniques) allows projected virtual images to be viewed in light (day) or dark (night) conditions.

Future Application of HUDs

Head-up display technologies have now reached a stage of near commercial introduction into vehicles. In the United States and Japan car manufacturers such as Nissan and General Motors have introduced first-generation car models with HUDs for primary information display (dashboard warning signals). Future applications of HUDs include the following:

- Primary information display (speedometer, dashboard warning signals and advance road/traffic warning information)
- Secondary information display (enhanced vision in fog, rain and snow or at night)
- Tertiary information display (for example, early warning signalling of road conditions such as ice, snow, rain and flood)

As part of the global research initiatives such as the equivalent of Europe's PROMETHEUS program in the United States and in Japan, car manufacturers are keen to prove that HUDs enhance driver alertness and improve driver focus on the road. However, the real barrier to the deployment of HUDs in cars is currently the cost of projection technology. DSP costs are still too high, and until such time that car manufacturers are convinced that customers will be willing to pay for these systems, they are likely to remain in research and development labs until around 2010.

The single most important market driver for HUDs is night vision enhancement, and this is the area where much of the current development is taking place. The key issues here are how to perfect a technology for image detection that is dazzle-proof. Image detection and projection in current solutions using infrared cameras and charge-coupled devices (CCDs) are affected by oncoming vehicle lights.

Another area for further development in HUD technology is to improve the image quality projected onto the windscreen for vision enhancement. Current systems that use ultraviolet technology for thermal image detection are not

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very good for image clarity or projection. Further technology development is required in this area to overcome this problem.

Although HUDs for speedometer and other dashboard applications are available, the market is very insignificant at the moment (see Table 6-10) as there is no real justification for this additional cost option item. Future systems will have capability for night vision enhancement, and this is the aspect of most interest to car manufacturers.

At present, General Motors has a HUD option available for its Oldsmobile Cutlass Supreme model and the Pontiac Bonneville models. These are cheaper, low-end HUD systems that cost $250 as a standalone option. Nissan also has a similar HUD system in its Sylvia car model built for the Japanese market only. Typical information displays of existing HUD systems include:

- Update of road signs
- Speed
- Fuel distance to empty
- Temperature (inside/outside)

HUD systems need a fairly sophisticated projection technology onto the windscreen. Some prototype systems use basic camera technology while for certain thermal image detection HUD systems, some fairly complex CCDs are used. Future applications for HUD will be for driver information purposes or warning signals to the driver such as the following:

- Enhanced night vision
- Warning of road conditions (black ice, oil spill, slippery surface, snow, rain and so on)
- Advance warning of route traffic conditions
- Navigation/travel direction display

Although this technology is unlikely to appear in cars for many years, there appear to be two companies very active in HUD technology for automotive applications; many other companies that manufacture HUD systems for the military and aviation industry are also known to be developing low-cost HUD prototypes for automotive vision enhancement applications. Many of these prototypes are currently in development and by 2000, first-generation systems should begin to gain entry into the high-end automotive markets, commercial vehicles, and vehicles used by the emergency services such as the police, fire, vehicle/disaster recovery and ambulance services.

Table 6-10
Worldwide Automotive Market Penetration of Head-Up Displays

Region	1993	1998	2000
Europe	0%	1%	1%
Japan	1%	2%	3%
North America	0%	2%	2%
Asia/Pacific–ROW	0%	0%	0%
Total	0%	1%	2%

Source: Dataquest (April 1995 Estimates)

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Major automotive HUD technology developers include the following:

- BMW
- British Aerospace
- Delco Electronics
- Fiat (Magneti-Marelli)
- Ford
- Libbys Owens Ford (LOF)
- Nissan
- Peugeot-Citroën
- Pilkington Glass and Jaguar Cars
- Renault
- Toyota

Near Obstacle Detection

What Is Near Obstacle Detection?

Near obstacle detection (NOD) systems monitor objects that come within short-range view of vehicles and warn the driver about these obstacles. They work on a principle utilizing electronic sensors that may fit into rear-end light panels or vehicle bumpers. Current systems designed for the automotive industry use ultrasonic sensors or infrared sensors that monitor moving vehicles in the blind spot area. The most common application is for reversing assistance (when gear selection is in reverse).

Features of Near Obstacle Detection

Near obstacle detection uses sensors to detect obstacles in the path of view. Some systems deploy infrared sensors, radars (microwave/millimeter wave) or CCD cameras.

Typically, a basic NOD will deploy a sensor which will detect obstacles. The sensor could be infrared, radar, or microwave. The electronic control unit will receive signals from the sensor, and each time an obstacle is detected in the view of the sensor, a break in signal transmission will trigger the warning. Based on a camera principle, each sensor sends and receives focused infrared rays through a special optical system. The system can be activated only by setting the turning indicators. Any object up to a preset distance away from the sensor triggers the warning signal.

Vehicle manufacturers may configure the warning signal to provide audible, visual or audio/visual warning signals. Price estimates of this kind of system range from around $50 and above, and it is anticipated that these systems will be first introduced for commercial vehicle applications before we see them in cars.

Convex and aspheric mirrors minimize the blind spot, but the scale differences easily confuse the driver as an estimation of the real distance of cars approaching from the back is almost impossible, especially at night.

Siemens Semiconductors and Autosense Ltd. of Denver, Colorado have developed a system based on this principle that will indicate the presence of any vehicle in the blind spot area through warning lamps inside the car or at the outside mirror.

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Table 6-11
Worldwide Automotive Market Penetration of Near Obstacle Detection Systems

Region	1993	1998	2000
Europe	0%	1%	5%
Japan	2%	7%	15%
North America	0%	3%	10%
Asia/Pacific–ROW	0%	0%	3%
Total	1%	3%	8%

Source: Dataquest (April 1995 Estimates)

Future systems could be integrated into active collision avoidance systems. Although existing systems are deployed by some commercial vehicle manufacturers, the use of these systems could become mandatory for commercial vehicles or vehicles with high driver cabins.

Table 6-11 gives Dataquest's current and projected penetration for near obstacle detection systems. Manufacturers and suppliers of the systems include the following:

- Delco Electronics
- HE Microwave
- Hitachi
- NEC Electronics
- Mitsubishi
- Sharp Electronics
- Siemens
- TEMIC (Telefunken)

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Chapter 7
Powertrain Electronics

Although the rate of penetration for powertrain electronics is fast approaching maturity as a result of legislation to curb exhaust emissions to protect the global environment, further advances in electronics are very actively pursued in this area. Powertrain electronics is increasingly seen as the powerhouse of all vehicle electronics. This segment will expand to gain control of other areas of automotive electronics as the need to merge functions of individual electronic control systems becomes a reality.

The merging of electronic control systems will depend largely on developments in the data-bus area where multiplexed wiring technology is replacing the traditional vehicle wiring harness. Future powertrain applications will involve and control all aspects of vehicle motion dynamics ranging from total control of vehicle stability, steering control, suspension control, braking control, transmission and safety, to security controls. In achieving this purpose, larger packets of input data will be processed by the engine control unit and larger-size software programs will need to be developed to cope with the diversity of algorithms that will be calculated. Research efforts geared toward reaching these objectives are already in place at most major motor manufacturers' research and development divisions.

Parallel to these developments are newer forces driving further use of electronics to achieve widely diverging solutions but converging applications that have become established parameters for engine management systems such as:

- Fuel crisis and fuel efficiency drive
- Performance enhancement and vehicle safety
- Environmental pressure
- Vehicle security and insurance costs
- Vehicle diagnostics control
- IVHS and advanced traffic telematics

In examining the potential for these developments, this chapter of the report covers the aspects of powertrain electronics and all directly and indirectly related emerging systems that will play a role in reaching the goal of intelligent vehicles or the so-called "smart car" of the next decade. The following applications are explained in this chapter to identify the importance and the use of each system:

- TCS/traction control (and antiskid control/ASR)
- Electronic power steering
- Active suspension/adaptive suspension
- Intelligent/smart cruise control
- Electronic transmission: Tiptronic
- Electronic clutch
- Electronic brakes (brake by wire)
- Collision avoidance
- Diesel electronic fuel injectors (electronics)
- Driving stability control and guidance system (DSC)

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TCS/Traction Control (and Antiskid Control/ASR)

What Is Traction Control?

Traction control prevents the wheels from spinning by reducing engine speed, whereas ABS prevents wheels from locking by optimizing braking pressure. Traction control (sometimes referred to as ASR or antiskid control) was first developed for high-performance cars. Most traction control systems are integrated into an ABS and often share the same electronic control unit.

Features of Traction Control

Earlier-generation traction control systems reduced engine speed when wheel sensors detected wheel spin. The application for traction control in cars first became popular in the 1980s to aid performance in sports cars.

Nowadays, traction control is being developed as a safety application for traction control in adverse road conditions (snow, rain, black-ice, and so on). Thus, to prevent loss of traction in adverse road conditions, the focus is on developing sensors for detecting road conditions. This is the newly emerging area of development that will move traction control into the mass market. Like ABS, traction control helps to maintain vehicle traction and steering.

The electronic control unit deploys wheel speed sensors, engine speed sensors/throttle valve position sensors, a brake switch, and an on/off switch for the traction control system itself. Data from the wheel speed, engine speed/throttle valve position sensors and brake switch state are processed by the electronic control system; output is fed though actuator control devices to the hydraulic brake valves, and the ABS pump relays and the electrical drive of the throttle valve. Thus, when a driving wheel slips it is braked by an active intervention of the brakes. In other extreme conditions, such as cornering on roads with reduced traction (wet roads), the processors decrease engine torque using the throttle valve actuator.

Like many safety critical electronics systems in cars, the electronic control unit uses multicontrollers and could have up to three microcontrollers (8-bit MCUs). One microcontroller is used for the main application, the second controller is a watchdog controller, and the third controller acts as a diagnostics and safety logic controller.

Future Traction Control Applications

Having first made its debut in racing cars, traction control has since gained entry for commercial vehicle applications. The next stage in the development of traction control systems is to advance the road condition sensor technology for this application to be deployed in the medium-size and small car markets.

Dataquest forecasts that this application, when perfected, will eventually become a standard offering with ABS. Eventually where advanced car electronics are deployed, traction control may be attached to engine management for engine braking. Table 7-1 gives current and forecast penetration of these systems.

It is conceivable that traction control, ABS and engine management systems connected with an active suspension system would provide an excellent solution for safer motoring and dynamic vehicle control. Driving stability control systems are themselves an extension of ABS and traction control.

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Table 7-1
Worldwide Automotive Market Penetration of Traction Control Systems

Region	1993	1998	2000
Europe	5%	30%	35%
Japan	5%	20%	35%
North America	8%	45%	50%
Asia/Pacific–ROW	1%	5%	10%
Total	5%	28%	34%

Source: Dataquest (April 1995 Estimates)

Major suppliers of ABS and traction control systems include the following:

- Alfred Teves/ITT
- Allied Signal
- Bendix
- FAG Kugelfischer (Motorcyles)
- Kelsey-Hayes
- Lucas Braking Systems
- Nippon ABS
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes
- TEMIC (Telefunken)

Electronic Power Steering

What Is Electronic Power Steering?

Conventional power steering systems use a method of magnification to reduce the amount of effort used to turn the steering wheel. This method operates with a hydraulic power steering pump system. Power steering systems with fixed-magnification ratio have major drawbacks. If the system is designed to reduce the force needed to turn the wheel when the car is stationary, steering becomes too loose when the car is driven at greater speeds; this is where electronics are used.

Features of Electronic Power Steering

The application of electronics in this area is focused on controlling the degree of magnification to apply equal amounts of hydraulic force to compensate for variable speeds. To control hydraulic power steering, speed sensors, solenoid valves, hydraulic pumps and a power steering gearbox is currently deployed by most of the emerging electronic power steering systems.

The only input to the electronic control unit for power steering is from the vehicle speed sensor. The output signal activates a linear solenoid valve (a solenoid valve that can be controlled at any arbitrary position depending on the average current). The solenoid valve is used to control the hydraulic power steering.

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Table 7-2
Worldwide Automotive Market Penetration of Electronic Power Steering Systems

Region	1993	1998	2000
Europe	1%	5%	10%
Japan	30%	45%	65%
North America	4%	9%	15%
Asia/Pacific–ROW	0%	3%	5%
Total	9%	16%	23%

Source: Dataquest (April 1995 Estimates)

Newer developments in power steering are expected to shift away from hydraulic system to electronic power motors which can be controlled more efficiently and will drain less engine power, thus becoming more energy-/fuel-efficient. These types of power steering system are now in development (particularly for electric vehicles) and are expected to become widely available by 2005 (see Table 7-2 for the Dataquest forecast out to 2000).

Active Suspension

What Is Active Suspension?

The concept of suspension control covers a number of functions aimed at improving the overall stability and performance of a vehicle. The basic objective of suspension control is to reduce vehicle rocking, rolling, pitching and yawing. A combination of driver-controlled actions such as steering, braking and speeding often lead to instability.

Several techniques may be used to avoid vehicle instability from such driver actions. Active suspension is one method, and is based on a principle of controlling dampers (shock absorbers) and springs while maintaining vehicle height to maximize stability. Softening the dampers reduces vehicle shock from jolts in road surfaces but increases springing, while hardening the suspension stiffens springs. A compensating compromise needs to be achieved to sustain comfortable ride quality. This can only be done by electronic suspension control. The damper and spring control system is described as ride control or adaptive suspension. Active suspension combines height control to adaptive control techniques. The height control system relies on sensors that monitor and control each wheel height.

Features of Active Suspension Systems

The electronic control unit (ECU) of an active suspension system receives signals from a number of peripherals and sensors. A fully configured system will receive inputs from the following:

- A mode select switch (which selects the ride quality parameters)
- Steering sensors (to calculate damping rock/roll compensation for sharp steering/cornering)
- Braking light sensors (to prevent diving when braking hard)
- Throttle control—via the engine control unit (to minimize dipping of the rear end when accelerating)
- Vehicle speed sensor (to improve roadholding when the vehicle is travelling at high speed)

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- Optional—automatic transmission neutral sensor (to monitor the vehicle's current travel status)
- Vehicle height control sensor (body to ground clearance sensors)—active suspension
- Diagnostic check system

How Does Active Suspension Work?

The electronic control unit processes signals from all the input sensors and outputs to actuators that control damping or suspension control. It uses algorithms that are developed to maintain optimal stability in all driving situations to aid vehicle control.

Active suspension systems are tailored for different types of vehicle as they incorporate specific algorithms related to vehicle weight/mass distribution and velocity metrics. The ECU sends signals to an actuator to select damping (shock absorber tensioning), an electronic DC motor, and a solenoid valve to control hydraulic pressure in the shock absorber. Typically, an 8-bit microcontroller is used for these functions.

For height control, the ECU receives signals from each wheel height sensor and applies the damping control to compensate for increases or decreases in height caused by loading. Maintaining vehicle height ensures vehicle stability and also minimizes changes in the optical axis of the headlamp illumination angle. Most active suspension systems use actuators for air or hydraulic springs to adjust vehicle height.

Active suspension emerged first in Formula 1 racing in the 1980s but has been slow to gain market acceptance by car manufacturers. As early as during the 1980s, Toyota and Nissan had been installing active suspension systems on their top-range cars as an option, but penetration remained low. During 1994, Citroën developed an "Activa" version of the new Xantia car model and offered this model with a hydraulic active suspension system. Toyota is now offering active suspension systems with the top-range Lexus cars. The costs of developing these systems and the length of development time make them a very expensive solution for car applications. Newer systems such as driver stability control systems are emerging as more cost-effective ways of achieving similar results.

Major suppliers of active suspension and damping control systems are listed below, and Table 7-3 contains Dataquest's projections for penetration of these systems:

- Lotus Engineering
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Tokiko
- Valeo

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Table 7-3
Worldwide Automotive Market Penetration of Active Suspension Systems

Region	1993	1998	2000
Europe	0%	1%	2%
Japan	1%	3%	5%
North America	0%	3%	6%
Asia/Pacific–ROW	0%	0%	1%
Total	0%	2%	4%

Source: Dataquest (April 1995 Estimates)

Intelligent/Smart Cruise Control

What Is Intelligent Cruise Control?

Cruise control or fixed-speed driving control is a system that allows drivers to travel at a constant fixed speed without using the accelerator pedal. The main benefit of cruise control is to reduce driver strain or fatigue during long motorway journeys. The earliest systems used analog circuitry but most current systems use digital circuitry.

Features of Intelligent Cruise Control

When cruising speed is set, the electronic control unit will calculate vehicle speed using signals from the speed sensor, and then maintain vehicle speed using a throttle control actuator. Fixed speed cruising is cancelled by a cancel signal which can be set using the foot brake pedal, clutch, or parking brake switch. Most systems use a 4-bit or 8-bit micocontroller for this application, but this is becoming increasingly integrated with engine management control systems.

Intelligent cruise control is the next-generation cruise control currently under development. Specifically designed to improve driver safety, intelligent cruise control can be set to adjust cruising speed with that of the vehicle in front of the driver. This is to avoid frontal collision when cruise control is set and the driver is lulled into a false sense of security. Intelligent cruise control will have more than one input signal and will take additional information from other obstacle detection sensors such as radar, microwave and/or infrared sensors.

Most drivers of cars fitted with cruise control systems rarely use this feature, but it is becoming standard equipment with most automatic transmission cars. Intelligent cruise control is a major function of so-called "cooperative driving" where cars travelling towards a common destination on motorways are batched together in wireless chains. The collision avoidance technology is employed in the cooperative driving system and is proven to improve traffic efficiency.

Future systems will incorporate near obstacle detection technology; consequently, it is likely that in the near future, newly developed systems will commonly be hybrid detection systems using both radar and infrared detection technology.

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Table 7-4
Worldwide Automotive Market Penetration of Intelligent Cruise Control Systems

Region	1993	1998	2000
Europe	0%	1%	2%
Japan	3%	5%	10%
North America	0%	2%	3%
Asia/Pacific–ROW	0%	0%	1%
Total	1%	2%	4%

Source: Dataquest (April 1995 Estimates)

Major developers of intelligent cruise control systems are listed below, and Table 7-4 gives Dataquest's projections for current and future penetration of the systems:

- Delco
- Denshi Giken
- Jidosho Denki Kogyo
- Fujitsu Ten
- Motorola
- Nippondenso
- Robert Bosch
- Mercedes-Benz Research
- Mitsubishi Electric
- Siemens Automotive
- TRW
- TEMIC (Telefunken)

Electronic Transmission: Adaptive Shift Pattern

What Is Electronic Transmission?

There are several different types of electronic transmission system, ranging from driving mode transmission control for automatics and continuous variable transmission (CVT) control systems and, ultimately, adaptive shift pattern (ASP) transmission. Most electronic automatic transmission control systems are programmed for economy and sport driving modes. ASP allows the driver to drive in three modes: manual, automatic and a third metric automatic mode that allows the transmission system to adapt a number of driving patterns. Table 7-5 gives the worldwide forecast for electronic transmission.

An example of an ASP transmission system is Porsche's Tiptronic developed by Porsche and Bosch for the Le Mans Porsche 962 and Maclaren F1. Tiptronic first appeared in production Porsche cars during 1990. Today, BMW (Alpina), Audi (A8), and Saab also offer this system in their top-range cars. Nissan (Maxima) and Toyota (MFG super-performance sportscar) have a similar system.

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Table 7-5
Worldwide Automotive Market Penetration of Electronic Transmission Systems

Region	1993	1998	2000
Europe	0%	5%	10%
Japan	0%	4%	15%
North America	0%	15%	20%
Asia/Pacific–ROW	0%	1%	3%
Total	0%	7%	12%

Source: Dataquest (April 1995 Estimates)

Features of Adaptive Shift Pattern Electronic Transmission

The major benefit of the ASP system is the ability to offer manual transmission driving in an automatic transmission car. The Porsche Tiptronic system receives input from eight sensors and interfaces with the ABS/traction control system and engine management systems:

- Engine speed sensors
- Lateral acceleration sensors
- Lateral deceleration sensors
- Road speed sensor
- Temperature sensors (engine)
- Throttle angle sensor
- Throttle speed sensor
- Transmission sensors

Current first- and second-generation Tiptronic systems were designed around an 8-bit microcontroller, but the trend is toward using 32-bit controllers for newer transmission systems as the new designs eliminate mechanical function replacing mechanics with electronics—this requires more software and faster processing performance—making them smaller and lighter. The complexity of the controller is dependent on transmission technology and design of transmission system. The electronic control units outputs signals to solenoid valve actuators that control the transmission system and also to the engine management systems.

The ECU in the Tiptronic system monitors and learns driver behavior, while assessing environmental conditions. Depending on the results of these factors, it selects from five automatic electronic shift maps and adjusts torque, power and speed (gear) accordingly. The five adaptive shift pattern algorithms contain programs that give optimal performance when driving uphill, for sporty driving, on bad road surfaces, in economy driving modes, and for city driving.

Electronic Clutch

What Is Electronic Clutch?

An electronic clutch involves a system of applying the clutch by using an electronic control unit to release gear-shift forks for manual transmission systems. This system has been used widely in Formula 1 racing for many years and is now beginning to appear in production vehicles. The first major debut in production cars was made in June 1994 by Renualt for the Twingo. In this car there are only two foot pedals: the brake and the accelerator pedal.

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Features of Electronic Clutch Systems

An electronic clutch system deploys an electrical pump, a receiver, an electronic control unit, a gear shift lever sensor, an engine speed sensor, and a transmission sensor. The electronic control unit receives input from the gear shift lever sensor, engine speed/throttle sensors, door switch, and transmission sensors. When the driver puts his hand on the gear lever, the sensor transmits this information to the control unit; this activates the gear shift forks, which take over the manoeuvre to operate the clutch by means of a hydraulic circuit. The system relies on a conventional clutch system but uses a hydraulic gear shifter circuit to control the clutch system.

With cars fitted with electronic clutch systems, it is impossible to stall, jerk or over-rev engines. Another benefit of the system is that it immobilizes the vehicle when the engine is switched off with a driving gear engaged.

Currently, Renualt offers the system with its Twingo car model and is expected to design the system into a new range of Clio cars. BMW's Rover subsidiary and Honda are also known to be evaluating the system in Europe. We expect to see some introductions in a range of vehicles including some sports cars, small vans and light trucks by 1996 (Table 7-6 shows the forecast). The sole supplier for this type of system is Automotive Products (AP) Borg & Beck, but Dataquest believes that many other manufacturers of transmission and clutch systems will follow with introductions of similar systems over the next two years.

Table 7-6
Worldwide Automotive Market Penetration of Electronic Clutch Systems

Region	1993	1998	2000
Europe	0%	12%	18%
Japan	0%	10%	15%
North America	0%	15%	20%
Asia/Pacific–ROW	0%	1%	3%
Total	0%	11%	15%

Source: Dataquest (April 1995 Estimates)

Electronic Brakes (Brake by Wire)

What Is Electronic Brakes?

Electronic brakes are a new technology involving an electronic actuation system that will maximize braking performance of vehicles fitted with an ABS. Electronic braking systems apply maximum brake servo force, irrespective of the amount of pedal pressure from the driver. The system has an electronic control unit that detects emergency braking patterns and applies a booster to the brake servo.

Features of Electronic Brakes

The system deploys a four-wheel ABS system (traction control optional), an electronic control unit, position sensor, and solenoid valves. Electronic brakes use position sensors to detect emergency braking by measuring the speed of the application of the brake pedal. As soon as the speed of application of the brake pedal exceeds a predetermined critical value, the system is engaged—the sensor sends signals to an electronic control unit to engage an electronic actuation system which applies the maximum possible servo force. The hydraulic

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pressure boost is applied to each wheel. This ensures that ABS is activated, bringing the car to a stop in the shortest possible distance while allowing the driver to steer.

Lucas and Mercedes-Benz have been developing such a system over the past few years, and this is expected to appear on some Mercedes cars from 1996 (see Table 7-7 for the worldwide forecast). Current systems will use a 16-bit microcontroller and typically share a module with the ABS and traction control units.

Table 7-7
Worldwide Automotive Market Penetration of Electronic Brakes

Region	1993	1998	2000
Europe	0%	1%	2%
Japan	0%	0%	1%
North America	0%	0%	1%
Asia/Pacific–ROW	0%	0%	0%
Total	0%	0%	1%

Source: Dataquest (April 1995 Estimates)

Future Electronic Braking Systems

Future developments of the electronic braking system will bring features such as:

- Active stability control and traction control (a driver stability control system)
- Hill-hold braking system
- Cruise control
- Autonomous intelligent cruise control (AICC)
- Constant pedal pressure (vehicle payload–dependent braking)

Several manufacturers of ABS and traction control systems are evaluating the use of hydraulic boosting of the braking force. The newest research in this area is examining ways of achieving proportional boost from the brake booster. This could allow the use of electronic brakes for the future development listed above at minimal cost. The system also allows for a less expensive ABS system, as ABS, traction control, AICC and constant pedal pressure systems are integrated into one complete system.

Dataquest believes that electronic brake boosters will eventually become a functional feature of future ABS and traction control systems. The application of this type of brake assistance system is likely to be fitted to cars with automatic transmissions. Although these systems are now only just emerging, the future uptake will depend on the uptake and success of ABS systems penetration into new cars.

Diesel Electronic Fuel Injectors (Electronics)

What Is Electronic Diesel Control?

Tougher emissions requirements will soon lead to totally smoke-free diesels. Many car manufacturers are designing newer diesel engines to meet these emission requirements. As the next-generation high-speed direct injection (HSDI) engines begin to replace existing injection engines, diesel engine fuel pumps will be rapidly replaced by electronic diesel unit injector systems. These

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new diesel injector systems each have a high-speed fuel injection pump per fuel injector. Solenoid valves control fuel flow, and these valves are controlled by an electronic control unit.

Lucas has developed an electronic unit injector (EUI) that meets the Euro 3 emission standards due for introduction in 1996 and the US Fed 98 legislation (a stricter requirement for exhaust emissions than the current emissions regulations). The objective is to develop a system that provides very high-pressure diesel injection into each engine cylinder. Currently, most diesel engines operate with injection pressure of 400 bar maximum. The new systems aim to deliver injection pressure rates of up to 2,000 bar. These systems will improve diesel fuel combustion; this provides a quieter diesel engine, with better performance and cleaner emissions.

Features of Electronic Diesel Control

The electronic control unit receives information from accelerator pedal sensors, engine speed sensors, camshaft sensors and air flow sensors. It uses this information to calculate the amount of fuel required per injection unit. Most diesel systems use a 16-bit MCU but are rapidly moving to 32-bit for commercial vehicles. However, the stricter US CARB is pushing 32-bit electronics into diesel engines in meeting new engine diagnostics regulations enforceable with the US Fed 98 legislation.

Table 7-8
Worldwide Automotive Market Penetration of Diesel Engine Injector Control

Region	1993	1998	2000
Europe	1%	5%	8%
Japan	1%	2%	5%
North America	1%	2%	3%
Asia/Pacific-ROW	0%	1%	2%
Total	0%	3%	5%

Source: Dataquest (April 1995 Estimates)

Major manufacturers of diesel engine electronics are listed below, while Table 7-8 gives the worldwide forecast for penetration of the systems:

- Delco
- Lucas
- Robert Bosch
- Nippondenso
- Nissan Diesel
- Toyota

Collision Avoidance

What Is Collision Avoidance?

Collision avoidance technology involves obstacle detection technology, which has been explained in some detail in the section on near obstacle detection (page 38). In the automotive industry, wherever collision avoidance is discussed two issues arise: active (preventive) collision avoidance; and passive (detection) collision avoidance. The fundamental technology, however,

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remains the same and involves a combination of either ultrasonic sensors, or radar/microwave or infrared sensor–based detection systems.

Features of a Collision Avoidance System

Currently, there are no fully deployed collision avoidance systems but many car manufacturers have developed prototype collision avoidance systems that could be deployed in passive or active systems. Typically, a passive system will give the driver advance warning of potential collision dangers, while active systems are configured with other electronic systems such as braking, transmission, cruise/engine control or, in extreme possibilities, steering control to actively avoid collision. Most of the research in collision avoidance technology is still under way, but we believe that first-generation systems will become available within the next few years (see Table 7-9 for the worldwide forecast).

Table 7-9
Worldwide Automotive Market Penetration of Collision Avoidance Systems

Region	1993	1998	2000
Europe	0%	5%	8%
Japan	0%	5%	7%
North America	0%	5%	10%
Asia/Pacific–ROW	0%	1%	5%
Total	0%	4%	8%

Source: Dataquest (April 1995 Estimates)

Future Applications of Collision Avoidance Systems

Active collision avoidance systems are designed to avoid collision. First-generation systems are already used in commercial vehicle applications for detecting objects in the drivers' blind spot areas. In the United States, Delco has developed a forward-looking radar warning system that is currently installed in Toyota's luxury Lexus range. Delco is also developing a full collision avoidance system integrated in an intelligent/active cruise control system.

Recent second-generation systems have been developed for use in cars to aid reversing and parking manoeuvres. In Europe, BMW is already offering this system as an option for its cars; in Japan, Mitsubishi offers intelligent cruise control connected to throttle and transmission control on the top-range Diamante car model. Third-generation systems will likely be proactive systems linked to engine management and cruise control, braking systems and, potentially, steering.

Major manufacturers developing collision avoidance systems include the following:

- Delco
- Kansei
- Mercedes-Benz
- Mitsubishi
- Nissan Diesel
- TEMIC (Telefunken)
- Toyota
- TRW

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Collision avoidance technology is a major function of so-called "cooperative driving" where cars travelling towards a common destination on motorways are batched together in wireless chains. The collision avoidance technology is deployed in the intelligent cruise control system (see earlier section) to facilitate a cooperative driving system which is proven in theory (simulation tests) to improve traffic efficiency.

Driving Stability Control Systems

What Is a Driving Stability Control System?

Driving stability control systems, known as DSC, are a new technology developed by Mercedes-Benz and Robert Bosch for next-generation, top-range Mercedes models. It involves a steering wheel angle sensor (optical sensor), a vehicle rotational speed sensor, acceleration sensors, wheel speed sensors, and yaw rate sensors; and deploys electronic steering with the ABS and traction control system. The main electronics of the DSC is integrated with the ABS and traction ECU. The objective of DSC is to monitor and maintain driver control of the vehicle to avoid loss of traction.

Features of Driving Stability Control

Driving stability control systems receive input from a steering wheel angle sensor, a mechanical magnetic vibration sensor (piezo-electric), wheel speed sensors, acceleration sensors and a yaw/rate sensor.

The system relies on a principle called "electronic brake force distribution," which governs the electronic system. Electronic brake force distribution applies a compensating brake force to diagonally opposite or adjacent wheels to counteract vehicle yawing and pitching. The system relies on many of the sensors in a traction control system and the ABS. The system processes data for rotational speed around the vertical axis and steering angle positioning for driver control analysis. DSC systems share the ABS and traction control actuators and output data are fed from the control unit to the actuators.

The electronic control unit of this system uses a 16-bit MCU. The system applies braking to slow down a car if driving too fast on ice. Demonstrations of these systems in countries like Sweden and Norway have already received very good reviews in the automotive industry.

Driving stability control systems are now emerging in high-end cars and will begin to take off from 1997 onwards (see Table 7-10 for the worldwide forecast). Mercedes-Benz will install this system on the new replacement E-class model. In Japan, Mitsubishi and Toyota are also evaluating a similar system for midrange vehicles.

Table 7-10
Worldwide Automotive Market Penetration of Driving Stability Control Systems

Region	1993	1998	2000
Europe	0%	1%	2%
Japan	0%	1%	2%
North America	0%	1%	2%
Asia/Pacific–ROW	0%	0%	0%
Total	0%	1%	2%

Source: Dataquest (April 1995 Estimates)

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The major ABS and traction control system manufacturers are leading in the development of driving stability control systems. Dataquest believes that by the end of the decade, driving stability systems will begin to appear in cars in all the major producing regions. Major manufacturers of driving stability control systems include the following:

- Allied Signal
- ITT Automotive (Teves)
- Kelsey-Hayes
- Lucas Braking Systems
- Nippondenso
- Robert Bosch
- Siemens Automotive
- Sumitomo Brakes

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Chapter 8
Body Control Electronics

Body control electronics includes all the electronics that control car body and chassis functions. Body control electronics improve vehicle comfort and convenience by making it easier to control body systems. They include such systems as central locking, sunroof, and memory seat controls.

As vehicle electronics in future systems begin to merge, many body control functions could be linked to other system controls such as powertrain management systems or dynamic vehicle control systems, which will include powertrain, suspension control and steering control.

This chapter covers emerging applications that fall within vehicle body control areas such as the following, all of which will have a direct connection on the functionality hardware:

- Tyre pressure monitors
- Multiplexing systems
- Car computer (on-board diagnostics)
- Noise cancellation
- Accident recorders—automotive "black-box"

Tyre Pressure Monitors

What Is a Tyre Pressure Monitor?

Tyre pressure monitors are not an entirely new concept but have been discussed in the automotive world for many years. A tyre pressure sensor (electromechanical limit switches or semiconductor pressure sensors) is used to monitor each individual tyre pressure, and sends an audible or visual warning signal to the driver reminding him to check air pressure. The sensor is actually located inside the rim of the wheel and is designed to withstand the high pressure of air in tyres. An electronic receiver/decoder receives radiofrequency signal transmissions and outputs either a warning signal or the actual tyre pressure of each individual tyre.

In Europe alone, official statistics show that 50,000 people are killed in road accidents resulting from tyre blowouts. Car manufacturers are keen to eliminate these fatalities by offering tyre pressure monitors as a standard safety feature.

It is also proven that maintaining proper tyre pressure improves tyre wear and fuel efficiency. In underinflated tyres, temperatures rise and this quickly deteriorates tread wear. Furthermore, underinflated tyres can severely affect vehicle handling and steering, and this is potentially dangerous in built-up areas where pedestrians could be put at higher risk.

The trend is toward integrating tyre pressure monitors with keyless entry systems using commonly shared RF receivers. Current pricing for tyre pressure monitors range from $100 upwards to around $400. This makes it prohibitive for car manufacturers to fit them as standard on cars.

Cheaper variations of tyre pressure monitoring incorporated in antilock braking systems involve using the wheel speed sensors to track individual wheel rotation speeds. General Motors' Delco Electronics subsidiary is exploiting the theory that an underinflated tyre has a smaller diameter, and therefore will have to rotate faster than a normally inflated tyre. In theory, the fastest rotating

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wheel will have a lower pressure, but this theory is not always reliable and requires further development. Delco Electronics is one of the companies known to have been developing such a system.

Major manufacturers of tyre pressure monitor systems are listed below, and Table 8-1 gives the worldwide forecast:

- Epic Technologies (USA)
- Schrader Automotive (USA)
- Robert Bosch (Germany)
- Delco Electronics
- Sentronics Limited (N. Ireland)

Table 8-1
Worldwide Automotive Market Penetration of Tyre Pressure Monitors

Region	1993	1998	2000
Europe	0%	1%	2%
Japan	0%	1%	2%
North America	0%	3%	5%
Asia/Pacific–ROW	0%	0%	0%
Total	0%	1%	2%

Source: Dataquest (April 1995 Estimates)

Dataquest believes that tyre pressure monitors could be mandated for all vehicles in the next decade either through government legislation or from insurance companies. The technology is still too expensive for car manufacturers to justify, but with the uptake of RF keyless entry in vehicle immobilization systems, the potential remains for tyre pressure monitors to be included.

Multiplexing Systems

What Is a Multiplexing System?

Multiplexing systems refer to the networked cabling and communications techniques designed to eliminate the multiplicity of wiring found in the typical vehicle, as brought on by the proliferation of electronic systems. Multiplexing technology allows the effective networked communications between linked electronic control units on the same data bus.

Features of Multiplex Systems

Multiplexing generally is segmented into speed classes. One segmentation adopted by the US-based Society of Automotive Engineers (SAE) defines the speed classes as follows:

- Class A: Low-speed for body-wiring applications up to 10 Kbit/s
- Class B: Medium-speed for data-sharing applications, between 10 Kbit/s to 125 Kbit/s
- Class C: High-speed for local area networking, greater than 125 Kbit/s

At the moment, many car manufacturers are using the Class A–type multiplexing for door applications such as power windows, central door locking, alarm (car security), electric mirrors and sunroof applications. Already, several standards are emerging from two major communication protocols, the J1850 and

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the ISO 9141. J1850 and ISO 9141 are the proposed protocols adapted for car diagnostics. Some car manufacturers are also developing their own proprietary communication protocols and standards. Table 8-2 lists some of the emerging systems.

Table 8-2
Emerging Multiplexing Systems

Standard	Diagnostic Data Link	Car Manufacturer
A-Bus	ISO 9141	Volkswagen
Basic CAN	ISO 9141	
CAN	ISO 9141	
C2D	J1850 or ISO 9141	
DLCS	J1850	General Motors
HBCC	J1850	Ford Motor Company
HSSD	J1850	Proposed US high-speed standard
ISO 9141		
ISO 9141 CARB		(Meets US CARB specification)
J1850		
PALMNET	J1850 or ISO 9141	Mazda
VAN	ISO 9141	PSA and Renault

Source: Dataquest (April 1995)

Benefits of Multiplexing

Probably the most measurable benefit of multiplexing technology is that it reduces the quantity of wiring harness in a vehicle. Each subsystem in the car will have a multiplex IC which acts as an interface chip with a defined I/O address and a priority rating for data processing and data management purposes on the data bus. This means that future systems will be easier to install as the wiring requirements will be greatly reduced.

From the point of view of the overall vehicle weight, a multiplexed data bus will reduce the weight of electrical wiring required for cars. This could also allow for more space in the vehicle body for additional electronics. The design of multiplexed wiring systems also eliminates wiring problems and difficulties associated with the already complex wiring harness of vehicles. The number of connectors required by existing wiring harness technology will also be reduced as a result of implementing this highly structured and hierarchical technology.

Overall, multiplexing technology contributes to integrating the vehicle's electronics and electrics by eliminating redundant sensors—sensors could be used more efficiently to feed input signals to one or more electronic control modules on the data bus. Likewise, multiplexed technology eliminates duplicate microcontroller functions by allowing more efficient use of microcontrollers in the same way as it allows the combination and integration of electronic control units.

Most importantly, this technology improves diagnostics as the communications systems and networks become integrated. This will speed up the processes of performing on-board diagnostic checks and off-board checks.

Future Multiplexing Systems

Future multiplexing systems will replace the complexities involved in contemporary vehicle wiring with potentially what will become a single "bus" (that is, one wire), using semiconductor interface chips as gateways. Low-speed

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multiplexing systems have been developed and are already in use by most car manufacturers for luxury cars. These systems operate such functions as windows, sunroof, door locking and memory seat applications. Future developments will be for medium-speed and high-speed data bus systems.

Recently, the United States has agreed the J1850 standard for Class B speeds. It incorporates many of the features that other US vehicle manufacturers use in their proprietary standards. It appears, however, that vehicles made for the European market will be based on ISO 9141, while the North American market will use the J1850 protocol for diagnostic links. The Japanese and Korean manufacturers are likely to make all varieties to satisfy their overseas markets. Developments continue in the high-speed data bus area to develop the integration of engine management, suspension, power steering, braking, and transmission systems.

Major suppliers of multiplexing systems for automotive applications are listed below and Table 8-3 gives the worldwide forecast:

- Chrysler
- Delco Electronics
- Ford Electronics
- Hella
- Nippondenso
- Robert Bosch
- Siemens Automotive
- TRW
- Valeo
- UK NSI

Table 8-3
Automotive Market Penetration of Multiplexing Systems

Region	1993	1998	2000
Europe	1%	5%	15%
Japan	2%	15%	20%
North America	3%	20%	25%
Asia/Pacific–ROW	0%	2%	5%
Total	2%	11%	17%

Source: Dataquest (April 1995 Estimates)

Car Computer (On-Board Diagnostics)

What Is a Car Computer?

Car computer systems were first developed in the 1980s. It was during this same phase in automotive electronics that voice annunciators were being introduced into cars. Initially, car computers were designed to provide synthesized voice information giving warnings about engine oil pressure, fuel left in tank, door opened, temperature and other such information.

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Features of Car Computer Systems

Newer systems include diagnostic check functions and are more sophisticated than the earlier-generation systems. The car computer system comprises a manually operated programmable input keyboard, LCD alphanumeric character display panel, and a microcomputer system. The keyboard acts as a driver interface with the system and the driver can set or obtain information including such functions as:

- Date, time (real time) and arrival time (estimated)
- Average fuel consumption
- Average speed
- Distance to destination
- Mileage conversions (miles to kilometres and kilometres to miles)
- Outside temperature
- Speed limit warning
- Stopwatch
- Timers (trip timers
- Travel range

Input data are received and processed by the microcomputer from all other critical electronic systems such as:

- Actuators
- Airbag system
- Air-conditioning control
- Alternator condition
- Antilock braking system
- Battery condition
- Door locks
- Engine management system
- Engine oil pressure
- Exhaust emission
- Fuel tank sensors
- Ignition control
- Lights
- Power steering
- Power supply
- Seat belts
- Speed
- Temperature (external/internal)
- Wiper control (windscreen and driving lamps)
- Wiring (short circuit detection)

All the above systems are tested by the microcomputer in a diagnostic check function by running programmed memory with test patterns for each system which can be retrieved and used for comparisons. Each peripheral system has

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an address and the data and address buses are included in the system test routines. Sensors are tested for performance within specified limits while open and short circuits can also be detected.

Output data from the test results (diagnostics) are fed back to the car computer and displayed, or audible synthesized voice annunciation is made to communicate the results to the driver through the car speakers.

Newer systems being developed provide temporary software solutions to provide a "limp home" solution to engine problems or electrical problems. Sometimes the limp home solutions may, for example, involve disabling electronic systems that control faulty mechanical functions or actuators. Here, multiplexing technology and its protocols will vastly improve the prioritizing of data checks that are required for systems diagnostics; thus, a faulty electronic transmission system would be switched off by a car computer to allow full manual operation as a limp-home solution.

The application of car computer systems such as the fully diagnostic system described above is very low (see Table 8-4). The development costs of such systems are very high as for each new generation of electronic systems that are input sources to the computer, the diagnostic software often needs redevelopment.

This has sustained the high cost of these systems and, consequently, the low penetration rates. Trip computers are a scaled-back version of the car computer system, and these are gaining some significant penetration rates. Dataquest believes, however, that future legislation and enforcement tactics of some car systems such as exhaust emissions may lead to increased use of such systems in cars and commercial vehicles.

Major players in car computer systems include the following:

- Delco Electronics
- Ford Electronics
- Magneti-Marelli
- Nippondenso
- Siemens Automotive
- TEMIC (Telefunken)
- Valeo
- VDO (Mannesmann)

Table 8-4
Worldwide Automotive Market Penetration of On-Board Car Computers

Region	1993	1998	2000
Europe	4%	15%	20%
Japan	5%	12%	20%
North America	8%	10%	15%
Asia/Pacific–ROW	1%	3%	5%
Total	5%	11%	15%

Source: Dataquest (April 1995 Estimates)

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Active Noise Cancellation (ANC)

What Is Active Noise Cancellation?

Noise cancellation systems are designed to electronically cancel unwanted cabin noise and external noise from the engine and exhaust mufflers. The benefits extend beyond making vehicles quieter to making them also more energy-efficient. The concept of active noise cancellation involves two major sources of noise, namely cabin noise and engine noise.

Features of Active Noise Cancellation

Cabin noise (or passenger compartment noise) is usually amplified through the body of the car from materials that absorb and transport noise into the car. Primary contributors of noise are the engine, engine mounts, suspension (shock absorbers), and the car body itself. Noise cancellation technology relies on the application of DSP chips to control noise from engine mounts, electronic mufflers and interior quieting. The controller processes a cancellation algorithm which is stored in the RAM of the DSP chip. The process of noise or vibration cancellation is performed by a signal that is its exact mirror image at the same noise/vibration amplitude but 180 degrees out of phase.

Current development for active noise cancellation ECUs will initially be stand-alone, although they could become integrated in engine management system.

Future Applications of Active Noise Cancellation

The electronic control unit itself receives signal input from the throttle and tachometer to predict engine noise occurring from car acceleration. Other sensors include a microphone in the muffler, a microphone in the air vents, and an additional number of microphones in the passenger compartment. Each of these signals are processed by the electronic control unit, which then outputs command signals to actuators that control loudspeakers and exhaust flow modulation for the electronic mufflers, hydraulic dampers and noise dampening systems on the car body, and the interior compartment loudspeakers through the car stereo. This particular application is deemed to be most attractive for small cars, which tend to have very small amounts of sound insulation by the nature of small car construction.

A major and measurable financial benefit and justification for noise cancellation systems is that they could offer fuel savings to the driver. ANC allows control of engine vibrations, allowing smaller engines to idle at lower speeds, thus saving fuel.

Noise cancellation systems are in use by specialist car manufacturers especially in the sport of motor-racing. But commercial application of noise cancellation has been slow because the systems contribute very little benefit for larger vehicles which have better insulation and, nowadays, highly refined engines that are quieter than earlier generations. Some commercial vehicle applications for exhaust mufflers have been established but with very limited success among commercial vehicle manufacturers.

In Europe and Japan, Fiat and Nissan have been reported as evaluating active noise cancellation systems for a new range of small cars planned for market introduction after 1998. Prototype small cars fitted with this technology drive very quietly, which gives a perception of being more expensive-sounding vehicles. Depending on the cost of future systems for small cars, these systems could appear in cars in a big way by the end of the century although at this point in time, we believe they are further away than that (see Table 8-5 for the worldwide forecast).

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Table 8-5
Worldwide Automotive Market Penetration of Active Noise Cancellation

Region	1993	1998	2000
Europe	0%	10%	15%
Japan	1%	5%	10%
North America	0%	13%	20%
Asia/Pacific–ROW	0%	2%	5%
Total	0%	8%	13%

Source: Dataquest (April 1995 Estimates)

Costs associated with DSP application are one of the major factors why introduction of these systems is being stalled. However, legislation against noise pollution from HGVs and commercial passenger buses could also affect the introduction of this technology in vehicles.

Companies developing active noise cancellation technology include the following:

- Calsonic (Tokyo)
- Digisonix (US pioneer of ANC)
- Elesa (a Fiat-owned Magneti-Marelli subsidiary, and joint-venture company with Noise Cancellation Technologies Inc.)
- Lotus Engineering
- Lucas Automotive
- Nissan (Japanese Bluebird model ANC)
- Saab
- Ultra Electronics (developed Saab commuter aircraft ANC system)

Accident Data Recorders—"Automotive Black-Box"

What Is an Accident Data Recorder?

Accident data recorders (ADRs) or automotive black boxes are a technology descended from the aviation industry that is slowly finding a place in modern vehicles. The applications of black boxes in the aviation industry are most commonly for aircraft diagnostics and also for examination to determine the likely causes of air crashes.

There are many different variations of accident data recorders, but the most sophisticated systems have diagnostic systems that monitor performance algorithms of all the key electronic systems in a vehicle.

Features of Accident Data Recorders

Aircraft accident data recorder systems emerged from diagnostic monitoring systems. The technology of these systems is now modified for cars to track vehicle behavior before, during and after an accident.

An accident data recorder receives input signals from diagnostic functions of car electronic subsystems. Typically, the ECU of the system has an 8- or 16-bit microcontroller, and a certain amount of memory buffer. The basic system receives input from the ignition switch, speedometer, brake light sensors,

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indicators (left/right) and lights. More sophisticated accident data recorders may receive signals from ABS/traction control (optional), airbag (including side impact airbags), navigation systems (optional), and engine management systems. All these systems include the following sensors that are constantly monitored by the ADR unit:

- Accelerometers
- Azimuth sensors
- Brake signals/sensors
- GPS data
- Lateral sensors
- Longitudinal sensors
- Transmission sensors
- Vertical sensors

After an accident has occurred, the latest driver reactions before impact are digitally stored in the system. This data could be analysed to prove cause of accident and performance of safety critical subsystems such as ABS, airbags and electronic brakes.

Future ADR Systems

The ADR system has many benefits that could become attractive for a range of applications. Firstly, for the general public, effective marketing of these systems by car manufacturers will help raise consumer awareness. If these systems are not marketed properly, consumers could view them as hostile electronics that monitor their driving habits.

Secondly, fleet operators may easily justify installing ADR systems for their vehicles. Taxi companies, for example, may find that their insurance claims will be less when drivers know that their vehicles are fitted with ADRs.

Thirdly, insurance companies may influence the installation of ADRs in cars to speed up processing of accident claims and to reduce the rate of accidents among their own policyholders. In theory, if drivers know that their driving habits are being recorded, then they might be more cautious about avoiding careless driving, and this could reduce accident rates in favor of insurance companies.

Fourthly, ADRs could provide safety-critical system diagnostics for the driver to enhance the diagnostics already in place for each car system. This could be beneficial for drivers who frequently wish to feel secure in their cars before making long journeys.

However, for these systems to gain market acceptance, they may require legislative instruments to support the application of the data they provide. For example, laws pertaining to road use vary across Europe; certain standards of data gathering that meet national traffic regulations will need to be developed further.

Major suppliers of accident data recorders are listed below, and Table 8-6 gives the worldwide forecast:

- Bosch
- Mannesmann
- Valeo

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- Sagem
- Siemens Automotive
- TEMIC (Telefunken)

Table 8-6
Worldwide Automotive Market Penetration of Accident Data Recorders

Region	1993	1998	2000
Europe	0%	3%	10%
Japan	0%	4%	20%
North America	0%	5%	20%
Asia/Pacific–ROW	0%	1%	1%
Total	0%	4%	13%

Source: Dataquest (April 1995 Estimates)

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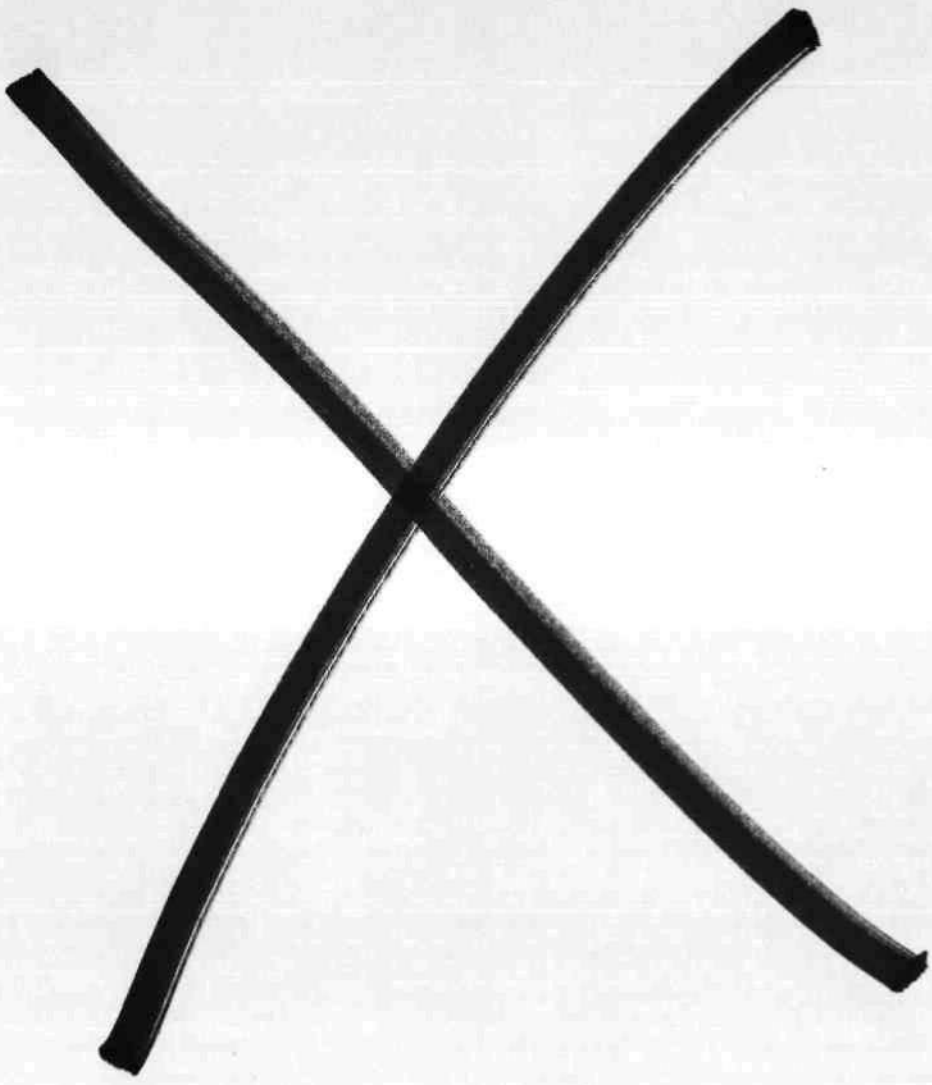
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Competitive Dynamics



Semiconductor Application Markets Europe

Competitive Analysis

Contract Electronics Manufacturers—Here to Stay

Abstract: *Continuing growth in unit production of electronic equipment as a result of increasing demand for existing and emerging products has led to the development of contract electronics manufacturers, both in Europe and worldwide. This report, based on a survey of European CEMs, looks at this development, assessing the size of the market, identifying the leading CEMs and their services, along with trends in the market.*

Introduction

Contract electronics manufacturers (CEMs) are an accepted, and growing, part of the electronic equipment production industry in 1995, due to the continuing growth in unit production of electronic equipment, and the trend of OEMs to outsource their manufacturing activities. This report, based on a survey carried out in Europe, covers:

- Reasons why original equipment manufacturers (OEMs) use CEMs
- The size of the European market for CEM services
- The leading CEMs in Europe
- Services offered by CEMs and a CEM cost model
- CEM procurement trends

The transition from OEMs carrying out their own equipment manufacture to outsourcing it to CEMs is governed by the now familiar make-or-buy decision. With current management doctrine emphasizing "do what you do best, and outsource the rest," there is more pressure than ever for OEMs to discontinue their in-house manufacturing, and pass it to CEMs.

The value of manufactured equipment continues to fall in proportion to the value of the intellectual property in the product and the cost of the channel. Because of this, more and more OEMs will seek to minimize the cost of equipment production, and add value at other stages of the design-through-supply chain.

Dataquest

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In the past, many items of electronic equipment had a three- or four-year lifetime and were redesigned almost from scratch at the end of their life. Now, in order for OEMs to stay ahead of the competition, they are constantly developing and enhancing existing products, and focusing on the marketing of these sometimes minor improvements. This means that the manufacturing process has changed from producing a stable product for long periods of time, to implementing frequent engineering changes on shorter production runs of subtly different products. It is the management of this flexibility, which CEMs offer, that allows OEMs to concentrate on design and marketing.

Methodology

This report is based on a survey of European CEMs. A list of the CEMs that responded to our survey is contained in appendix A. Where necessary, survey data have been supplemented by information from other Dataquest publications and surveys, as well as information from the public domain and industry sources.

Definition

Dataquest defines a contract electronics manufacturer as a company or division of a company that provides electronics manufacturing, design or other services to the market. CEM work predominantly (but not exclusively) includes printed circuit board assembly (PCA), system assembly, and component procurement.

Product sector and component definitions are contained in appendix B.

History

In the United States, CEMs grew up around the defense and space industries from the 1960s onwards. During the 1970s, CEMs started to diversify (to try to counter cyclical defense spending), by taking on one-off "jobs" for commercial OEMs. This "job-shop" mentality continued into the 1980s, but was being tempered by the rapid growth of the major CEM players, and the long-term strategies they were developing.

In Europe, the situation differed because the defense spending was placed with well-established, national companies which had their own manufacturing capabilities. There were few start-up companies requiring significant manufacturing capacity, and no European equivalent with NASA's budget.

During the 1980s, the proliferation of OEMs of electronic equipment in Scotland and Ireland (located in these regions for financial and other reasons) spawned a secondary industry of contract manufacturers. Many of these companies (and others located in the United Kingdom and in continental Europe) continued to serve a few major customers which were located nearby.

When the big US-based CEMs started to follow their major PC OEM customers, and invested in European plants (either by taking over existing facilities or by opening "greenfield" sites), the European CEM industry discovered that it was part of a global switch to outsourced manufacturing.

As the industry has matured in the 1990s, a few US-headquartered companies dominate the market worldwide. Europe-headquartered CEMs, with a few exceptions, tend to be smaller players focused on local customers and markets.

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Why OEMs Choose to Outsource

Advantages of Using a CEM

The reasons most often cited for using a CEM are as follows (in order of importance):

- Lower total cost of materials. This includes materials management, vendor assessment and approval, just-in-time (JIT) delivery and quality control
- High level of service
- Manufacturing expertise
- Additional manufacturing capacity
- Ease of doing business

Disadvantages of Using a CEM

Paradoxically, many of the reasons for using a CEM are also given as reasons not to use one. These include:

- The cost of doing business with a CEM
- Loss of control over equipment production
- Production-cycle times too long, or inflexible

Reasons for Using a CEM

Essentially, the CEM removes the "hassle" in manufacturing electronic equipment—a complex task requiring a high level of experience and expertise. The advantage of additional manufacturing capacity has two benefits: firstly, it offers a degree of flexibility when demand rises in the short to medium term; and it also removes the need for costly capital investment.

Surface mount (SMT) assembly equipment is costly to capitalize and may have to be upgraded (or replaced) at regular intervals in order to maintain production capability. It can also be expensive to run, due to direct labor costs and the cost of equipment support.

CEMs can offer genuine cost savings to the OEM. They ensure that the use of manufacturing capacity is well planned, which ensures that capital equipment is fully utilized. And their large-scale component procurement offers scope for reduced material costs.

Market Size and Forecast

Reasons for Market Growth

European, and global, CEM growth (and the demand for CEM services) has been strengthened by two main factors:

- The continuing growth in unit production of electronic equipment, due to the increasing demand for existing and emerging products. In Europe, equipment production revenue is forecast to grow with a compound annual growth rate (CAGR) of 6 percent.
- The continuing trend of OEMs to outsource their manufacturing activities.

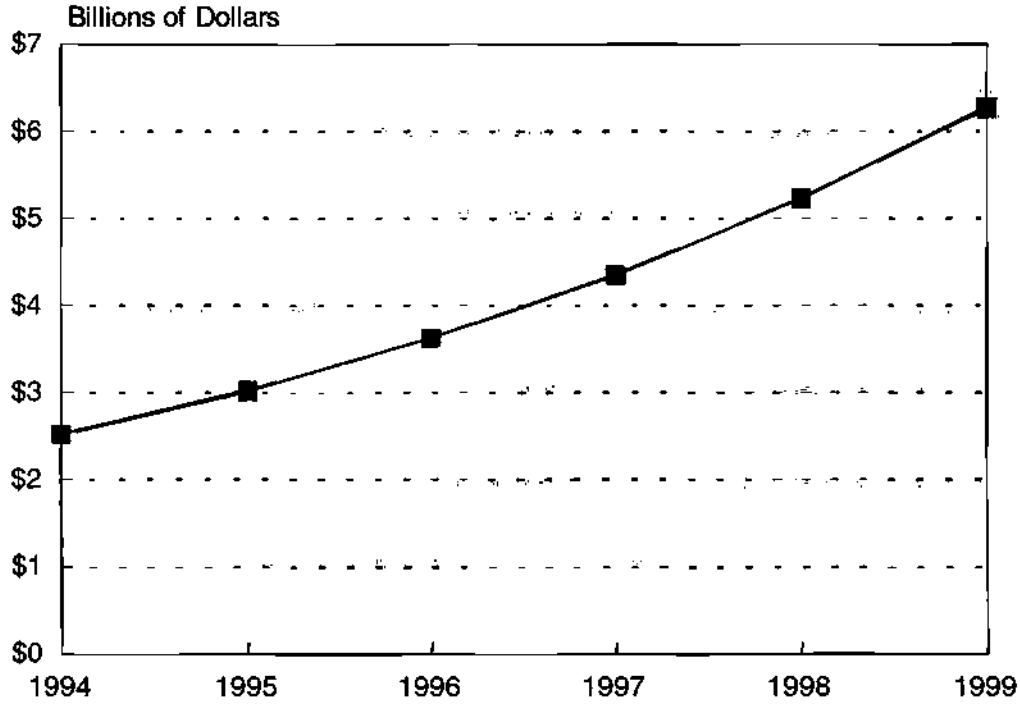
In 1994, the total value of electronic equipment production in Europe was $156 billion (measured by factory sales revenue). European OEMs outsourced manufacturing services worth about 1.6 percent of total production; this is forecast to rise to 4.0 percent by 1999.

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Factory sales revenue for European CEMs was $2.52 billion in 1994, and this is forecast to rise to $6.27 billion in 1999. Figure 1 shows the revenue generated by European CEMs from manufacturing services.

Table 1 shows factory sales revenue for manufacturing services, generated by European CEMs. CEM factory sales revenue is forecast to grow with a CAGR of 20 percent from 1994 to 1999.

Figure 1
European CEM Services
Factory Sales Revenue, History and Forecast



Source: Dataquest (September 1995 Estimates),Technology Forecasters

Table 1
European CEM Services
Factory Sales Revenues, History and Forecast
(Billions of Dollars)

Year	Revenue ($M)
1994	2.52
1995	3.02
1996	3.63
1997	4.35
1998	5.23
1999	6.27
CAGR 1994-1999	20%

Source: Dataquest (September 1995 Estimates),Technology Forecasters

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European Market Share

The European market for CEM services is served by a variety of companies. These range from several companies with a turnover in excess of $200 million, to a myriad of smaller companies, many of which serve niche markets. In this report we have only included companies whose primary business is the provision of CEM services. For companies which have worldwide production sites, we have only included revenue generated from European production. Table 2 shows Europe's top 15 CEMs ranked by 1994 factory sales revenue.

Many of the large CEMs in the United Kingdom, Ireland and France are in fact plants owned by US-based CEMs. The United Kingdom and Ireland, in particular, have experienced rationalization in the CEM sector. This has included Flextronics International's purchase of Assembly and Automation, TT Group's acquisition of Race (to complement AB Electronics and Welwyn Systems), and Keltek's recent purchase of EDMS.

This has taken place alongside acquisitions by CEMs of OEM manufacturing plants, including SCI and Solectron taking over Hewlett-Packard plants in France, and the recent purchase by Ogden (a US-based CEM) of Logitech's plant in Ireland.

This has led to fewer players, with larger revenues and multiple production facilities. However, in much of continental Europe the picture is very different. Outsourcing has not occurred to the same extent as it has in the United Kingdom and Ireland, and it may be some years before there are sizeable CEMs in many European countries.

Production Share by Application Sector

Figure 2 shows how 1994 factory sales revenue is split by application sector. Just under 50 percent of revenue is from the EDP sector. Most of this revenue is derived from manufacturing PCs. The PC is a high-volume commodity product, and is an ideal candidate for outsourcing to CEMs.

Another 30 percent of revenue is derived from communications products. This reflects the explosive growth in communications equipment production, which may have exceeded OEMs' in-house manufacturing capacity.

Many CEMs report revenue growth in the sectors which currently dominate their business. Although some are trying to reduce their dependence on particular product sectors, they are attempting to achieve this by increasing alternative business, rather than reduce their existing business.

CEMs with a diverse customer base are seeing a decline in industrial and military/aerospace work. However, more focused CEMs that currently derive a significant amount of revenue from these areas are reporting growth in these sectors.

CEM Services

Scope of CEM Services

In the past, CEMs provided a PCA service to their OEM customers. In many cases this business was then augmented by system assembly. However, in addition to manufacturing, design and logistics services, most CEMs will now purchase components for their customers, in order to offer a "turnkey" service.

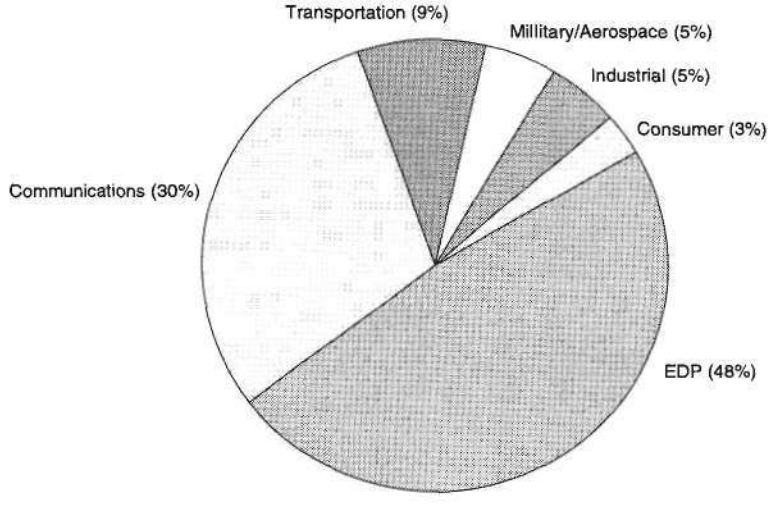
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Table 2
Top 15 European CEMs
Ranked by 1994 Factory Sales Revenue

Rank	Company	Country
1	Solectron Corporation (Europe)	France/UK
2	SCI Systems (Europe)	France/Ireland/UK
3	Kyrel Oy	Finland
4	Design to Distribution	UK
5	Jabil Circuit (Europe)	UK
6	Avex Electronics (Europe)	UK
7	AB Electronic Assemblies	UK
8	Welwyn Systems	UK
9	Race Electronics	UK
10	Hughes Microelectronics Europa	UK/Spain
11	Dovatron (Europe)	Ireland
12	Assembly & Automation	UK
13	Keltek Electronics	UK
14	EDMS	UK
15	SM2E Electronique	France

Source: Dataquest (September 1995 Estimates)

Figure 2
European CEM Services by Application Sector
Ranked by 1994 Factory Sales Revenue



1994 Revenue
$2.52 Billion

Source: Dataquest (September 1995 Estimates)

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When contract manufacturing was in its infancy, OEMs would supply components free of charge (free issue), or charge them at cost to the CEM (consignment). This was done for several reasons: because the OEM had greater buying power than the CEM, and could obtain the components at lower cost; or because the component manufacturer would only supply to the OEM due to component warranty issues; or because there was a restricted supply of particular components. In many cases, though, CEMs now have greater purchasing power than their OEM customers, and component warranty has ceased to be a major issue.

By offering additional (and complementary) services, CEMs can increase their revenue and profitability. In turn, OEMs can benefit by outsourcing more of their production activities.

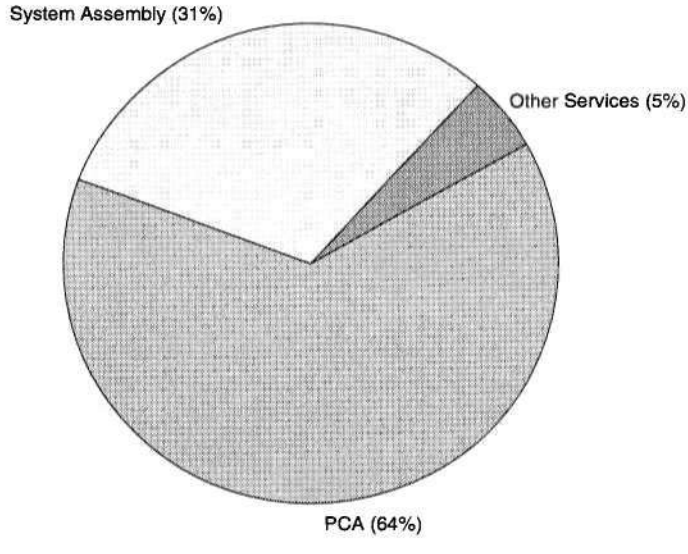
European CEMs still derive most of their revenue from PCA services. Figure 3 shows the split between PCA, system assembly and "other services." These other services include design for manufacture, product distribution, electromagnetic compatibility (EMC) testing, and full product design.

European CEMs report significant growth in both PCA and system assembly work, and a smaller increase in other work. Much of the growth over the last few years has been in PCB assembly capacity. As CEMs win PCA business to fill the new capacity, they then attempt to increase revenue by bidding for additional system assembly work.

CEM Cost Model

As various items of electronic equipment cease to be differentiated by proprietary intellectual property, and become commodity products which are predominantly sold on a cost per function basis, it is essential that the manufactured goods are as cost-effective as possible.

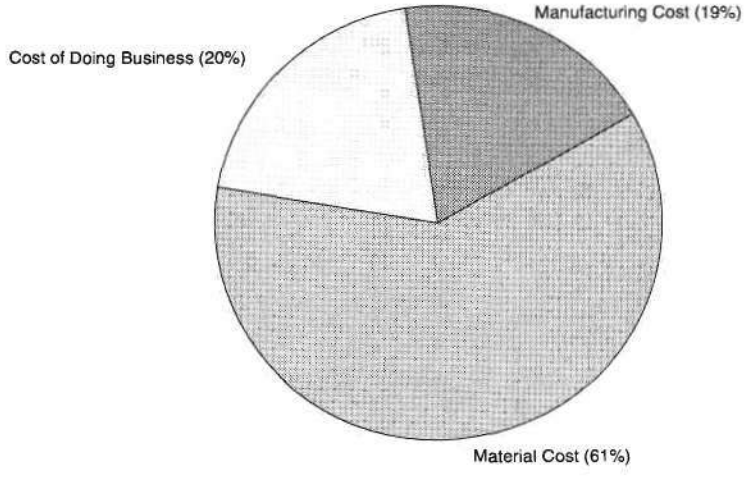
Figure 3
European CEM Services
Ranked by 1994 Factory Sales Revenue



Source: Dataquest (September 1995 Estimates)

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Figure 4
CEM Cost Model



Source: Dataquest (September 1995 Estimates)

One of the major benefits of using a CEM is the lower cost of manufactured equipment. The CEM should be able to manufacture equipment more cost-effectively than an OEM, which is likely to have higher manufacturing costs for historic, or other, reasons. However, a significant part of the total cost of CEM-produced equipment is the "cost of doing business." This includes receiving, inventory and shipping costs, as well as the cost of managing the CEM.

The cost of doing business must be offset by cost savings due to material procurement and management, and lower direct manufacturing costs. Figure 4 shows the cost model for a typical CEM. The percentage split will vary among CEMs, depending on their product mix, the value of the material content, and how good their partnership is with their OEM customers.

Procurement Trends

A global procurement service means that CEMs can buy parts at favorable prices, as well as ensuring that their component supply is not interrupted. A global presence also helps CEMs understand local markets, both from a purchasing stance, and from the point of view of their customers.

Value of Purchased Components

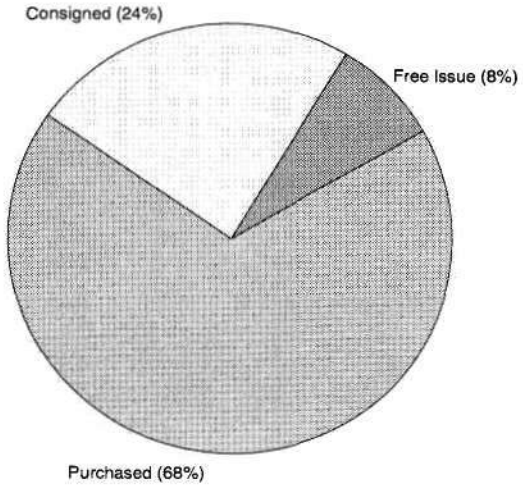
In 1994, the total value of semiconductors purchased was $896 million; this was 4.3 percent of the total European semiconductor market of $20.8 billion. The value of other components was $340 million ("other" components are defined in appendix B). The ratio of semiconductors to other components varies between CEMs, depending on production levels of semiconductor-hungry applications such as PCs.

Component Sourcing

Most components are now purchased by the CEM on behalf of their OEM customers. In 1994, 68 percent (by value) of components were purchased, .

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Figure 5
1994 CEM Component Procurement (by Value)



Source: Dataquest (September 1995 Estimates)

24 percent were consigned (charged at cost by the OEM), and 8 percent were supplied at no charge (by the OEM). Figure 5 shows 1994 component procurement, by value.

Over 90 percent of those who responded to our survey reported growth in purchased value, and 33 percent reported growth in the value of free-issue parts. About 15 percent reported growth in the value of consigned parts. These trends were not related to the size (measured by factory sales) of a CEM.

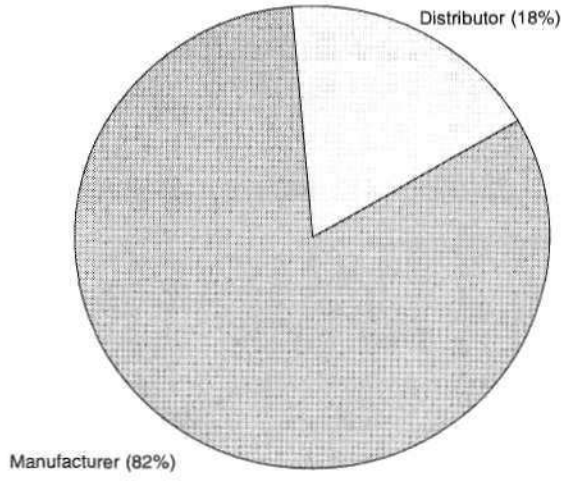
Component Suppliers

The majority of components (by value) are purchased from component manufacturers, rather than component distributors. However, this is related to the size of the CEM (measured by factory sales). Generally, CEMs with sales of more than $50 million will purchase at least 70 percent (by value) from component manufacturers. CEMs with sales less than $50 million, generally purchase the majority of their components from distributors. Figure 6 shows CEM component suppliers, by value.

Just over 70 percent of those who responded to our survey reported growth in component supplier value, and 58 percent reported growth in the value of distributor supplied parts. These trends were not related to the size (measured by factory sales) of a CEM.

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Figure 6
CEM Component Supplier (by 1994 Value)



Source: Dataquest (September 1995 Estimates)

Dataquest Perspective

In addition to the overall growth in equipment production, these are the reasons why the CEM industry is growing:

- OEMs outsourcing part of their production (for capacity reasons, or for other reasons), in order to reduce the total cost of manufacturing electronic equipment
- OEMs using CEMs to manufacture equipment until it becomes cost-effective to invest in their own manufacturing capabilities
- OEMs choosing not to manufacture, either because they cannot justify manufacturing capacity, or do not see manufacturing as a strategic part of their business

While some of the newer single-product companies (such as the dedicated PC manufacturers) will build up in-house manufacturing capacity, many companies will continue to outsource. Many smaller companies will initially use CEMs, and as they grow will decide whether to add in-house capacity.

There is a continuing trend towards a handful of large, global CEM players—CEMs with a turnover of several billion dollars, worldwide production facilities and significant purchasing power. Only CEMs of this size, which can invest in sophisticated production technology and force down material costs, will be able to provide OEMs with the low-cost, high-volume products they demand.

There will be continued restructuring in the United Kingdom, Ireland and continental Europe, as larger players emerge. However, smaller players will continue to provide manufacturing services to various niches within the market, predominantly for low-volume, higher-value equipment.

By Robin Daines

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Appendix A—Survey Respondees

The CEM companies listed in Table 3 responded to our questionnaire.

Table 3
Respondents to CEM Survey

Company	Location	Country
AB Electronic Assemblies	Newport	UK
AB Mikroelektronik GmbH	Salzburg	Austria
ACW Technology	Petersfield	UK
Avex Electronics Ltd	East Kilbride	UK
Brother Industries (IRL) Ltd	Drogheda	Ireland
Celab Ltd	Bordon	UK
Chase Advanced Technology Ltd	Bradford	UK
DDL Electronics Ltd	Craigavon	UK
Design to Distribution Ltd	Stoke-on-Trent	UK
Dovatron Ireland	Cork	Ireland
EDMS Ltd	Maldon	UK
Evic Electronics	Echt	Netherlands
GEC Alsthom Electronic Service	Stafford	UK
GSPK Electronics Ltd	Knaresborough	UK
Genrad Manufacturing	Stockport	UK
Hosiden Besson Limited	Hove	UK
Hughes Microelectronics Europe	Glenrothes	UK
Jabil Circuit	Livingston	UK
Karavale Enterprises Ltd	Welwyn Garden City	UK
Kemitron Manufacturing	Deeside	UK
Kyrel Oy	Kyroskoski	Finland
Lucas Electronics	Birmingham	UK
Manufacturers Services Ltd	Athlone	Ireland
Mion Electronics	Wombwell	UK
Quantum Electronics Manufactur	Pontsewett	UK
SPA Superior Print Assembly BV	Almelo	Netherlands
Securicor Electronics Ltd	Bath	UK
Solectron	Fife	UK
Solectron France S.A	Cestas Cedex	France
Surtech Interconnection	Basingstoke	UK
Welwyn Systems Ltd	Blyth	UK

Source: Dataquest (September 1995)

Appendix B—Product Sector and Component Definitions

Product Sectors

This section defines the product sectors used in this report. Dataquest's objective is to provide relevant data about the electronic equipment manufacturing industry, and component applications markets. For forecasting purposes, Dataquest segments the electronics industry into six broad product sectors, these six sectors are defined by the narrower product sectors they represent:

- **Electronic Data Processing**
  - Computers

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- Data storage
- Input/output devices
- Dedicated systems

- **Communications**
  - Premise telecoms
  - Public telecoms
  - Mobile/radio communications equipment
  - Other communications
  - Broadcast and studio equipment
- **Industrial**
  - Security and energy management systems
  - Manufacturing and instrumentation systems
  - Robot systems
  - Medical equipment
  - Other industrial equipment
- **Consumer**
  - Audio
  - Video
  - Personal electronics
  - Appliances
- **Military and Civil Aerospace**
  - Transportation

Component Sectors

- **Semiconductor components**: Includes memory, microprocessors, microcontrollers, microperipherals, logic, ASICs, analog semiconductors, discrete semiconductors (diodes, transistors, and so on), optoelectronic semiconductor components (LEDs, opto-isolators, and so on), LCD display devices
- **Other components**: Includes batteries, cables, capacitors, connectors, crystals, fans, filters, fuses/protection, inductors, keypads/keyboards, microphones, oscillators, PCBs, resistors, sockets, speakers/sounders, switches, transformers, others

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