Semiconductor Application Markets *Worldwide*

Dataquest

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, CA 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

United Kingdom
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Nr Uxbridge,
Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

France
Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (01)48 97 34 00

Germany
Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
011 49 89 93 09 09 0
Fax: 011 49 89 930 3277

Japan
Dataquest Japan Limited
Shinkawa Sanko Building 2 Fl
1-3-17 Shinkawa
Chuo-kuTokyo 104
Japan
011-81-3-5566-0411
Telex: 781-32768
Fax: 011-81-3-5566-0425

Korea
Dataquest Korea
Dacheung Building Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-80
Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
(508) 370-5555
Fax: (508) 370-6262

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1290 Ridder Park Drive • San Jose • CA • 95131-2398 • Phone 408-437-8000 • Fax 408-437-0292

Preliminary 1992 Worldwide Semiconductor Market Share Estimates—Intel Is No. 1

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Rankings and Company Performance

Fueled by remarkable demand for its "second wave" microprocessor products (386SL and 486 MPUs), Intel overtook NEC and Toshiba to claim the No. 1 position in the 1992 worldwide rankings (see Table 1). The achievement completes an impressive five-year string of successes in which Intel more than doubled its worldwide market share percentage (see Figure 1). Intel's revenue grew a staggering 26 percent, an increase of more than $1 billion.

At the same time Intel grew its revenue by $1 billion, Motorola grew its revenue by $833 million. This growth is in large part because of the growth of Motorola's non-MOS business, which grew at a rate of 16 percent, compared with the industry's growth in the same families of only 1 percent—a remarkable achievement.

During November and December, Dataquest surveyed more than 150 semiconductor vendors throughout the world who provided us with a detailed breakout of their revenue based upon a combination of actual year-to-date revenue and company-generated forecast for the balance of the year. These data were then verified using a combination of primary and secondary research, along with a bottoms-up analysis by company, product, and region in order to arrive at the information published in this article. Dataquest will continue to refine and update the data until our final market statistics documents are published in May 1993.

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Source: Dataquest (January 1993)

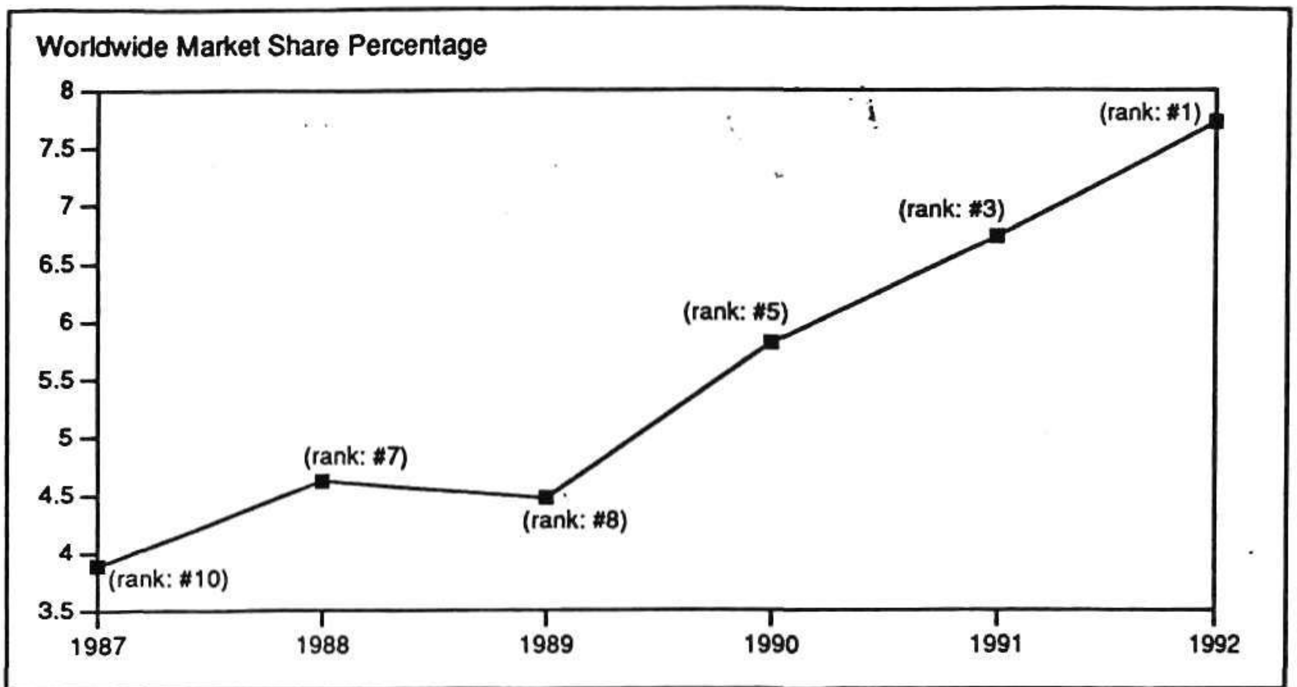
computers (such as fax/modem cards, memory upgrades, and microprocessor clock speed doublers).

Taking advantage of both a downturn in the Japanese economy and a heightened emphasis on the U.S.-Japan semiconductor trade agreement, North American companies' 1992 market share grew significantly to 41.1 percent, compared with last year's 38.4 percent (see Figure 2). The top six U.S.-based companies (Intel, Motorola, Texas Instruments, National Semiconductor, Advanced Micro Devices, and AT&T) all gained in worldwide market share in 1992.

Japanese companies' market share dropped by 3.6 percent in 1992 to 42.8 percent. However, the Japanese companies still managed to perform well in many areas. NEC Corporation easily retained its top ranking in the Japanese market, and Toshiba Corporation, based on strong sales in the logic and memory areas, overtook Intel as the top company in the Asia-Pacific region.

Due to phenomenal growth rates by its top 3 companies—Samsung (up 29.1 percent), Goldstar (up 106.8 percent), and Hyundai (up 124.2 percent)—market share for Asian

Figure 1
Intel Moves Up the Ranking Ladder



Source: Dataquest (January 1993)

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Figure 2
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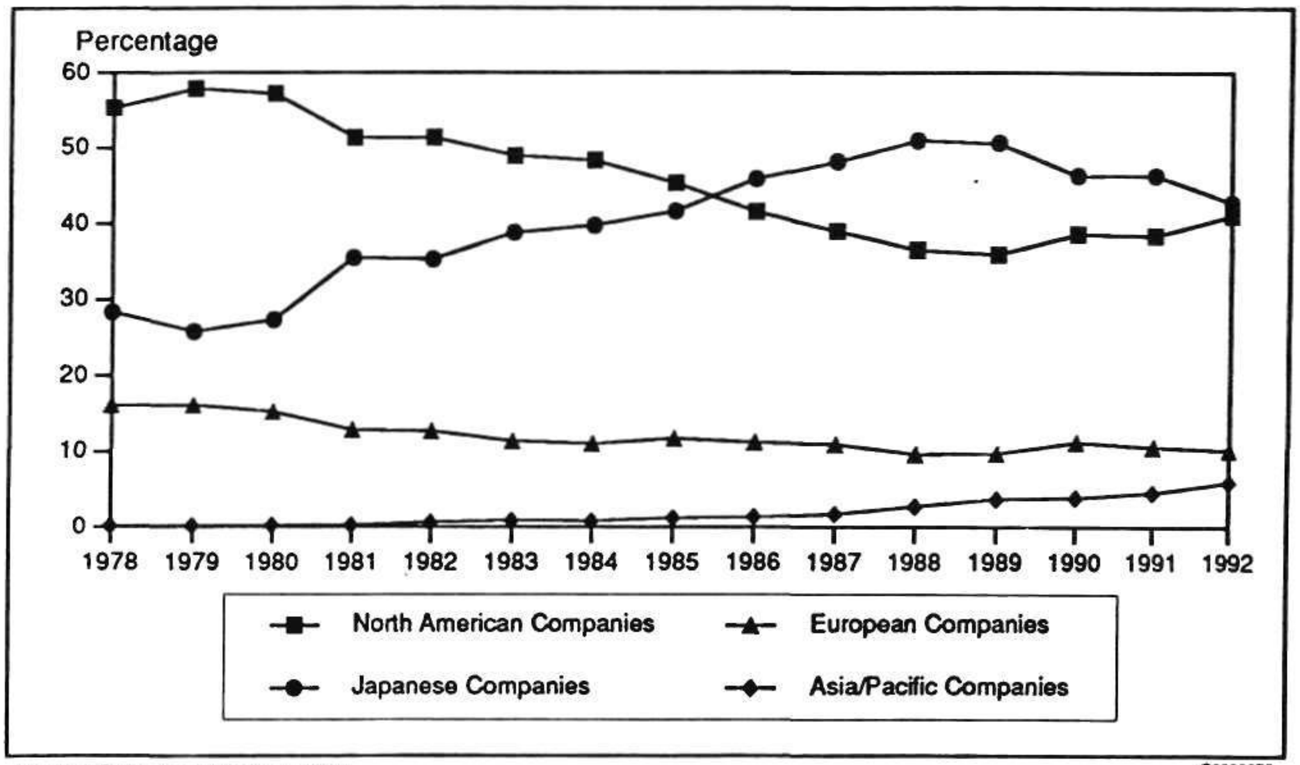

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companies continued to increase for the eighth straight year, this time to 5.9 percent versus 4.6 percent in 1991.

Market share for European companies remained essentially flat in 1992 at 10.2 percent. Philips, despite a lackluster sales performance over the course of the year, managed to retain its top ranking in the European semiconductor market. SGS-Thomson, which over the past three years has greatly increased its emphasis on sales outside of Europe, had the strongest growth among the major European companies at 11.8 percent.

Table 2 provides a detailed look at how regionally-based companies fared in 1992.

Exchange Rate Effects

In many instances, using regional exchange rates can paint a clearer picture of market conditions throughout the world. Table 3 provides Dataquest's 1992 regional growth numbers in both U.S. dollars and in local currencies.

Product Performance

For the third straight year, the microcomponents category was the top growth contributor in the semiconductor market, growing at approximately 22 percent. Not surprisingly, this area was led by growth from the two main competitors in the 80x86 microprocessor market—AMD and Intel. AMD, showing that the 386 market still had plenty of life in it, saw its MPU revenue grow an astounding 74 percent in 1992, now accounting for well over half a billion dollars. Intel, on the other hand, succeeded in pushing many users to upgrade to its more powerful 486 version, and saw its MPU revenue grow 42 percent to well over $3.5 billion.

The MOS memory market, fueled by a large increase in bit demand, increased by slightly more than 19 percent in 1992. The DRAM market was the high-growth leader in this area, increasing 25 percent in 1992. As PC users began running many more graphics-intensive software packages such as Microsoft Windows, the demand for extra memory helped push the DRAM market. Additionally, antidumping suits filed by both the U.S. and European companies helped firm DRAM prices in the latter half of 1992, thereby allowing many companies to increase their revenue due to higher ASPs.

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The bipolar digital market continued its downward trend for the fourth straight year, falling by 10.1 percent. TI dropped 13 percent in this product area, but still managed to remain No. 1. Hitachi overtook Fujitsu, which suffered an 18 percent decline in bipolar revenue, to claim the No. 2 spot. Each company in the top 10 saw its bipolar revenue shrink from 1991 levels except Motorola, which saw a very modest 1 percent growth.

Analog grew 5.8 percent in 1992 and once again was the most chaotic category in terms of ranking changes among the leaders. Eight of the top 10 companies switched places, starting at the top, where National Semiconductor, with the second strongest growth among the top 15 analog players at 17 percent, moved past Philips into the No. 1 spot. SGS-Thomson, Motorola, and Toshiba rounded out the top 5, with each company's sales in the $600 to $660 million dollar range. (According to Dataquest's policy, we include hybrid ICs in this analog category an d also in the total IC and semiconductor categories. One should note this difference when comparing our statistics to the World Semiconductor Trade Statistics (WSTS) or MITI/MOF statistics.)

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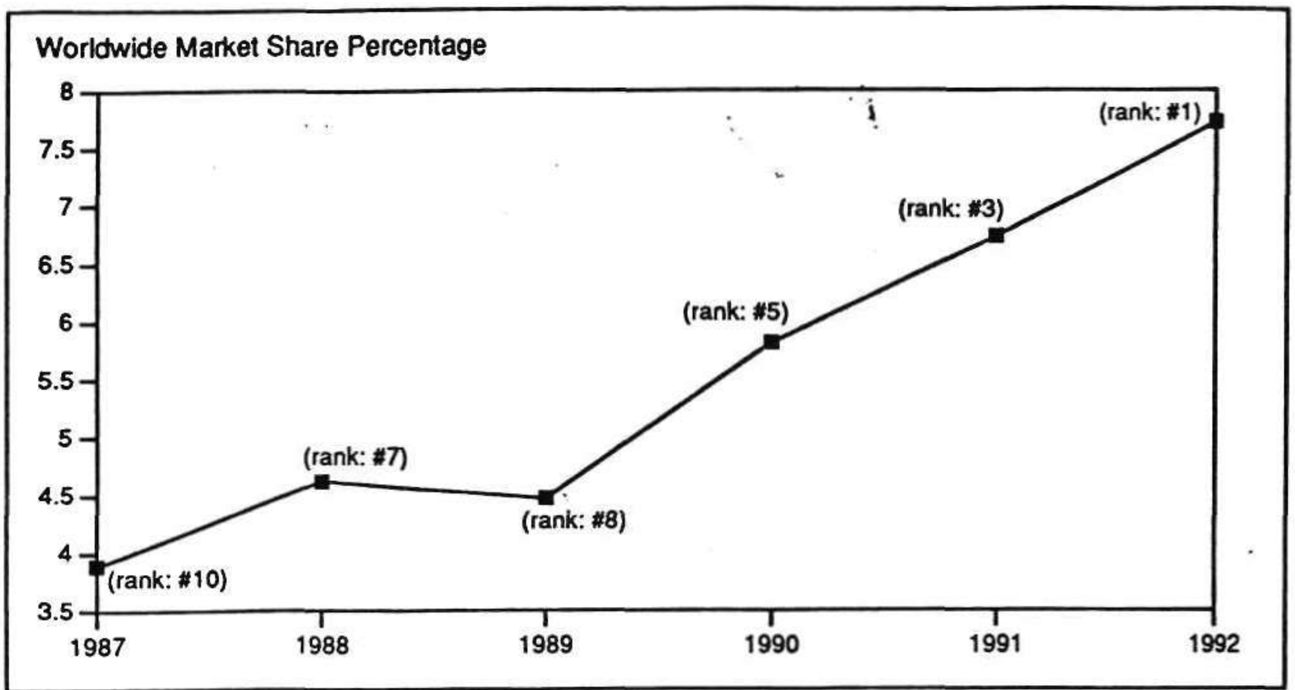

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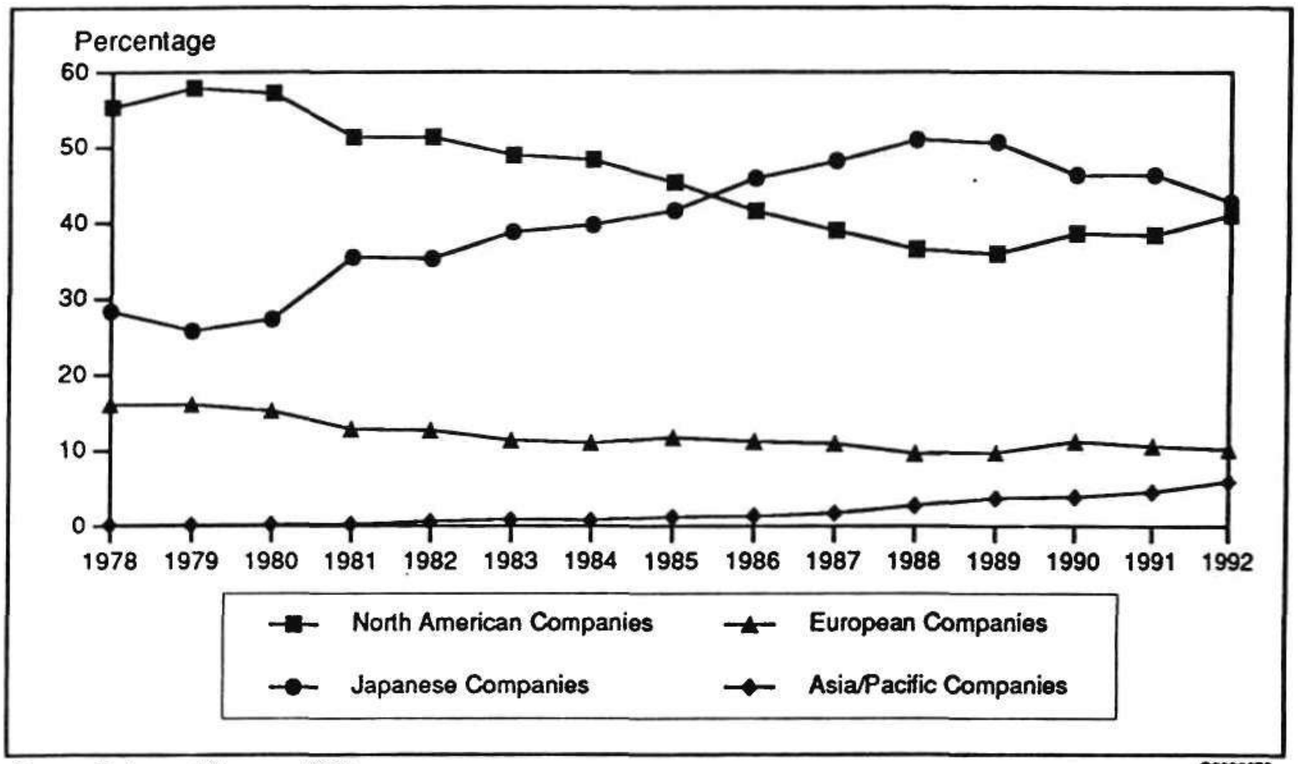

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Recovery in Capital Spending One Year Off

The end game to the global semiconductor investment downturn that began in 1990 is under way. Ironically, the final corrective adjustments are taking place in Japan, the very country that led the investment boom.

As a result, we expect worldwide semiconductor capital spending and semiconductor wafer fab equipment sales to be flat in 1993 and then begin a sustained period of growth through the middle of the decade (see Tables 1 and 2). Our forecast has global spending declining 0.1 percent in 1993 and equipment sales up 1.2 percent.

The adjustments to capital spending that has been under way over the last three years is finally bringing semiconductor capacity into line with demand. The bottom line is that IC manufacturers have cut the rate at which capacity will grow in the future. Not only are plans to add new capacity being delayed or canceled, but also device manufacturers are closing down older fabs.

On a square-inch basis, 1992 actual capacity will be 10 percent less than was originally planned for one year ago, and 11 percent less in 1993. The decreases occurred in all regions of the world, but the steepest cuts have occurred in capacity that Japanese companies had planned to bring online.

The sharp retrenchment in Japanese capital spending is at the center of the decline in capacity. We estimate that spending in Japan will be slashed by 29 percent in 1992, and will further decline by 13 percent in 1993. The United States will show surprising strength in 1993. Capital spending and equipment sales in the United States are expected to be up 13 percent because of increased investment by microprocessor makers. Investment in Europe will decline further in 1993. Plans to add capacity in the Asia/Pacific region continue to push ahead.

Dataquest Perspective

Dataquest believes that the adjustment to capacity taking place now will lead to an improvement in the profitability of device makers over the next several years. Better profitability for device makers is the cornerstone assumption in our forecast of an accelerating capital spending and equipment sales cycle, which we expect to begin in 1994.

Table 2-2
Worldwide Semiconductor Capital Spending, by Region - Forecast, 1991-1996 (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
North America	3,851.4	3,558.7	4,003.5	4,327.8	4,786.6	5,346.6	6.8
Percent Growth	-3.8	-7.6	12.5	8.1	10.6	11.7	
Japan	5,636.4	4,018.8	3,508.4	3,894.3	4,233.1	5,058.5	-2.1
Percent Growth	1.0	-28.7	-12.7	11.0	8.7	19.5	
Europe	1,233.6	1,086.8	1,041.2	1,143.2	1,400.4	1,862.5	8.6
Percent Growth	-17.5	-11.9	-4.2	9.8	22.5	33.0	
Asia/Pacific-ROW	2,273.6	2,319.1	2,416.5	2,631.5	3,118.4	3,975.9	11.8
Percent Growth	63.9	2.0	4.2	8.9	18.5	27.5	
Worldwide	12,995.0	10,983.3	10,969.5	11,996.8	13,538.4	16,243.6	4.6
Percent Growth	2.9	-15.5	-0.1	9.4	12.9	20.0	

Source: Dataquest (December 1992)

Table 3-2
Worldwide Wafer Fab Equipment Market, by Region - Forecast, 1991-1996 (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
North America	1,536.3	1,516.7	1,711.0	1,947.5	2,249.7	2,619.8	11.3
Percent Growth	-3.8	-1.3	12.8	13.8	15.5	16.5	
Japan	3,016.7	2,108.0	1,960.5	2,102.9	2,328.2	2,782.2	-1.6
Percent Growth	1.0	-30.1	-7.0	7.3	10.7	19.5	
Europe	633.6	596.0	566.2	628.8	770.2	1,024.4	10.1
Percent Growth	-17.5	-5.9	-5.0	11.0	22.5	33.0	
Asia/Pacific-ROW	852.3	883.3	928.0	1,053.5	1,295.3	1,711.1	15.0
Percent Growth	63.9	3.6	5.1	13.5	23.0	32.1	
Worldwide	6,038.9	5,104.0	5,165.7	5,732.7	6,643.4	8,137.5	6.1
Percent Growth	2.9	-15.5	1.2	11.0	15.9	22.5	

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AMD Loses Round 2 of the Intel Microcode Suit

On Wednesday, December 2, 1992, Judge Ingram ruled that AMD does not have the rights to copy Intel's microcode for use in microprocessors. This ruling comes nearly six months after the first decision by Judge Ingram, who found specifically that AMD did not have the rights to copy Intel's 80287 math coprocessor microcode. A summary of the key decisions made to date is as follows:

- AMD wins arbitrator's decision (February 1992) regarding contract breach, which awarded AMD rights to all intellectual property used in its 386 (including microcode) and offsetting damages to both parties ($15 million to AMD, $23 million to Intel).
- Arbitrator's decision was upheld (May 1992) in California State Superior Court, whereupon Intel appealed the arbitrator's decision to award its 386 microcode to AMD as damages, claiming that this intellectual property is beyond the scope of the arbitrator's jurisdiction. The success of this appeal does not look likely because preliminary rulings recently released indicate a predisposition to remain with the arbitrator's decision. However, if victorious, Intel will ask for damages in excess of $600 million (based on lost revenue).
- Intel wins round 1 (June 1992) and round 2 (December 1992) of the microcode suit against AMD. The ruling is that AMD does not have the rights to ship Intel's microcode for math coprocessors or microprocessors, respectively, with the exception of the 386 because of arbitration (under appeal). Intel has requested damages of $35 million for AMD's shipment of 287s. Intel has requested AMD destroy all copied Intel 486 microcode, including any physical samples distributed to its customers.

The two major outstanding issues surrounding the legal rivalry between these companies are as follows:

- What impact will this decision have on AMD's 486 introduction plans?
- Will the appellate court reverse the arbitrator's decision regarding AMD's rights to 386 microcode?

Dataquest Perspective

This verdict was no surprise to us. It affirms the predictions we made back in June, including a scenario calling for a delay in AMD's 486 shipments until the second quarter of 1993, and a loss of competitive advantage (offering direct replicas of Intel's architecture). However, we also believe that this decision was no surprise to AMD, which was prepared for it and had taken steps to minimize its affect on its marketing efforts, including the following:

- Moving ahead quickly on developing a forward-engineered version of the 486DX, which we anticipate will be at first silicon late in the first quarter of 1993.
- Demonstrating high-performance 50-MHz 486DX chips at COMDEX/Fall and previously in a European trade show, proving its ability to design a 486DX-level chip.
- Working with key OEMs to design systems around its pending 486 product line (microcode will have no effect on system design), to have a level of demand pre-established as production ramp begins.

As to the future, Dataquest predicts that AMD will lose market share in the next 6 months as the PC product mix shifts to the 486. However, it will emerge somewhat strengthened in the long term as it switches to a forward-engineered x86s architecture. Ironically, AMD will become the beneficiary of a decision made for it by the legal system that it should have made internally.

Ken Lowe, Senior Industry Analyst
Dataquest Microcomponents Service

October 9, 1992

Dear Dataquest Client:

For those of you who haven't responded to our annual research needs questionnaire.

You still have time to get your 1993 research needs into our research plan. Please return by fax your three page questionnaire form that was sent to you on October 2 to (408) 437-0292 by October 14, 1992. This will ensure that your voice is heard in our soon to be finalized 1993 research plan.

Regards,

Gregory Sheppard

Semiconductor Application Markets *Worldwide*
Survey

1. Are you the principal binder holder of the service? Yes No

2. Regarding our newsletter and focus report deliverables, please rank your preference on a basis of 1 (highest) to 3 (lowest):

___ Deliver more newsletters but have more topics with less in-depth coverage per topic; and include more focus reports (e.g., Multimedia)

___ Deliver fewer newsletters but have fewer topics with more in-depth coverage; and have two focus reports (the number to be delivered this year)

___ Keep the same as this year

3. How important is it to cover the following subjects within each application topic newsletter article (e.g., rigid disk drives)?

	Not Important — Very Important
System forecast	0 1 2 3 4 5
System market trends	0 1 2 3 4 5
OEM analysis/market share	0 1 2 3 4 5
Block diagram trends	0 1 2 3 4 5
Semiconductor content analysis/forecast	0 1 2 3 4 5
Semiconductor company analysis/market share	0 1 2 3 4 5

Questions 4 through 6 pertain to the core database information found in the Source: Dataquest binder (the booklets labeled Source: Dataquest).

4. Please rate on a scale of 0 to 5 (5 the most important, 0 do not use at all) the material you find most useful in doing your job.

	Not Important — Very Important
Worldwide and North American Electronic Equipment Forecast	0 1 2 3 4 5
Worldwide and North American Consumption by Application	0 1 2 3 4 5
Data Processing Statistics Worldwide	0 1 2 3 4 5
Communications Statistics North America	0 1 2 3 4 5
Industrial Statistics North America	0 1 2 3 4 5
Consumer Statistics North America	0 1 2 3 4 5
Mil/Aero Statistics North America	0 1 2 3 4 5
Transportation Statistics North America	0 1 2 3 4 5
North American OEM Revenue	0 1 2 3 4 5

5. In reference to the sections mentioned in question 2, how could we improve their scope to better serve your needs (please be specific)?

6. What would be your level of interest in the following reference databases which we currently don't publish? Please rate (0 to 5).

6a. A North American OEM Semiconductor Purchases database (lists semiconductor purchase estimates by North American OEM) 0 1 2 3 4 5

6b. A North American OEM Electronic Production Survey (lists production sites and unit volumes for PC, workstation, storage, and printers and board contractors) 0 1 2 3 4 5

Questions 7 through 9 relate to potential newsletters or focus reports.

7. Listed below are some candidate topics for 1993. Please rate these topics as to your interest level.

	Not Important Very Important
Data Processing Topics	
Personal Information and Communications Devices	0 1 2 3 4 5
Pen-Based PCs	0 1 2 3 4 5
Notebook PCs	0 1 2 3 4 5
Desktop PCs	0 1 2 3 4 5
Personal Workstations	0 1 2 3 4 5
Other Workstations	0 1 2 3 4 5
Graphics and Digital Video	0 1 2 3 4 5
Sound/Sound Boards	0 1 2 3 4 5
Rigid Disk Drives	0 1 2 3 4 5
Optical Disk Drives	0 1 2 3 4 5
Tape Drives	0 1 2 3 4 5
Ink Jet Printers	0 1 2 3 4 5
Laser Printers	0 1 2 3 4 5
Scanners	0 1 2 3 4 5
Point-of-Sale Systems	0 1 2 3 4 5
Hand-Held terminals	0 1 2 3 4 5
Communications Topics	
Fiber Optics (SDH/SONET)	0 1 2 3 4 5
High-Performance Networking (ATM, FDDI...)	0 1 2 3 4 5
LAN Cards/Embedded	0 1 2 3 4 5
Internetworking (Bridges, Routers, Hubs...)	0 1 2 3 4 5
Wireless Data Communication	0 1 2 3 4 5
ISDN	0 1 2 3 4 5
ATM/SMDS/Frame Relay	0 1 2 3 4 5
Cellular/PCN	0 1 2 3 4 5
Modem	0 1 2 3 4 5
Fax	0 1 2 3 4 5
Navigation Systems (GPS)	0 1 2 3 4 5
Industrial Topics	
Medical	0 1 2 3 4 5
ATE	0 1 2 3 4 5
Test and Measurement Instrumentation	0 1 2 3 4 5
Robotics	0 1 2 3 4 5
Industrial Boards (VME, etc.)	0 1 2 3 4 5
Consumer Topics	
Advanced Consumer Video	0 1 2 3 4 5
Advanced Consumer Audio	0 1 2 3 4 5
Interactive/Entertainment (CD-I, Video Games)	0 1 2 3 4 5
Home Satellite/Cable Terminals	0 1 2 3 4 5
Automotive Topics	
Advanced Automotive Systems	0 1 2 3 4 5

8. What other topics would you be interested in?

9. Of the topics listed earlier, which 5 would be of the most interest?

10a. How important is it to have OEM profiles detailing their design and purchasing information?
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10b. Which OEMs would you like covered?

11. Over the next two months you will receive two focus reports, one on multimedia and one on hand-held information and communications devices (PICDs). How important are these topics to you?

Multimedia	0 1 2 3 4 5
PICDs	0 1 2 3 4 5

12. In December you will receive an OEM Purchaser Wants and Needs report detailing key services issues, contracting trends, and product needs. How interested do you think you will be in this information? 0 1 2 3 4 5

13. Any other comments?

Thank you! Your help is appreciated.

October 2, 1992

Dear Dataquest Client,

Each year we survey the clients of the **Semiconductor Application Markets *Worldwide*** Service to capture their input for our research scope for the following year. We would like very much to have your ideas for our 1993 program. The survey touches on both our core reference databases found in the Source: Dataquest binder, and the potential topics in our newsletters and reports. Your input directly influences our research plan and this is a prime opportunity to ensure we are covering the topics of greatest interest to your company.

Please take some time to fill out the attached survey and fax it back to me at (1) (408) 437-0292 before October 9. Give me a call if you like as well at (1) (408) 437-8261. Thank you!

Sincerely,

Gregory Sheppard
Dataquest

Semiconductor Application Markets *Worldwide*
Survey

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Thank you! Your help is appreciated.

EC Imposes Provisional 10 Percent Antidumping Penalty on Korean DRAM Suppliers

The European Community Commission (EC) has imposed a 10.1 percent provisional antidumping duty on the import of DRAMs from Korean suppliers Goldstar, Hyundai, and Samsung. The penalty applies to DRAM die, wafer, discrete devices, and modules. The next likely step will be approval by the Council of Ministers. The provisional penalty--which applies for four months unless extended or otherwise modified--is not retroactive. The 10.1 percent penalty compares with a finding of the following dumping margins: Goldstar at 122 percent; Hyundai at 57 percent; and Samsung at 18 percent.

Dataquest Perspective

The European import duty is 14 percent on discrete DRAMs and 4.1 percent on modules. For South Korean suppliers, the antidumping penalty increases the total duty to 25.1 percent on discrete DRAMs and 14.2 percent on modules. Dataquest expects this action not only to increase European DRAM pricing--which has been the instant response of some suppliers in the region--but also to add another touch of market volatility for buyers in other regions such as North America. For example, the U.S. Department of Commerce (DOC)-International Trade Commission should issue a preliminary decision on Micron's DRAM dumping complaint against these Korean suppliers on about September 30--and shortly before the U.S. presidential election.

The EC, along with Korean suppliers and users in Europe, has a challenging road ahead. The EC aims to balance the conflicting concerns of the European supplier and user communities. For example, the 10.1 percent penalty should be less devastating to emerging DRAM suppliers such as Goldstar and Hyundai than a penalty in the 25 to 50 percent range. The EC has two distinct systems for monitoring DRAM pricing: this antidumping system and the reference pricing (RP) system. Some users and other market participants have criticized the RP system for increasing market uncertainty and volatility. The relatively low level of penalty in this action moderates against increased uncertainty. However, the global network of DRAM suppliers and users must now brace for another bout of DRAM market volatility. For example, the existing Reference Price Arrangement affecting Japanese DRAM suppliers may force the affected Korean companies out of some European market segments because of the current pricing penalties.

Regarding the future of this provisional penalty, the EC may decide--depending on the course of negotiations with the affected Korean suppliers--to eliminate the penalty for any given supplier, maintain the same penalty, or, less likely, increase it.

Otherwise, once this provisional penalty expires, what will replace it? Dataquest sees two distinct possibilities, as follows:

- A new "FMV-type" structured cost price scheme similar to the U.S. DOC model
- Korean DRAM suppliers' inclusion in the current Reference Price Arrangement

THE DATAQUEST PERSPECTIVE

San Jose, Calif., July 27, 1992 -- *Dataquest today, issues the top-line semiconductor industry forecast numbers along with assumptions supporting the forecast to the Dataquest Semiconductor Service Clients. This is to insure that our clients will receive the latest data as soon as it is available. The final market share booklet have been sent and the latest forecast booklet will be shipped this week. Should you have questions regarding the market share or forecast data, please contact your semiconductor account manager. Dataquest will also be releasing a subset of the forecast data to the press in the form of a press release on July 28, 1992.*

Semiconductor Industry Assumptions

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 15.1 percent in 1992, up from a meager 2.7 percent in 1991. The market is clearly on target midway through the year. According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in June was 18.0 percent above year-earlier bookings, compared with 11.9 percent in May. Total semiconductor billings growth for the same period was 14.8 percent above year-earlier billings, compared with 13.3 percent in May.

Strength in the North American market can be attributed largely to the recovery of the U.S. economy and the relaxation of household and business budget constraints for durable goods and capital equipment. In particular, however, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

Dataquest expects the Japanese market to decline 9.4 percent (dollar-based) in 1992, the first yearly decline sin 1985. The latest market statistics support this outlook. The dollar value of total semiconductor billings for the three months ended in May was 14.5 percent *below* year-earlier billings. The bookings picture is even more bleak. Total semiconductor bookings for the same period were 17.7 percent *below* year-earlier levels. Japan's situation is due to more than just weakness in its European export market. Other factors include a heightened level of international competition in chips and systems, a glut of worldwide DRAM fab capacity, rising costs of capital in Japan, and a dearth of new, high-volume consumer electronic systems. Dataquest does not expect an improvement in Japan's export market to alleviate these structural problems in 1992.

Dataquest forecasts the European market to grow 7.2 percent in 1992, up from 5.8 percent in 1991. Total semiconductor billings for the three months ended in June was 9.0 percent above year-earlier billings. Total semiconductor bookings for the same period were 7.1 percent above year-earlier levels. We believe that the European market will show more growth in the second half of 1992 than usual, as recovery in the U.S. market starts to pull through demand in Europe later in the year. Recovery of the U.K. and French economies will help offset decelerating growth in Germany. PC manufacture in Ireland is strong, and much of the growth in the United Kingdom is related to multinational companies increasing their data processing and consumer equipment production. Investment in telecommunications infrastructure and the introduction of GSM mobile cellular phon also provide growth stimulus.

Dataquest forecasts the Asia/Pacific-Rest of World market to grow 21.6 percent in 1992. Again, the latest statistics support this outlook. Total semiconductor bookings growth for the three months ended in May was 15.8 percent above year-earlier bookings. Total semiconductor billings growth for the same period was 25.5 percent above year-earlier billings. Expansion continues to be driven by foreign investment and improvement in Western export markets.

Semiconductor Consumption (Millions of $): Worldwide

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total Semiconductor	38,250	50,859	54,339	54,545	59,694	62,925	72,668	82,627	88,122	94,991
Total Integrated Circuit	29,886	41,068	44,613	44,459	48,855	52,074	60,902	70,002	74,609	80,720
Bipolar Digital	4,760	5,200	4,314	4,173	3,628	3,271	2,989	2,733	2,498	2,252
Bipolar Memory	621	689	460	431	356	339	274	209	185	176
Bipolar Logic	4,139	4,511	3,854	3,742	3,272	2,932	2,715	2,524	2,313	2,076
MOS Digital	17,473	26,988	31,140	30,152	34,315	37,287	45,007	53,063	56,540	61,713
MOS Memory	6,056	11,692	15,405	12,128	12,841	14,683	18,927	22,888	21,978	23,661
MOS Microcomponent	5,108	7,144	7,808	9,584	11,774	12,985	14,804	17,258	20,016	21,920
MOS Logic	6,309	8,152	7,927	8,440	9,700	9,619	11,276	12,917	14,545	16,132
Analog	7,654	8,880	9,159	10,134	10,912	11,516	12.907	14,206	15,571	16,754
Total Discrete	6,655	7,612	7,320	7,674	8,035	8,126	8,730	9,290	9,868	10,403
Total Optoelectronic	1,709	2,179	2,406	2,412	2,804	2,725	3,036	3,335	3,645	3,868

Source: Dataquest
24-Jul-92

Semiconductor Consumption Growth (%): Worldwide

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	91-96 CAGR
Total Semiconductor	24.1	33.0	6.8	0.4	9.4	5.4	15.5	13.7	6.7	7.8	9.7
Total Integrated Circuit	26.5	37.4	8.6	-0.3	9.9	6.6	17.0	14.9	6.6	8.2	10.6
Bipolar Digital	10.1	9.2	-17.0	-3.3	-13.1	-9.8	-8.6	-8.6	-8.6	-9.8	-9.1
Bipolar Memory	2.5	10.9	-33.2	-6.3	-17.4	-4.9	-19.1	-23.7	-11.6	-4.9	-13.2
Bipolar Logic	11.3	9.0	-14.6	-2.9	-12.6	-10.4	-7.4	-7.0	-8.4	-10.2	-8.7
MOS Digital	36.3	54.5	15.4	-3.2	13.8	8.7	20.7	17.9	6.6	9.1	12.5
MOS Memory	34.2	93.1	31.8	-21.3	5.9	14.3	28.9	20.9	-4.0	7.7	13.0
MOS Microcomponent	46.4	39.9	9.3	22.7	22.9	10.3	14.0	16.6	16.0	9.5	13.2
MOS Logic	31.0	29.2	-2.8	6.5	14.9	-0.8	17.2	14.6	12.6	10.9	10.7
Analog	18.2	16.0	3.1	10.6	7.7	5.5	12.1	10.1	9.6	7.6	9.0
Total Discrete	16.1	14.4	-3.8	4.8	4.7	1.1	7.4	6.4	6.2	5.4	5.3
Total Optoelectronic	15.0	27.5	10.4	0.2	16.3	-2.8	11.4	9.8	9.3	6.1	6.6

Source: Dataquest
24-Jul-92

THE DATAQUEST PERSPECTIVE

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Source: Dataquest
24-Jul-92

AMD Loses Round 1 of the Intel Microcode Suit

After deliberating for nearly a week, a jury in San Jose, California concluded that Advanced Micro Devices Inc. (AMD) does not have the right to distribute Intel Corporation's microcode in microprocessor products, the 80287 specifically, in this case. This is the first of three modules; a misrepresentation module and a maskwork infringement module are still to come to trial.

The disputed rights refer to an agreement made in 1976 and later extended in 1982 in which AMD claimed it was given the rights to use and distribute Intel's microcode in microprocessors. Though Intel concurred that AMD had the rights to use its microcode, the arguments focused on what form of distribution AMD had permission to use. These arguments centered around the definition of the term "microcomputer," the operative term used in the agreement. AMD argued that the term (as used in the original 1976 agreement) was (at that time) used interchangeably with the term "microprocessor" and thus conferred rights to distribute component-level products. Intel argued that the term microcomputer meant system-level products such as development systems. To settle this module, the jury was instructed to return with answers to the following specific questions, where the burden of proof rested on either AMD or Intel as listed:

Q: Did AMD prove that the disputed language "microcodes contained in Intel microcomputers and peripheral products sold by Intel" referred to microcode contained in the AMD 80287?
A: No, AMD did not prove this.

Q: Did Intel prove that the two parties disagreed as to the meaning of the language when the agreement was extended in 1982?
A: No, Intel did not prove this.

In addition, two other questions regarding third-party duplication rights and willfulness of infringement were also returned negative, neither party meeting its burden of proof. AMD will appeal this verdict on Monday, when it will ask for a judgment by the court as a matter of law, notwithstanding jury verdict. AMD contends that the jury was confused and thus ruled in each question that neither party was able to prove its case.

Dataquest Perspective

This was a surprise verdict and counterbalances the rights set forth in the earlier arbitration decision where AMD was awarded specific rights to manufacture and sell (including microcode) the reverse-engineered 386 product. Assuming that both judgments stand intact, AMD will be pushed into forward engineering all future generations with the following impact:

• Schedule delays: Introduction of its preannounced 486 products may be delayed by as much as 6 months, though work toward a forward-engineered version has already been under way.

• Technical risks: Though AMD has the engineering talent to provide forward-engineered parts, it will have to reestablish the compatibility of its 80x86 line.

• Loss of competitive advantage: AMD had a differential advantage over all other 80x86 cloners by providing exact duplicates of Intel parts, the loss of which creates a market acceptance risk.

Correlating these impacts with the state of the industry, Dataquest predicts the following scenario to take place: AMD will refocus its 486 development on a forward-engineered approach; AMD will demonstrate working prototypes by the end of this year and begin shipping in the second quarter of 1993; AMD will lose market share as the PC product mix shifts to the 486 (pushed by both Intel and Cyrix/TI); AMD will lose account control as upcoming socket opportunities go to Intel or Cyrix/TI.

Though AMD will suffer in the short term, it may actually emerge somewhat strengthened in the long term by having shifted to forward-engineering and thus being able to introduce new generations without waiting for Intel.

Ken Lowe
Senior Industry Analyst
Dataquest Microcomponents Service

Rambus-NEC-Fujitsu-Toshiba Partnership: A Challenge to Traditional DRAM Architecture

Rambus Inc. was founded in March 1990 by Dr. Mike Farmwald and Dr. Mark Horowitz. The initial funding ($1.8 million), was provided by three venture capital firms: Kleiner Perkins Caufield and Byers; Merrill, Pickard, Anderson and Eyre; and Mohr, Davidow Ventures. Geoff Tate is president, and CEO, Bill Davidow is chairman, and Takahiro Kamo is chairman of Rambus K.K. (Japan). The company has 35 employees.

Rambus Inc. has developed and licensed a new DRAM architecture and very high speed chip-to-chip data transfer technology to NEC, Fujitsu, and Toshiba. This technology is based on a proprietary interface that will be implemented on DRAMs, graphics, video ICs, and other high-performance VLSI components. Rambus claims that its proposed solution achieves up to 10X increase in throughput, while using fewer ICs. A Rambus DRAM (RDRAM) is able to transfer 500MB of data per second over the so-called "Rambus Channel," which is a relatively simple 16-bit, high-speed bus. To achieve this, the company stripped away most of the circuitry from the standard DRAM and substituted its own interface. The internal sense amps are used in a caching scheme, in effect creating an on-chip cache! Using standard CMOS technology with internal voltage swings of 0.6V, the memory chip is internally split into two banks of 256KB. Each bank is associated with a 1KB "Sense Amp Cache." Data transfers of 1 to 256 bytes use a synchronous packet-oriented protocol that utilizes both edges of a 250-MHz clock to achieve the 500-MHz throughput rate. The 4Mb generation of RDRAM is configured as 512Kx9 and the 16Mb as 2Mx9, effectively yielding 4.5Mb and 9Mb devices, respectively. The company claims performance improvement of 3 to 5 times over VRAMs. In the near term ASIC devices will be used to interface RDRAMs with standard microprocessors. The company hopes that the proposed interface succeeds as a standard, and then migrates onto future versions of CISC and RISC microprocessors and other devices.

Cost effectiveness comes from eliminating the need for an external cache controller/SRAM and/or substituting RDRAMS for VRAMs. The VRAM cost ratio is 1.8 to 2 times that of equivalent DRAMs. At the 1Mb level a typical VRAM may incur a 50 percent die size penalty over the 1Mb DRAM. Rambus says its proprietary interface (overhead on the standard memory array) results in a 25-percent die size penalty at a 4Mb DRAM density and drops to 5 percent at a 64Mb device density.

Fujitsu has announced that it intends to manufacture RDRAMs in 1992 and incorporate the technology into ASICs and microprocessors. Toshiba plans to introduce a 4Mb RDRAM in 1992, and offer other products along with 16Mb RDRAM in 1993. NEC is now developing a 16Mb RDRAM as well as ASIC cells.

RAMBUS architecture is meant to be an open standard. Companies other than those announced in this partnership may license the technology. The question of a single standard is important, as compatibility has plagued VRAMs. Rambus did an impressive job selecting and lining up the three top memory and ASIC players. The group represents a formidable mass, eliminating right away multiple-source questions.

Rambus is following the business model of a technology developer/licensor, similar to Adobe Systems and Dolby Laboratories. Even though it does not intend to sell silicon, Rambus may be a model for "semiconductor" companies of the future. Rambus will receive license fees and royalties from NEC, Fujitsu, Toshiba, and other companies that implement its RAMBUS technology.

Dataquest Perspective

Ultimately, as is the case with many new technologies, it will be up to the users to vote it in or out. The company's greatest short-term challenge will be to educate the engineering community that is perhaps skeptical of buses switching at 500 MHz. Also, its claim that RDRAMs will hit the market at a 25 percent price premium (a fair markup for such performance) must be backed up by silicon. The acid test should come later this year.

Most likely this new technology will be embraced first by vendors that need the blazing performance RDRAMS may offer in video applications: companies such as Sun Microsystems, Silicon Graphics, HP, and IBM, along with companies able to exercise reasonable control over hardware and software, such as Apple.

This new technology may replace VRAMs in the long run. Right now users are moving from VRAMs toward standard DRAM technology. The primary reason is the price differential for what amounts to a marginal performance boost. Furthermore, because of its serial nature VRAM can only be used for video applications, resulting in lower volume and high average selling prices. Unlike VRAM, the Rambus-proposed architecture can be used for both main memory and video memory. The challenge for RAMBUS, Fujitsu, NEC, and Toshiba will be to change the status quo. The benefits will be substantial: monetary for this partnership, and performance for users. The question is whether computer vendors can afford to ignore this development. In a fierce competitive environment where product differentiation is based on performance, the answer is no.

Why did three Japanese giants form a partnership with a small startup? Because this may represent a ray of hope for DRAMs; prices for standard DRAMs are depressed, pressure from Korea is intensifying, and the PC market shows no signs of a speedy recovery. This may be attributed to the fact that PCs have reached a performance plateau and need a kick-start to get moving. If this new technology allows PCs to manipulate VGA/SVGA graphics in real time, then we may be looking at a quantum step forward in PC performance and memory sales. It would certainly provide a renaissance for PCs.

By Nicolas Samaras
Principal Analyst/Director, Dataquest Semiconductor Group

Semiconductor Application Markets *Worldwide*

Dataquest

Semiconductor Market Definitions

March 1992

Source: Dataquest

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Table of Contents

Chapter 1

Market Share Survey Overview

Each year, Dataquest surveys semiconductor vendors in order to estimate their annual sales. The survey covers approximately 140 semiconductor vendors worldwide (this varies according to mergers, acquisitions, liquidations, start-ups, and so on) by 56 individual semiconductor product categories (excluding subtotals), 6 application segments, and 5 world regions (Europe is split into a further subregions). This exercise helps Dataquest maintain its dynamic database of semiconductor supply by company, and semiconductor shipments by world region and product. The information gained is supplemented by, and cross-checked with, Dataquest's various other information sources.

The semiconductor market share survey takes place twice each year. The first survey is to prepare preliminary estimates for the calendar year. This is then followed by a second survey of the same companies three months later in order to finalize estimates for the same calendar year. The first survey takes place during October and November. Our preliminary estimates are completed by the end of the calendar year under review, and the results are summarized in a research report (a *Dataquest Perspective* document), which is released on January 1 following the end of the year. Preliminary vendor rankings are featured in a Dataquest press release shortly after this date.

The second survey takes place during March. Our final semiconductor market share estimates are then published in greater depth in a reference report (a *Source: Dataquest* document) by May 31. There is usually minimal difference between preliminary and final rankings, as Dataquest makes every effort to ensure preliminary estimates are as accurate as possible. However, there will be occasions when some company results are revised according to unexpected late billings or order cancellations in the final months of the calendar year being reported.

The categories for which semiconductor revenue is reported are defined comprehensively for the purpose of clarity and guidance to survey participants. These definitions may occasionally be revised, altered or expanded to reflect changes in the industry. To support these definitions, Dataquest will issue an annual survey guide to all participants in its semiconductor market share survey program. This document comprises the 1991 survey guide.

Chapter 2

Semiconductor Companies Surveyed Worldwide 1991

North American Companies

Actel
Advanced Micro Devices
Allegro MicroSystems
Altera
Analog Devices
Appian Technology
Applied Micro Circuits Corporation
AT&T
Atmel
Brooktree
Burr-Brown
California Micro Devices
Catalyst
Cherry Semiconductor
Chips & Technologies
Cirrus Logic
Comlinear
Crystal
Cypress Semiconductor
Dallas Semiconductor
Elantec
Exar
General Instrument
Gennum
Gould AMI
Harris
Hewlett-Packard
Honeywell
Hughes
IMI
Integrated Device Technology
Intel
International CMOS Technology
International Microelectronic Products
International Rectifier
ITT
Kulite
Lattice
Linear Technology
LSI Logic
Maxim
Micro Linear
Micro Power Systems
Microchip Technology
Micron Technology
Microsemi
Mitel
MOSel
Motorola
National Semiconductor
NCR
Novasensor Inc.
Optek
Performance Semiconductor
Powerex
Quality Technologies
Raytheon
Rockwell
SEEQ Technology
Semtech
Sierra Semiconductor
Silicon General
Silicon Systems
Siliconix
Sipex
Solitron
Standard Microsystems
Supertex
Tektronix
Teledyne
Texas Instruments
TRW
Unitrode
Universal
Vitelic
VLSI Technology
VTC
WaferScale Integration
Weitek
Western Digital
Xicor
Xilinx
Zilog

Japanese Companies

Fuji Electric
Fujitsu
Hitachi
Matsushita

Mitsubishi
NEC
New JRC
NMB Semiconductor
Oki
Ricoh
Rohm
Sanken
Sanyo
Seiko Epson
Sharp
Shindengen Electric
Sony
Toko
Toshiba
Yamaha

European Companies

ABB-HAFO
ABB-IXYS
Austria Mikro Systeme
Ericsson
Eupec
European Silicon Structures
Eurosil
Fagor
GEC Plessey
Matra-MHS
MEDL
Mietec
Philips Semiconductors
Semikron
SGS-Thomson
Siemens
STC
TAG
Telefunken Electronic
TMS
Zetex

Asia/Pacific Companies

Daewoo
Goldstar
Hualon Microelectronics Corporation
Hyundai
Korean Electronic Company
MOSpec
Samsung
Silicon Integrated Systems
United Microelectronics
Winbond Electronics

Summary

83 North American Companies
20 Japanese Companies
21 European Companies
10 Asia/Pacific Companies
134 Worldwide Companies

Chapter 3

General Sales Definitions

1. **Sales to customer**. All sales are reported according to customer location, that is, the shipping destination.

2. **Finished semiconductor products**. Defined as assembled and tested semiconductor products. *Only count sales of finished semiconductor products to distributors and equipment manufacturers.* Do not include sales of finished semiconductors to other semiconductor vendors for value-added resale. Resale revenue will be estimated separately for these companies.

3. **Unfinished semiconductor products**. Defined as wafer and die foundry products. *Only count sales of unfinished semiconductor products to distributors and equipment manufacturers.* Do not include sales of unfinished semiconductors to other semiconductor vendors for resale. Resale revenue will be estimated separately for these companies.

4. **Internal semiconductor sales**. Defined as revenue from finished or unfinished semiconductor products from intracompany (internal or in-house) transfers to divisions and subsidiaries of your parent company that manufacture end equipment. *Include all such internal semiconductor sales at market price.*

5. **Hybrid products**. Defined as products that comprise a number of active semiconductor die and/or passive components in a single package. *Only count sales of hybrid products that conform with definition 2 or 3.*

6. **Modules and board-level products**. Defined as products that comprises a number of active semiconductor and/or passive components mounted on a single printed circuit board (PCB). Only count sales of modules and board-level products that conform with definition 2 or 3. *Only include the market value of the active semiconductors in the module or board-level product.*

7. **System-level products**. Defined as products that comprise a number of module and/or board-level products amounting to a single system or subsystem. Examples include development systems, hardware platforms, and box-level products. *Do not include any sales from such system-level products.*

8. **NRE charges**. Defined as nonrecurring engineering charges made to customers as the result of costs incurred during the design or customizing of a semiconductor device for that customer. This occurs in the following product areas:

   - Design charges for ASICs including gate arrays, cell-based ICs, and full-custom ICs.
   - Mask charges that result from the customizing of a programmable array logic (PAL), when the customer's fuse pattern is masked into it to produce a hard-wired array logic (HAL).
   - Mask charges that result from the customizing of ROMs.
   - Mask charges that result from the storage of the customer's microcode in a microcontroller.

   Only count revenue from NRE charges on active semiconductor products that conform with definition 2 or 3. Include these NRE charges as part of the revenue received from associated semiconductor product. Do not include revenue from NRE charges incurred during research, feasibility studies, or facility rental to third parties.

9. **Electronic design automation (EDA) software**. EDA software is used to automate the design of semiconductors. Dataquest includes revenue from ASIC semiconductor vendors that also sell their own EDA software. *Include any revenue derived from EDA software in the appropriate ASIC product category.* The applicable categories are PLD, gate array, and cell-based IC.

10. **IPR income.** Defined as intellectual property rights, income from royalties, licensing agreements, technology transfers, and dispute settlements. *Do not include any such IPR income.*

Chapter 4

Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the 1991 exchange rates provided below. This will prevent inconsistencies in the conversion of offshore sales between each company. These are the exchange rates that will be used in the final 1991 semiconductor market share survey. Exchange rates for historical years are available on request.

Average 1991 Exchange Rates against the U.S. Dollar

Country	1991 Rate	Currency
Austria	11.67	Schillings/$
Belgium	34.13	Belgian Francs/$
Denmark	6.39	Danish Kroner/$
Finland	4.04	Markka/$
France	5.64	French Francs/$
Germany	1.66	Deutsche Marks/$
Ireland	0.62	Pounds/$
Italy	1,238.93	Lire/$
Japan	134.68	Yen/$
Luxembourg	34.13	Luxem. Francs/$
Netherlands	1.87	Gulden/$
Norway	6.49	Norwegian Kroner/$
Portugal	144.02	Escudos/$
South Korea	730.90	Won/$
Spain	103.81	Pesetas/$
Sweden	6.04	Swedish Kronor/$
Switzerland	1.43	Swiss Francs/$
Taiwan	26.50	NT$/$
United Kingdom	0.57	Pounds/$
ECU	0.81	ECU/$

Chapter 5

Semiconductor Product Category Hierarchy

The following semiconductor product category hierarchy begins with **total semiconductor**, and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategories is marked as a "Data Point."

Total Semiconductor:	**IC + Discrete + Optoelectronic**
Total Integrated Circuit:	Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Analog/Mixed-Signal Monolithic IC + Hybrid IC
Bipolar Digital IC:	1. Bipolar Digital TTL/Other IC + Bipolar Digital ECL IC—*technology split* 2. Bipolar Digital Memory IC + Bipolar Digital Microcomponent IC + Bipolar Digital Logic—*function split*
Bipolar Digital TTL/Other IC:	Data Point
Bipolar Digital ECL IC:	Data Point
Bipolar Digital Memory IC:	Data Point
Bipolar Digital Micro IC:	Data Point
Bipolar Digital Logic IC:	Bipolar Digital Application-Specific IC + Bipolar Digital Standard Logic IC + Other Bipolar Digital Logic IC
Bipolar Digital ASIC:	Bipolar Digital Gate Array + Bipolar Digital Programmable Logic Device + Bipolar Digital Cell-Based IC + Bipolar Digital Full-Custom IC
Bipolar Digital GA:	Data Point
Bipolar Digital PLD:	Data Point
Bipolar Digital CBIC:	Data Point
Bipolar Digital FCIC:	Data Point
Bipolar Digital Standard Logic IC:	Data Point
Other Bipolar Digital Logic IC:	Data Point
MOS Digital IC:	1. CMOS Digital IC + BiCMOS Digital IC + NMOS/Other Digital IC—*technology split* 2. MOS Memory IC + MOS Microcomponent IC + MOS Logic IC—*function split*
CMOS Digital IC:	Data Point
BiCMOS Digital IC:	Data Point
NMOS/Other Digital IC:	Data Point

MOS Digital Memory IC:	DRAM + SRAM + EPROM + Other Nonvolatile MOS Digital Memory IC + Other MOS Digital Memory IC
DRAM:	Data Point
SRAM:	Data Point
EPROM:	Data Point
Other NV MOS Memory IC:	Data Point
Other MOS Memory IC:	Data Point
MOS Digital Microcomponent IC:	MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral
MOS Digital MPU:	Data Point
MOS Digital MCU:	Data Point
MOS Digital MPR:	Data Point
MOS Digital Logic IC:	MOS Digital Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic IC
MOS Digital ASIC:	MOS Digital Gate Array + MOS Digital Programmable Logic Device + MOS Digital Cell-Based IC + MOS Digital Full-Custom IC
MOS Digital GA:	Data Point
MOS Digital PLD:	Data Point
MOS Digital CBIC:	Data Point
MOS Digital FCIC:	Data Point
MOS Digital Standard Logic IC:	Data Point
Other MOS Digital Logic IC:	Data Point
Analog IC:	Monolithic Analog IC + Hybrid IC
Monolithic Analog IC:	Linear IC + Mixed-Signal IC
Linear IC:	Amplifier IC + Voltage Regulator IC + Voltage Reference IC + Comparator IC + Special Function IC + Special Consumer IC + Special Automotive IC + Linear Array ASIC
Amplifier IC:	Data Point
Voltage Regulator IC:	Data Point
Voltage Reference IC:	Data Point
Comparator IC:	Data Point
Special Function IC:	Data Point
Special Consumer IC:	Data Point
Special Automotive IC:	Data Point
Linear Array ASIC:	Data Point
Mixed-Signal IC:	Data Converter IC + Telecom IC + Interface IC + Switch/Multiplexer IC + Disk Drive IC + Mixed-Signal ASIC
Data Converter IC:	Data Point
Telecom IC:	Data Point

Interface IC:	Data Point
Switch/Multiplexer IC:	Data Point
Disk Drive IC:	Data Point
Mixed-Signal ASIC:	Data Point
Hybrid IC:	Data Point
Total Discrete:	Transistor + Diode + Thyristor + Other Discrete
Transistor:	Small-Signal Transistor + Power Transistor
Small-Signal Transistor:	Data Point
Power Transistor:	Bipolar Power Transistor + MOS Power Transistor + Power Insulated Gate Bipolar Transistor (IGBT)
Bipolar Power Transistor:	Data Point
MOS Power Transistor:	Data Point
Power IGBT:	Data Point
Diode:	Small-Signal Diode + Power Diode
Small-Signal Diode:	Data Point
Power Diode:	Data Point
Thyristor:	Data Point
Other Discrete:	Data Point
Total Optoelectronic:	LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Solar Cell
LED Lamp/Display:	Data Point
Optocoupler:	Data Point
CCD:	Data Point
Laser Diode:	Data Point
Photosensor:	Data Point
Solar Cell:	Data Point

Chapter 6

Semiconductor Product Category Definitions

The following semiconductor product category definitions begin with **total semiconductor**, and continue through each subcategory in the same order as shown in the preceding semiconductor product category hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are given at every level.

Total Semiconductor:	(IC + Discrete + Optoelectronic.) Defined as an active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide) 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 Monolithic IC + Hybrid 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 die.
Bipolar Digital IC:	1. *technology split*—(TTL/Other Bipolar IC + ECL) 2. *function split*—(Bipolar Digital Memory IC + Bipolar Digital Microcomponent 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.
TTL/Other Bipolar Digital IC:	Defined as a bipolar digital IC manufactured using transistor-transistor logic (TTL) semiconductor technology. Other bipolar technologies include resistor-transistor logic (RTL) and diode-transistor logic (DTL).
ECL IC:	Defined as a bipolar digital IC manufactured using emitter-coupled logic (ECL) semiconductor technology.
Bipolar Digital Memory IC:	Defined as a bipolar digital semiconductor product in which binary data are stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, first-in/first-out (FIFO) memory.

Bipolar Digital Micro IC:	Defined as a bipolar digital semiconductor product 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) processor architectures. Includes bipolar digital microprocessor (MPU), bipolar digital microcontroller (MCU), and bipolar digital microperipheral (MPR), where applicable.
Bipolar Digital Logic IC:	(Bipolar Digital Application-Specific IC + Bipolar Digital Standard Logic IC + Other Bipolar Digital Logic IC.) 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.
Bipolar Digital ASIC:	(Bipolar Digital Gate Array + Bipolar Digital Programmable Logic Device + Bipolar Digital Cell-Based IC + Bipolar Digital Full-Custom IC.) Defined as a single-user bipolar digital logic IC that is manufactured using vendor-supplied tools and/or libraries. Do not include bipolar digital ASICs incorporating microcontroller cells, as these should be reported in the bipolar digital microcontroller IC category.
Bipolar Digital GA:	Bipolar Digital Gate Array is defined as an ASIC device that is customized by the vendor to end-user specification using layers of interconnect. Included in this category are generic or base wafers with embedded functions, for example, SRAM, EEPROM.
Bipolar Digital PLD:	Bipolar Digital Programmable Logic Device is defined as an ASIC device that is customized by the end user after assembly. Included in this category are bipolar field-programmable logic (bipolar FPL), bipolar field programmable gate array (bipolar FPGA), bipolar programmable array logic (bipolar PAL), bipolar programmable logic array (bipolar PLA), bipolar electrically programmable logic device (bipolar EPLD), and bipolar programmable multilevel logic device (bipolar PMD).
Bipolar Digital CBIC:	Bipolar Digital Cell-Based IC is defined as an ASIC device that is produced from a library of standard circuits/cells to a single-user specification. This process involves automatic routing and placement of cells. Included in this definition is bipolar standard cell IC. Excluded from this definition are cell-based ICs with processor cores. These should be reported under bipolar digital microcomponents.
Bipolar Digital FCIC:	Bipolar Digital Full-Custom IC is defined as an ASIC device that is produced for a single user using a full set of masks. This manufacturing process involves manual routing and placement of cells.
Bipolar Digital Standard Logic IC:	Defined as commodity bipolar family logic with less than 150 gates. Sometimes referred to as glue logic. Examples include TTL, ECL and other family logic: TTL-compatible SSI, MSI, LSI; standard, AS, FAST, LS, ALS lines; ECL-compatible SSI, MSI, LSI. Also RTL and DTL.

Other Bipolar Digital Logic IC:	Defined as all other bipolar digital logic ICs not accounted for in the preceding categories. Includes bipolar commodity family logic with 150 or more gates, and bipolar digital general-purpose logic not belonging to any families.
MOS Digital IC:	1. *technology split*—(CMOS + BiCMOS + NMOS/Other) 2. *function split*—(MOS Digital Memory IC + MOS Digital Microcomponent IC + MOS Digital Logic IC) A MOS digital IC is 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 that 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.
CMOS Digital IC:	Defined as a MOS digital IC manufactured entirely in complementary metal oxide semiconductor (CMOS) technology.
BiCMOS Digital IC:	Defined as a MOS digital IC manufactured using bipolar and complementary metal oxide semiconductor (CMOS) technologies.
NMOS/Other Digital IC:	Defined as a MOS digital IC manufactured entirely in N-channel metal oxide semiconductor (NMOS) technology. Other MOS technologies include P-channel metal oxide semiconductor (PMOS).
MOS Digital Memory IC:	(DRAM + SRAM + EPROM + Other Nonvolatile MOS Digital Memory + Other MOS Digital Memory.) Defined as a MOS digital IC in which binary data are stored and electronically retrieved.
DRAM:	Defined as Dynamic RAM, Multiport-DRAM (M-DRAM), and Video-DRAM (V-DRAM). DRAMs have memory cells consisting of a single transistor, and require externally cycled memory cell refreshes on a regular basis. These are volatile memories and addressing is multiplexed.
SRAM:	Defined as Static RAM, Multiport-SRAM (M-SRAM), Battery Backed-Up SRAM (BB-SRAM), and Pseudo SRAM (PSRAM). SRAMs have memory cells consisting of a minimum of four transistors, except PSRAM, which has a memory cell consisting of a single transistor and is similar to DRAM. SRAMs do not require externally cycled memory cell refreshes. These are volatile memories and addressing is not multiplexed (except in the case of PSRAM). Note that color palette DACs are included in the mixed-signal data converter category.
EPROM:	Defined as Erasable Programmable Read-Only Memory. Includes Ultraviolet EPROM (UV EPROM) and One-Time Programmable Read-Only Memory (OTP ROM). EPROMs have memory cells consisting of a single transistor, and do not require any memory cell refreshes. These are nonvolatile memories.
Other NV MOS Memory IC:	Includes EEPROM, flash memory, and mask ROM. These are all nonvolatile memories.

EEPROM is defined as Electrically Erasable Programmable Read-Only Memory. Includes Serial EEPROM (S-EEPROM), Parallel EEPROM (P-EEPROM), and Electrically Alterable Read-Only Memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors, and do not require memory cell refreshes. Includes Nonvolatile RAM (NVRAM), also known as Shadow RAM. These semiconductor products are a combination of an SRAM and a P-EEPROM in each memory cell. The P-EEPROM functions as a shadow backup for the SRAM when power is lost.

Flash memory is defined as rapidly electrically erasable nonvolatile memory. Includes flash memory based on an EPROM cell structure (that is, single transistor) and flash memory based on an EEPROM cell structure (that is, minimum of two transistors), and does not require memory cell refreshes. Includes flash memory based on single- or dual-voltage supply. Mask ROM is defined as Mask-Programmable Read-Only Memory. Specifically, a form of memory that is programmed by the manufacturer to a user specification using a mask step. Mask ROM is programmed in hardware rather than software.

Other MOS Digital Memory IC: Defined as all other MOS digital memory not already accounted for in the preceding categories. Includes MOS digital content addressable memory (CAM), MOS digital cache-tag RAM, MOS digital first-in/first-out memory (FIFO), MOS digital last-in/first-out (LIFO) memory, ferroelectric memory.

MOS Digital Microcomponent IC: (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral.) 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) processor architectures.

MOS Digital MPU: Defined as a MOS Digital Microprocessor. A semiconductor product serving as the central processing unit (CPU) of a system. Consists of an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. An MPU performs general-purpose computing functions by executing external instructions and manipulating data held in external memory. Includes MOS digital MPUs incorporating or developed from an ASIC design.

MOS Digital MCU: Defined as a MOS Digital Microcontroller. A semiconductor product serving as a dedicated, or embedded controller in a system. Consists of an integral MPU, some nonvolatile memory containing end-user-specified instructions, and some volatile memory for temporary storage of code or data. An MCU can perform basic computing functions without support form microperipheral (MPR) products. This category also contains members of microcontroller product families that have had the on-chip nonvolatile memory removed and instead, access the end-user program contained in external nonvolatile memory. Includes MOS digital MCUs performing a standalone digital signal processing (DSP) function. Includes MOS digital MCUs incorporating or developed from an ASIC design.

MOS Digital MPR:	Defined as a MOS Digital Microperipheral. A semiconductor product serving as a logical support function to an MPU or MCU in a system. An MPR provides enhancement of system performance and/or interface with external systems. Includes MOS digital MPRs comprising more than one device, such as PC chip sets. Examples of a MOS digital MPR include: timer, interrupt control, DMA, MMU, peripheral controllers (for example, disk, graphics display, CRT, keyboard controllers), communications controllers (for example, UART), chip sets for microprocessor support, LAN coprocessors, accelerator coprocessors (for example, floating-point unit, graphics coprocessor, image processor).
MOS Digital Logic IC:	(MOS Digital Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital 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.
MOS Digital ASIC:	(MOS Digital Gate Array + MOS Digital Programmable Logic Device + MOS Digital Cell-Based IC + MOS Digital Full-Custom IC.) Defined as a single-user logic IC that is manufactured using vendor-supplied tools and/or libraries. Do not include ASICs incorporating microcontroller cells that should be included in microcontroller revenue.
MOS Digital GA:	MOS Digital Gate Array is defined as an ASIC device that is customized by the vendor to end-user specification using layers of interconnect. Included in this category are generic or base wafers with embedded functions, for example, SRAM, EEPROM.
MOS Digital PLD:	MOS Digital Programmable Logic Device is defined as an ASIC device that is customized by the end user after assembly. Included in this category are MOS field-programmable logic (MOS FPL), MOS field-programmable gate array (MOS FPGA), MOS programmable array logic (MOS PAL), MOS programmable logic array (MOS PLA), MOS electrically programmable logic device (MOS EPLD), and MOS programmable multilevel logic device (MOS PMD).
MOS Digital CBIC:	MOS Digital Cell-Based IC is defined as an ASIC device that is produced from a library of standard circuits/cells to a single-user specification. This process involves automatic routing and placement of cells. Included in this definition is MOS standard cell IC. Excluded from this definition are cell-based ICs with processor cores. These should be reported under MOS digital microcomponent.
MOS Digital FCIC:	MOS Digital Full-Custom IC is defined as an ASIC device that is produced for a single user using a full set of masks. This process involves manual routing and placement of cells.
MOS Digital Standard Logic IC:	Defined as commodity MOS family logic with less than 150 gates. Sometimes referred to as glue logic. Examples include: HC, HCT, AC, ACT, FACT, and 74BC BiCMOS family logic.

Other MOS Digital Logic IC:	Defined as all other MOS digital logic ICs not accounted for in the preceding categories. Includes MOS commodity family logic with 150 or more gates, and MOS digital general-purpose logic not belonging to any families.
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 a semiconductor product that consists 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. Note that hybrid digital ICs are reported in this category, and not under the earlier category of monolithic digital ICs. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.
Monolithic Analog IC:	(Monolithic Linear IC + Monolithic Mixed-Signal IC.) Monolithic linear IC is defined as an analog device that has only analog I/O, therefore its characteristics are inherently linear. Monolithic mixed-signal IC is defined as an analog device that has both analog and digital I/O (see mixed-signal IC definition).
Monolithic Linear IC:	(Amplifier IC + Voltage Regulator IC + Voltage Reference IC + Comparator IC + Special Function IC + Special Consumer IC + Special Automotive IC + Linear Array ASIC.) Defined as an analog device that has 100 percent analog I/O.
Amplifier IC:	Defined as a general-purpose linear IC that provides a voltage or current gain to an input signal. Includes operational amplifiers (mono, dual, quad, and so on), instrumentation amplifiers, buffer amplifiers, and power amplifiers. Consumer-dedicated amplifier ICs are counted in special consumer IC. Amplifier ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in analog/mixed-signal ASIC.
Voltage Regulator IC:	Defined as a general-purpose linear IC that outputs a variable current at a regulated DC voltage to other circuits from a variable current and voltage input. Regulator ICs are either linear regulators in which the device provides an input-to-output voltage drop, or switching regulators, in which the device provides switched quantities of power to a smoothing circuit to gain higher efficiency and reduce power dissipation.
Voltage Reference IC:	Defined as a general-purpose linear IC that outputs a precise reference voltage to other circuits from a variable voltage input. A reference IC differs from a regulator IC in that it is not expected to power other circuits. In fact, voltage regulator ICs incorporate a voltage reference circuit.

Comparator IC:	Defined as a general-purpose linear IC that compares two analog signal inputs and provides a single logic bit output. Although the output could be considered digital, these products are classed as linear ICs because they are specialty high-gain amplifiers, used in an open loop mode, and for which the output is constrained to only two states. By using a comparator, an unknown voltage can be compared with a known reference voltage.
Special Function IC:	Defined as either general-purpose linear ICs that do not fit into the other categories, or market/application-specific linear ICs for which a category does not yet exist. The main products that fall into this category include timers, phase-locked loops (PLLs), voltage-controlled oscillators (VCOs), signal/function generator ICs, and analog multipliers. Disk-drive analog ICs should be reported in their dedicated category under mixed-signal analog.
Special Consumer IC:	Defined as a general-purpose linear IC that is dedicated to general consumer applications, but is not application-specific. Includes analog ICs implemented in audio, video, radio, speech synthesis and recognition, electronic games, personal and home appliances, and electronic cameras. Consumer ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC or mixed-signal ASIC.
Special Automotive IC:	Defined as a linear IC that is used in the following applications: entertainment, engine control, safety, traction, and in-car electrical and suspension systems.
Linear Array ASIC:	Defined as a single-user linear IC that is manufactured using vendor-supplied tools and/or libraries. Linear arrays fall into one of three types, as follows: 1. Arrays of discrete-level cells such as transistors, diodes, and transistors 2. Arrays of discrete device combinations referred to as tiles 3. Arrays of higher-level functional macro cells such as operational amplifiers, comparators, VCOs, references, and other analog functions. These arrays are interconnected with a metal mask or by means of some user-programmable interconnect scheme. Unlike cell-based designs, they do not have a unique set of masks for all layers.
Mixed-Signal IC:	(Data Converter IC + Telecom IC + Interface IC + Switch/Multiplexer IC + Disk Drive IC + Mixed-Signal ASIC.) Defined as an analog IC that carries information in both digital (numeric) and signal/power forms. An IC is considered mixed-signal if it has both analog I/O and digital I/O pins. This definition is not based on the comparative size of the IC's analog and digital circuitry. It is a definition based on external pin functionality. ICs that are mainly digital but have some nominal analog housekeeping functions such as voltage monitors, power-on reset, or clock oscillators are not considered to be mixed-signal because there is no analog signal being received by or sent from the active component.

Data Converter IC:	Defined as a general-purpose mixed-signal IC that converts an analog signal into a digital signal, or vice versa. Includes analog-to-digital converters (ADCs), digital-to-analog convertors (DACs), comparators, sample-and-hold circuits (SHCs), voltage-to-frequency circuits (VFCs), frequency-to-voltage circuits (FVCs), synchro-to-digital circuits (SDCs), and digital-to-synchro circuits (DSCs). All these are general-purpose data convertor ICs. *Also included in this category are color-palette DACs.* Consumer-dedicated data converter ICs are counted in special consumer IC. Data converter ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in analog/mixed-signal ASIC.
Telecom IC:	Defined as a general-purpose mixed-signal IC used for voice band communication or data communication over voice band media. This category includes CODECs, combos and SLACs, SLICs, modem and fax/modem ICs, dialler and ringer ICs, repeaters, cellular communications ICs, ISDN ICs, telecom filter ICs, and other telecom-specific circuits. Telecoms ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC or mixed-signal ASIC.
Interface IC:	Defined as a general-purpose mixed-signal IC that serves as an interface between a digital system and other external nonsemiconductor systems. Includes line drivers, peripherals drivers, display drivers, keyboard encoders, receivers, transmitters, and transceivers. Consumer-dedicated interface ICs are counted in special consumer ICs. Interface ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC or mixed-signal ASIC.
Switch/Multiplexer IC:	Defined as a mixed-signal IC that digitally controls analog transmission gates. These products connect or disconnect the analog signal path in analog circuits. Analog switches operate in a mode where each switch is operated independently by a single logic bit. Multiplexers are multiple analog switches that are connected in a dependent manner, where only one signal path is connected through to the output depending on the state of a digital address word (greater than one bit). Thus, analog multiplexers are really addressable signal selector switches that select one-out-of-many signals for further analog processing. Because these addressable analog switches were the key element in time-division multiplexing, the term "multiplexer" has remained. They are an important part of the data conversion product family in that they are used to provide time-division multiplexing of signal inputs to a fast analog-to-digital converter.
Disk Drive IC:	Defined as a mixed-signal IC that is designed specifically for the rotating mass storage market. Applications include the read/write path from preamp up to the ENDEC, head positioning controller, and spindle motor control.
Mixed-Signal ASIC:	Defined as a mixed-signal analog IC that is manufactured for a single user, using vendor-supplied tools and/or libraries.

Hybrid IC:	Defined as a semiconductor product consisting of more than one die contained in a single package. May perform digital, analog, or mixed-signal functions. May be manufactured using bipolar, MOS, or BiCMOS technology. Includes hybrid implementation of all monolithic IC functions described in the preceding categories.
Total Discrete:	(Transistor + Diode + Thyristor + Other Discrete.) A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.
Transistor:	(Small-Signal Transistor + Power Transistor)
Small-Signal Transistor:	Defined as signal transistors, RF microwave transistors, dual transistors, MOS field-effect transistors (MOS-FETs), conductivity modulated field-effect transistors (COMFETs), insulated gate bipolar transistors (IGBTs), and MOS-bipolar transistors (MBTs). All rated below 1W power dissipation, 1A current rating, or 100V operating voltage.
Power Transistor:	(Bipolar Power Transistor + MOS Power Transistor + Power IGBT.) All rated 1W power dissipation and above, 1A current rating and above, or 100V operating voltage and above.
Bipolar Power Transistor:	Defined as bipolar Darlington transistor, bipolar microwave transistor, bipolar radio frequency (RF) transistor.
MOS Power Transistor:	Defined as MOS field-effect transistor (MOS-FET), MOS Darlington transistor, MOS microwave transistor, MOS radio frequency (RF) transistor.
IGBT Power Transistor:	Defined as insulated gate bipolar transistor (IGBT). Also includes conductivity modulated field-effect transistor (COMFET), MOS-bipolar transistor (MBT), and GEMFET.
Diode:	(Small-Signal Diode + Power Diode)
Small-Signal Diode:	Defined as signal diodes, Schottky diodes, zener diodes, switching diodes, voltage reference diodes, voltage regulator diodes, and rectifier diodes. All rated below 0.1A.
Power Diodes:	Defined as zener diodes and rectifier diodes. All rated 0.1A and above.
Thyristor:	Defined as thyristors, silicon-controlled rectifiers (SCRs), diacs, and triacs. Also includes solid-state relays (SSRs) incorporating triacs, thyristors, resistors, and capacitors.
Other Discrete:	Defined as all other discrete semiconductor products not accounted for in the preceding categories. Includes microwave diodes, varactors, tuning diodes, tunnel effect diodes, and selenium rectifiers.

Total Optoelectronic:	(LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Solar Cell.) 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.
LED Lamp/Display:	LED Lamp + LED Display. An LED lamp is defined as a light-emitting diode: a semiconductor product consisting of a single die in which photons are emitted at frequencies dependent upon the semiconductor material employed. An LED display is defined as an array of LEDs: a semiconductor product consisting of more than one die in which photons are emitted at frequencies dependent upon the semiconductor material employed.
Optocoupler:	Defined as an optocoupler or optoisolator. A semiconductor product consisting of an LED separated from a photosensor by a transparent, insulating, dielectric layer. These are mounted inside an opaque package. Includes optointerrupters, in which the separation between LED and photosensor is large enough to allow external physical systems to influence the device.
CCD:	Defined as a charge-coupled device. A semiconductor product consisting of an array of photodiodes, an analog CCD shift register, and an output circuit. Includes linear array CCDs with serial shift registers and area array CCDs with parallel shift registers. Includes charge injection device (CID), charge-coupled photodiode (CCP), charge-priming device (CPD), self-scanning photodiode (SSP).
Laser Diode:	Defined as a diode that produces coherent light. A semiconductor product in which the heterojunction structure stimulates light amplification by stimulated emission of radiation (laser), resulting in coherent light. Includes Fabrey-Perot laser diodes, pulsed laser diodes, and phase-shifted laser diodes.
Photosensor:	Photodiode + Phototransistor. Defined as a diode or transistor in which photons are used to affect current flow.
Solar Cell:	Defined as photovoltaic or solar cells. A semiconductor device in which photons are used to generate current flow.

Chapter 7

Worldwide Geographical Region Definitions

North America

Includes *United States* (50 states: Illinois, Indiana, Michigan, Ohio, Wisconsin, Alabama, Kentucky, Mississippi, Tennessee, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, New Jersey, New York, Pennsylvania, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Alaska, California, Hawaii, Oregon, Washington, Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Arkansas, Louisiana, Oklahoma, Texas), Puerto Rico, and *Canada* (12 provinces: Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Labrador, Northwest Territories).

Japan

Includes Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shihoku, and Kyushu.

Europe

Includes *Benelux* (Belgium, Netherlands, Luxembourg), *France, Italy, Scandinavia* (Denmark, Finland, Norway, Sweden, Iceland), *United Kingdom and Eire* (England, Wales, Scotland, Northern Ireland, Republic of Ireland), *Germany* (including former east Germany), and *Rest of Europe* (Austria, Gibraltar, Greece, Liechtenstein, Malta, Monaco, Portugal, San Marino, Spain, Switzerland, Turkey, Andorra, Vatican City).

Asia/Pacific

Includes *East Asia* (China, Hong Kong, Macau, North and South Korea, Taiwan), *South Asia* (Bangladesh, Myanmar, India, Nepal, Maldives, Pakistan, Sri Lanka, Bhutan), *Southeast Asia* (Brunei, Timor, Indonesia, Kampuchea, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Borneo, Sumatra, Sulawesi, Java).

Rest of World

Includes Mexico, Arctic, Antarctica, Greenland, St. Pierre and Miquelon, *Australia, New Zealand* (North Island, South Island, Stewart Island), Tasmania, Christmas Island, Cocos Islands, New Zealand, Norfolk Island, *Oceania* (American Samoa, Canton and Enderbury Islands, Fiji, French Polynesia, Guam, Johnson Island, Kiribati, Midway Islands, Nauru, New Caledonia, Niue, Pacific Islands, Papua New Guinea, Pitcairn, Samoa, Solomon Islands, Toelau, Tonga, Tuvalu, Vanuatu, Wake Island, Wallis and Futuna Islands, New Britain, New Ireland, Admiralty Islands), *Africa* (Algeria, Libya, Egypt, Morocco, Mauritania, Mali, Senegal, Guinea, Sierra Leone, Liberia, Ghana, Ivory Coast, Togo, Benin, Nigeria, Niger, Chad, Sudan, Ethiopia, Central African Republic, Somalia, Zimbabwe, Uganda, Gabon, Cameroon, Congo, Zaire, Tanzania, Zambia, Malawi, Kenya, Cabinda, Namibia, Botswana, Mozambique, Rwanda, Burundi, South Africa, Swaziland, Benin, Equatorial Guinea, Burkina Faso, Djibouti, Lesotho, Ciskei, Transkei, Bophuthatswana, Venda), Madagascar, Mauritius, Comores, Réunion, *Central America* (Nicaragua, Panama, Guatemala, El Salvador, Belize, Honduras, Granada, Costa Rica), *South America* (Brazil, Chile, Uruguay, Paraguay, Argentina, Colombia, Peru, Bolivia, Venezuela, Guyana, Surinam, French Guiana, Equador, Falkland Islands), *Caribbean Islands* (Cuba, Jamaica, Haiti, Dominican Republic, Anguilla, Montserrat, Trinidad, Tobago, Dominica, Guadeloupe, Saint Lucia, Barbados, Martinique, Grenadine Islands, Bermuda, Bahamas, New Providence, Saint Vincent and The Grenadines, Saint Croix, Antilles), *Eastern Europe* (Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Yugoslavia, Romania, Estonia, Latvia, Ukraine, Belorussia, Lithuania, Latvia, Georgia), *Commonwealth of Independent States* (formerly USSR: Russian Federation, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kirghizia, Turkmenistan), *Inner Asia* (Afghanistan, Bhutan, Mongolia, Pakistan), *Middle East* (Bahrain, Cyprus, Democratic Yemen, People's Republic of Yemen, Egypt, Gaza Strip, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, United Arab Emirates, Syria).

Chapter 8

Semiconductor Application Segment Definitions

Data Processing

Defined as computer systems, terminals, smart cards, data storage devices, input/output devices, and dedicated systems:

- *Computer systems* includes supercomputers, mainframe computers, superminicomputers, minicomputers, microcomputers, workstations, personal computers.
- *Data storage devices* includes flexible/removable disk drives, fixed/rigid disk drives, optical disk drives, tape drives (streamers).
- *Terminals* includes alphanumeric terminals, graphics terminals, point-of-sales terminals, funds transfer terminals.
- *Smart cards* includes credit cards or credit card-size devices with one or more integrated circuits such as token cards, entry key cards, bank cards, medical cards, computer peripheral cards.
- *Input/output devices* includes dot matrix printers, thermal printers, ink jet printers, fully formed printers, page printers, other input/output devices such as monitors, key-entry equipment, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, voice recognition/synthesizer computer equipment, mice, keyboards, digitizers.
- *Dedicated systems* includes office equipment such as copiers, duplicators, full-color copiers, electronic calculators, dictating/transcribing equipment, electronic typewriters, word processors, banking systems and cash registers, mailing/letter-handling/addressing equipment.

Communication

Defined as premise telecom equipment, public telecom equipment, radio, and broadcast and studio:

- *Premise telecom equipment* includes image and text communication such as facsimile, video conferencing, telex, videotex, CCTV; data communications equipment such as modems, statistical multiplexers, time-division multiplexers, local area networks (LANs), private packet data switching; PBX/key telephone systems; call processing equipment such as answering machines, attendant consoles, automatic call distributors (ACDs), voice response units (VRUs), voice terminals, voice messaging systems, call management systems; desktop terminal equipment such as standard telephones, cordless telephones, cellular telephones, video telephones, answering machines.
- *Public telecom equipment* includes transmission equipment, central office switching, public packet switching, and mobile communication such as mobile radio base stations, pagers, base stations.
- *Radio* includes communications equipment transmitting and receiving sound through the use of electronic waves/signals.
- *Broadcast and studio* includes all electronic equipment used to make information public by means of radio and television.

Consumer Appliances

Defined as audio equipment, video equipment, personal electronics, and electronic/electrical:

- *Audio equipment* includes compact disc players, radio combinations, stereo hi-fi components: amplifiers, preamplifiers, tuners, cassette decks, graphic equalizers, turntables, speakers, and equipment used in studio, broadcast, and home environments (equipment that interprets frequencies corresponding to audible sound waves), musical instruments.
- *Video equipment* includes video cameras, video camcorders, videocassette recorders, videotape recorders, color televisions, black-and-white televisions.
- *Personal electronics* includes watches, clocks.
- *Electronic/electrical appliances* includes air conditioners, microwave ovens, washers and dryers, refrigerators/freezers, dishwashers, ranges, ovens.

Industrial

Defined as security/alarm management, manufacturing systems, test equipment, process control equipment, robot systems, automated material handling, instrumentation, medical equipment, vending machines, laser equipment, power supply, traffic control, industrial and scientific research equipment, and other industrial electronic equipment such as vending machines, laser systems, teaching machines, and aids.

Military and Civil Aerospace

Defined as *military electronic equipment* and *civil aerospace*. This includes radar, military/civil sonar, missile weapon, space military equipment, military/civil navigation, communication, electronic warfare, reconnaissance, aircraft systems, military computer systems, military simulation and training, miscellaneous military equipment, civilian space, civil aircraft flight systems, and miscellaneous avionic equipment.

Transportation

Defined as in-car entertainment systems, body control electronics, driver information, powertrain, and safety and convenience electronics:

- *In-car entertainment* includes FM/AM radio, cassette, compact disc player, radio cassette combination systems, two-way radio communications systems, CB radio.
- *Body control electronics* includes vehicle controls such as four-wheel steering control, 2WD/4WD control, multiplex systems such as driver's door, auto-climate control, door locks, windshield wipers, heated rear windows, memory seats, remote security systems, steering wheel, other multiplex systems; lighting controls including automatic headlight systems, timers, reminders, sequential signal controls, other lighting controls; other body electronics including aerodynamic aid control, power roof/window controls, other body electronics.
- *Driver information* includes 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.
- *Powertrain* controls include engine management systems, powertrain sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, and wheel speed sensors.
- *Safety and convenience* includes air purifier systems, airbag control systems, antilock braking systems (ABS), active suspension, collision avoidance systems, collision warning systems, cruise control, suspension control and traction control; and other safety and convenience systems.

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: 01 (408) 437-8000
Telex: 171973
Fax: 01 (408) 437-0292
Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: 01 (508) 370-5555
Fax: 01 (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: 01 (714) 957-0171
Fax: 01 (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61 (2) 959-4544
Fax: 61 (2) 929-0635

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 44 (895) 835050
Fax: 44 (895) 835260/1

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33 (1) 48 97 31 00
Telex: 233 263
Fax: 33 (1) 48 97 34 00

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 49 (89) 93 09 09 0
Fax: 49 (89) 930 3277

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49 6173/61685
Fax: 49 6173/67901

Dataquest Hong Kong
Rm. 401. Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: (852) 8387336
Fax: (852) 5722375

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo, 104
Japan
Phone: 81 (3) 5566-0411
Fax: 81 (3) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: 82 (2) 556-4166
Fax: 82 (2) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65 4597181
Telex: 38257
Fax: 65 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886 (2) 501-7960
886 (2) 501-5592
Fax: 886 (2) 505-4265

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Electronic Equipment

MarketTrends

Semiconductor Application Markets *Worldwide*

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Table of Contents

List of Figures

List of Tables

List of Tables (Continued)

List of Tables (Continued)

Chapter 1
Introduction

This document contains detailed information on Dataquest's view of the electronic equipment markets.

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. Readers should note that some columns in the tables may not add to totals shown because of rounding.

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 semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for market comparisons. In the forecast period, Dataquest assumes that the most recent actual month's exchange rate will apply throughout all months of the forecast. For example, the current semiconductor forecast uses actual exchange rates through June 1992, and assumes that the June rate applies throughout all future months. Then the quarterly and annual exchange rates are estimated as described in the previous paragraph.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* 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 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 *Dataquest Research and Forecast Methodology* document located in the Source: Dataquest binder. For a complete listing of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

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
  - Terminals
  - Input/Output Devices
  - Dedicated Systems
- Communications
  - Premise Telecom
  - Public Telecom
  - Mobile Communication
  - Broadcast and Studio Equipment
  - Other Communication
- 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. 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.*

Electronic systems groups are comprised of the following specific electronic equipment types.

Computer Systems: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers).

Data Storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.

Terminals: Includes alphanumeric terminals and graphics terminals (for example, X terminals)

Input/Output Devices: Includes printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, voice recognition/synthesizer equipment, mouse, keyboard, and digitizers.

Dedicated Systems: Includes electronic copiers, electronic calculators, smart 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.

Premise Telecom Equipment: Includes image and text communication, such as facsimile and video teleconferencing; data communications equipment such as modems, statistical multiplexers, T-1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area networks, internetworking, network management, and packet data switching/wide area networks; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, call accounting, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay 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, mobile radios, and mobile radio base station equipment; 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 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.

Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems, and energy management systems.

Manufacturing Systems and Instrumentation: Includes semiconductor production equipment, controllers and actuators, sensor systems, management systems, and robotics; and semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and waveform analyzers, nuclear instruments, and other test and measurement equipment.

Medical Equipment: Includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analyzers, patient monitoring equipment, and other diagnostic and therapeutic equipment.

Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

(Consumer) Audio Equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.

(Consumer) Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, and color and monochrome TVs.

Personal Electronics: Includes electronic games and toys, 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: Includes military electronics, such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, computer systems, simulation systems, and military electronics not elsewhere classified; and civilian aerospace electronics, such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

Transportation Electronics: Includes entertainment systems, vehicle controls, body controls, driver information systems, powertrain systems, and safety and convenience systems.

Regional Definitions

North America: Includes United States and Canada (and, in future documents, Mexico)

United States: Includes 48 contiguous states, Washington, D.C., Alaska, Hawaii, and Puerto Rico

Canada: Canada

Europe: Western Europe includes Benelux (Belgium, Netherlands, and Luxembourg), France, Italy, Scandinavia (Denmark, Finland, Norway, Sweden, and Iceland), United Kingdom and Eire (England, Wales, Scotland, Northern Ireland, and Ireland), Germany (including former East Germany), and Rest of Europe (Austria, Gibraltar, Greece, Liechtenstein, Malta, Monaco, Portugal, San Marino, Spain, Switzerland, Turkey, Andorra, and Vatican City)

Japan:. Japan

Asia/Pacific: Includes East Asia (People's Republic of China, Hong Kong, Macau, North and South Korea, and Republic of China), South Asia (Bangladesh, Myanmar, India, Nepal, Maldives, Pakistan, Sri Lanka, and Bhutan), Southeast Asia (Brunei, Timor, Indonesia, Kampuchea, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Borneo, Sumatra, Sulawesi, and Java)

Rest of World: All other countries

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 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 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 association data
- 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 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 and Forecast Methodology Guide.*

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. 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 trend 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 are, in general, comprised of 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 judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Forecast Assumptions

The worldwide economy is expected to show mixed results in 1992. The Dun & Bradstreet Corporation forecasts the following outlook for the Group of Seven (G7) Countries:

- The U.S., Canadian, and U.K. economies are expected to recover from the recession in 1992. Real gross domestic product (GDP) is expected to expand 2.1, 1.6, and 0.5 percent, respectively, in 1992. (These economies contracted at rates of 0.7, 1.5, and 2.4 percent, respectively, in 1991.) Though modest in comparison to historical rates of expansion during recovery periods, the benefit is that inflationary pressures will likely be held in check, sustaining the expansion's duration. Expansion should accelerate to 2.5, 4.0, and 2.2 percent, respectively, in 1993.
- Real GDP growth is expected to accelerate in France and Italy during 1991, from 0.9 percent in 1991 to 2.1 percent and from 1.4 percent in 1991 to 1.5 percent, respectively. The pace of growth should pick up in 1993 to 2.7 and 2.2 percent, respectively.
- Real GDP growth is expected to decelerate in Germany and Japan during 1992, from 3.2 percent in 1991 to 1.1 percent and from 4.4 percent in 1991 to 2.0 percent, respectively. Moderating these countries' short-term growth prospects are the cost burden of Germany's reunification and the rise in Japan's cost of capital and recent bout with asset deflation. The respective economies are expected to reaccelerate to 2.8 percent and 3.3 percent growth in 1993.

Overall, worldwide electronic systems production is expected to expand 3.1 percent in 1992, slightly faster than the 2.4 percent rate of growth in 1991. Expansion is expected to accelerate further in 1993 to 7.6 percent as the worldwide economic climate improves. In 1992, however, the value of worldwide production will be constrained by two important influences:

- A moderate—in contrast to booming—rate of recovery from recession
- An abundance of productive capacity, combined with further proliferation of product and technology standards, both placing pressure on costs and prices

From a semiconductor application-market perspective, the forecast carries assumptions detailed in the following paragraphs.

Data processing production will begin to make a moderate 2.6 percent recovery in 1992, after a depressing 2.2 percent decline in 1991. In

North America, recovery will continue into 1993 as economic conditions continue to improve and stabilize. Japanese production will remain hemmed in for the remainder of 1992, as business and households adjust downward their spending plans in response to the lackluster business climate. The year 1993 and beyond should, however, find Japan back on the path of normal growth. Local content regulations are spurring the placement of production facilities in Europe, helping explain the boost of growth in 1993. Once facilities are in place, though, growth is expected to assume a more sustainable pace. Asia/Pacific-ROW production prospects remain upbeat as it increasingly becomes the region of choice for mass manufacturing of established technologies.

Communications production growth—the most stable-growing of the application markets, owing to its heterogeneous composition of personal wireless communications, premise voice, and data products, and large-scale, long-life investment in public telecommunications infrastructure—will decelerate slightly in 1992 to 6.1 percent from 7.3 percent in 1991. Investment in networking the existing stock of data processing equipment will help drive communications hardware growth through 1996.

As is usually the case, production of industrial and consumer equipment have borne the brunt of the recent downturn in business conditions, especially in North America and Japan. Europe and A/P-ROW have been somewhat insulated from the recent cycle, owing to foreign investment spurred by local production factors and cost of production advantages, respectively. In North America and Japan, though, these application markets are forecast to rebound in 1993, with the expected relaxation of business and household budget constraints.

Military/civil aerospace electronics production was hit hard by Washington, D.C. budget cuts in 1991, declining 5.5 percent worldwide. Few positive opportunities remain for all but the most specialized niche players participating in simulation systems, dedicated military computer systems, and civil-space projects. Civil aerospace electronics production will remain the bright spot in this application market, fueled by replacement of aging jet airliners and upgrades of the worldwide air traffic control system.

Transportation electronics production growth is expected to accelerate from 4.8 percent growth in 1991 to 6.0 percent in 1992, and to 10.2 percent in 1993. Production was hurt by the recession, but growth prospects are relatively upbeat because of increased household spending, combined with increasing share of electronic systems' added value to new vehicles.

Tables 1-1 and 1-2 provide a top-level forecast of worldwide electronics equipment production by geographic area.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. The following outlines these rates for 1991:

Japan (Yen/U.S.$)	136.00
Europe (ECU/U.S.$)	0.81
France (Franc/U.S.$)	5.64
Germany (Deutsche Mark/U.S.$)	1.66
United Kingdom (U.S.$/Pound Sterling)	1.77

Project analyst: Gregory Sheppard

Table 1-1
Worldwide Electronic Equipment Production, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
North America			
Data Processing	77,501	81,234	73,691
Communication	28,360	29,935	31,832
Industrial	32,302	33,687	33,909
Consumer	17,082	16,995	16,660
Military/Aerospace	59,876	60,569	55,257
Transportation	4,153	4,115	3,881
Total	219,274	226,535	215,230
Japan			
Data Processing	47,941	46,771	51,342
Communication	19,752	21,337	22,926
Industrial	24,861	26,412	28,719
Consumer	52,474	54,439	61,773
Military/Aerospace	1,825	1,602	1,583
Transportation	9,199	9,469	9,931
Total	156,052	160,031	176,275
Europe			
Data Processing	31,242	33,575	30,392
Communication	27,436	32,734	35,102
Industrial	31,111	35,981	36,356
Consumer	30,777	32,241	33,817
Military/Aerospace	21,749	20,976	21,171
Transportation	4,613	5,556	6,064
Total	146,928	161,063	162,902
Asia/Pacific-ROW			
Data Processing	24,954	27,356	30,826
Communication	8,944	10,455	11,480
Industrial	2,666	3,059	3,530
Consumer	23,893	27,773	32,204
Military/Aerospace	3,281	3,583	3,907
Transportation	1,625	1,852	2,124
Total	65,363	74,078	86,228
Worldwide			
Data Processing	181,638	188,936	188,409
Communication	84,492	94,461	101,340
Industrial	90,940	99,139	102,514
Consumer	124,226	131,448	144,454
Military/Aerospace	86,731	86,730	81,918
Transportation	19,590	20,992	22,000
Total	587,617	621,707	640,635
Exchange Rates:			
Yen/U.S.$	138	144	136
ECU/U.S.$	0.908	0.788	0.811

Source: Dataquest (October 1992)

Table 1-2
Worldwide Electronic Equipment Production, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
North America					
Data Processing	75,861	78,258	82,433	85,554	90,265
Communication	34,037	36,375	38,882	41,470	43,888
Industrial	35,483	37,959	40,548	43,396	46,479
Consumer	17,312	18,216	19,161	20,155	21,127
Military/ Aerospace	54,937	56,068	57,463	58,924	60,132
Transportation	4,252	4,694	4,996	5,265	5,516
Total	221,882	231,570	243,483	254,764	267,407
Japan					
Data Processing	51,246	53,581	55,827	57,762	60,510
Communication	23,298	24,536	25,748	26,898	28,311
Industrial	27,646	29,848	32,270	34,591	37,357
Consumer	59,633	63,750	66,275	69,059	72,849
Military/ Aerospace	1,567	1,603	1,595	1,612	1,635
Transportation	9,935	10,533	11,018	11,411	11,854
Total	173,325	183,849	192,732	201,334	212,516
Europe					
Data Processing	31,850	34,733	36,713	38,879	41,282
Communication	36,956	40,440	42,355	46,427	48,484
Industrial	37,756	40,878	43,382	45,335	47,593
Consumer	35,706	39,237	42,346	44,706	47,959
Military/ Aerospace	21,544	22,893	23,851	24,531	25,266
Transportation	6,681	7,610	8,348	9,214	10,169
Total	170,493	185,791	196,995	209,092	220,753
Asia/Pacific-ROW					
Data Processing	37,798	41,691	46,089	51,230	57,075
Communication	13,224	15,543	17,627	20,035	22,772
Industrial	4,017	4,434	4,987	5,373	6,057
Consumer	36,567	42,600	47,923	53,634	60,041
Military/ Aerospace	4,318	5,000	5,507	5,989	6,482
Transportation	2,451	2,856	3,296	3,780	4,186
Total	98,375	112,124	125,429	140,041	156,613

(Continued)

Table 1-2 (Continued)
Worldwide Electronic Equipment Production, 1992-1996
(Millions of U.S. Dollars)

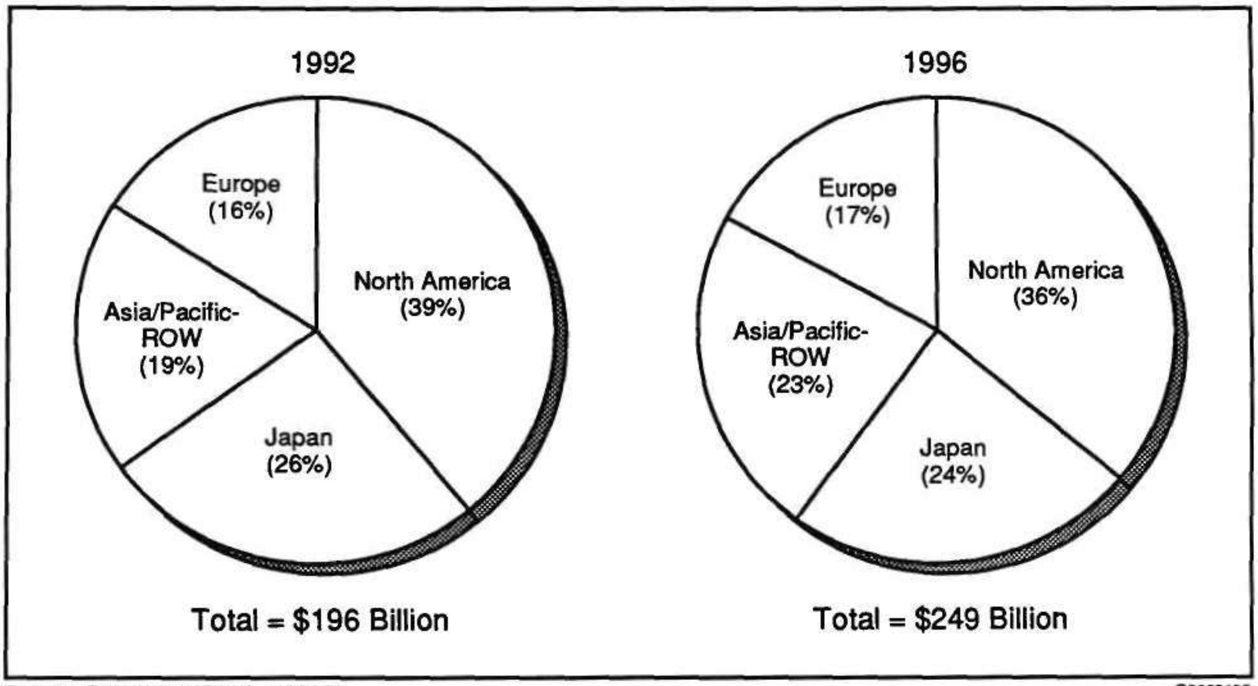
	1992	1993	1994	1995	1996
Worldwide					
Data Processing	196,755	208,263	221,062	233,425	249,132
Communication	107,515	116,893	124,612	134,831	143,455
Industrial	104,902	113,119	121,187	128,695	137,486
Consumer	149,218	163,803	175,705	187,554	201,976
Military/ Aerospace	82,366	85,564	88,416	91,056	93,515
Transportation	23,319	25,693	27,658	29,670	31,725
Total	664,075	713,334	758,639	805,231	857,289
Exchange Rates:					
Yen/U.S.$	136	136	136	136	136
ECU/U.S.$	0.791	0.791	0.791	0.791	0.791

Source: Dataquest (October 1992)

Chapter 2
Data Processing Equipment: Worldwide

Figure 2-1 shows the regional production of data processing equipment (computers, peripherals, and office equipment, among others). Figure 2-2 shows the global geographic markets for computer systems. North America will remain the largest producer of data processing equipment, but Japan and the Asia/Pacific countries such as Taiwan, South Korea, and Singapore—plus developing countries such as Malaysia—will grow faster in production revenue. The Asia/Pacific countries, in particular, continue to find roles as either captive or contract producers of cost-sensitive hardware such as motherboards and disk drives. If the North American Free Trade Agreement is ratified, there could be a substantial shift of production to North America.

Figure 2-1
Regional Data Processing Production Revenue



Source: Dataquest (October 1992)

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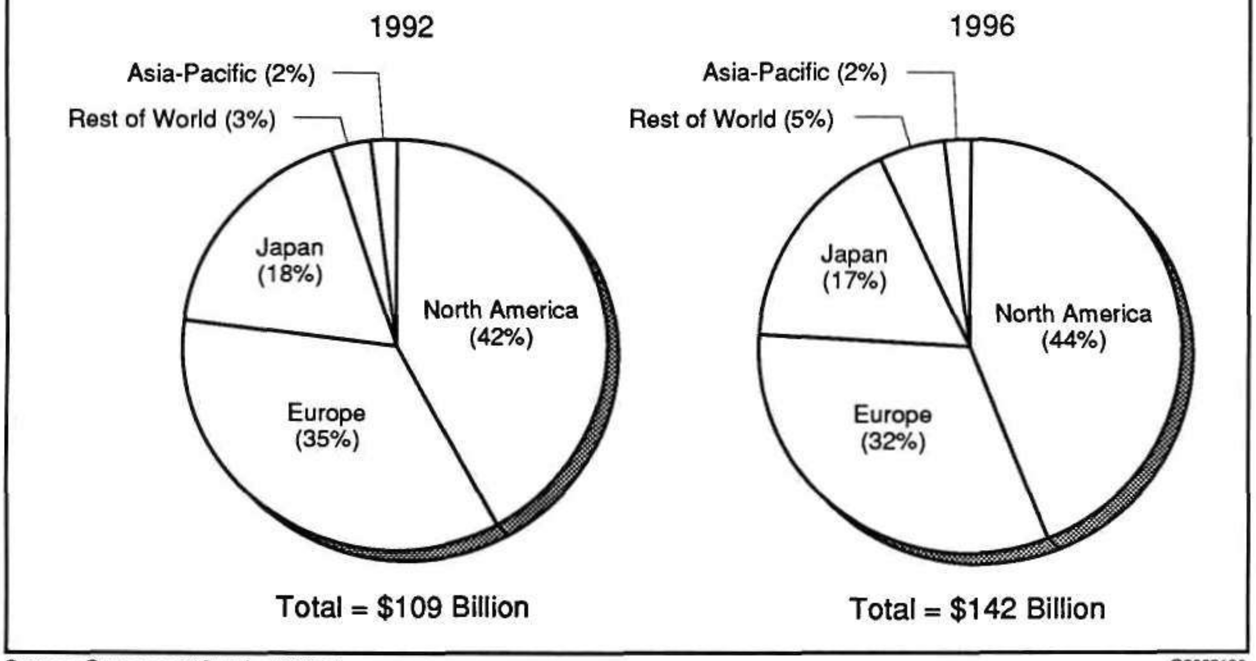
Figure 2-2
Regional Computer Markets



Source: Dataquest (October 1992)

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North America is expected to be the most fertile region on a market basis for sales of computer systems through the middle of the decade. North American growth principally will come from a resurgence in capital spending investment after several years of delayed update plans.

Computer Systems

Tables 2-1 through 2-7 and Figures 2-3 through 2-6 present Dataquest's outlook for the worldwide computer systems markets. Key trends to note include the following:

- There will be a dramatic movement of product mix to downsized, distributed computing based on workstation networks. Workstation market growth will come principally at the expense of midrange and mainframe systems.
- Open or UNIX-based server versions of workstation and midrange systems will displace a substantial percentage of the traditional midrange and mainframe markets.
- Traditional desktop PCs will drop to 27 percent of the global PC revenue as ongoing price pressure and unit drop-off in favor of personal workstations and portables affect the market.
- Notebook, pen-based, and hand-held PCs will surge in popularity as functionality increases and prices decrease.

- Personal workstations based on Intel's P5 (also known as 586) and the Power PC from IBM/Apple/Motorola operating under power multitasking, 32-bit operating systems (Windows NT, O/S 2 x.x, and UNIX) will capture the so-called "power" PC users.
- On a unit basis, there will be definitive shift to 486 SX/SL-based systems as they displace the 386 versions and capture a large percentage of portables.
- Proliferation of nonstandard PC backplane buses, particularly with portable PCs, will continue.
- IBM and Apple will continue to be the largest producers of PCs. Apple benefited from a cost-cutting strategy that boosted its share to 9.0 percent on a unit basis. Market share is being picked up by low-cost operations that focus on channel and service value added.
- The PC market will remain fragmented, with the top 10 marketers only accounting for 49 percent of the market.
- Sun Microsystems will remain the leader in workstations, with Hewlett-Packard gaining share with aggressive price performance products based on its PA RISC architecture. NeXT will nearly quadrupled its share as it finds success in the financial markets.

Table 2-1
Worldwide Computer Systems Forecast, Factory Revenue (Millions of Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Supercomputer	1,854.0	2,023.5	2,236.9	2,516.2	2,831.4	3,190.6	3,600.0	12.2
Mainframe	30,865.2	26,649.8	25,967.8	25,029.1	24,139.8	23,376.0	22,700.0	-3.2
Midrange	26,821.0	25,255.0	25,382.3	25,538.1	25,765.0	25,997.0	26,270.0	0.8
Workstation	7,614.9	8,709.8	9,812.3	13,886.8	19,604.1	25,577.6	33,512.8	30.9
Superworkstation	1,095.1	939.2	867.4	900.7	957.4	1,019.2	1,057.7	2.4
Traditional Workstation	2,796.0	5,018.2	5,524.9	7,271.7	8,015.7	8,399.9	9,085.5	12.6
Entry-Level Workstation	3,723.8	2,753.2	3,417.6	3,964.4	5,631.0	8,158.5	9,969.7	29.4
Personal Workstation	0.0	0.0	2.4	1,750.0	5,000.0	8,000.0	13,400.0	NM
PC Subtotal	48,519.9	44,374.5	45,911.0	48,953.0	51,092.0	53,811.0	56,693.0	5.0
Transportable	405.0	326.0	180.0	101.0	63.0	42.0	26.0	-39.7
Laptop AC	1,185.0	444.0	210.0	103.0	68.0	56.0	48.0	-35.9
Laptop DC	5,184.0	4,852.0	5,256.0	5,513.0	5,980.0	5,860.0	5,965.0	4.2
Notebook	810.0	1,795.0	2,857.0	4,369.0	5,798.0	8,238.0	10,410.0	42.1
Pen-Based	19.0	85.0	268.0	1,917.0	4,391.0	7,966.0	11,978.0	169.0
Hand-Held	43.0	86.0	254.0	653.0	1,193.0	1,832.0	2,083.0	89.2
Desktop	37,913.0	33,079.0	32,078.0	30,334.0	27,124.0	22,963.0	19,030.0	-10.5
Deskside	2,961.0	3,709.0	5,077.0	5,964.0	6,474.0	6,834.0	7,152.0	14.0
Total	115,675.0	107,012.6	109,310.3	115,923.2	123,432.3	131,952.2	142,775.8	5.9

NM = Not meaningful
Source: Dataquest (October 1992)

Table 2-2
Worldwide Computer Systems Forecast, Unit Shipments

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Supercomputer	1,008	1,062	1,229	1,424	1,645	1,909	2,210	15.8
Mainframe	15,115	14,142	13,640	13,167	12,721	12,299	11,900	-3.4
Midrange	727,712	754,917	754,537	754,418	754,548	754,912	755,500	0.0
Workstation	407,624	528,915	677,000	1,130,000	2,217,000	3,802,000	6,500,000	65.2
Superworkstation	19,703	15,925	12,500	14,950	17,400	20,300	22,500	7.2
Traditional Workstation	120,100	230,618	246,000	317,150	370,700	416,700	476,900	15.6
Entry-Level Workstation	267,821	282,371	418,200	547,900	828,900	1,365,000	2,000,600	47.9
Personal Workstation	0	0	300	250,000	1,000,000	2,000,000	4,000,000	NM
PC Subtotal	23,935,200	24,987,000	26,710,000	29,836,000	33,774,000	39,127,000	42,648,000	11.3
Transportable	101,000	78,000	42,000	24,000	15,000	10,000	7,000	-38.0
Laptop AC	349,000	124,000	65,000	37,000	28,000	24,000	21,000	-29.9
Laptop DC	2,491,000	2,764,000	3,101,000	3,392,000	3,669,000	3,933,000	4,114,000	8.3
Notebook	408,000	1,136,000	1,794,000	2,816,000	4,393,000	6,809,000	9,464,000	52.8
Pen-Based	10,000	41,000	122,000	800,000	1,759,000	3,289,000	5,098,000	162.4
Hand-Held	217,000	238,000	763,000	2,042,000	3,877,000	6,188,000	7,314,000	98.4
Desktop	19,773,200	19,626,000	19,441,000	19,078,000	18,204,000	16,899,000	14,527,000	-5.8
Deskside	587,000	981,000	1,383,000	1,648,000	1,829,000	1,975,000	2,104,000	16.5
Total	25,086,659	26,286,036	28,156,406	31,735,009	36,759,914	43,698,120	49,917,610	12.1

NM = Not meaningful
Source: Dataquest (October 1992)

Table 2-3
Worldwide Computer Systems Forecast, Average Selling Price (Thousands of Dollars)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Supercomputer	1,839.4	1,905.1	1,820.5	1,767.2	1,721.6	1,671.6	1,629.0	-3.1
Mainframe	2,042.0	1,884.4	1,903.8	1,900.9	1,897.7	1,900.6	1,907.6	0.2
Midrange	36.9	33.5	33.6	33.9	34.1	34.4	34.8	0.8
Workstation	18.7	16.5	14.5	12.3	8.8	6.7	5.2	-20.6
Superworkstation	55.6	59.0	69.4	60.2	55.0	50.2	47.0	-4.4
Traditional Workstation	23.3	21.8	22.5	22.9	21.6	20.2	19.1	-2.6
Entry-Level Workstation	13.9	9.8	8.2	7.2	6.8	6.0	5.0	-12.6
Personal Workstation	0.0	0.0	8.0	7.0	5.0	4.0	3.4	NM
PC Subtotal	2.0	1.8	1.7	1.6	1.5	1.4	1.3	-6.3
Transportable	4.0	4.2	4.3	4.2	4.2	4.1	3.8	-2.0
Laptop AC	3.4	3.6	3.2	2.8	2.4	2.3	2.3	-8.4
Laptop DC	2.1	1.8	1.7	1.6	1.6	1.5	1.5	-3.8
Notebook	2.0	1.6	1.6	1.6	1.3	1.2	1.1	-7.0
Pen-Based	1.9	1.9	2.2	2.4	2.5	2.4	2.4	4.3
Hand-Held	0.2	0.4	0.3	0.3	0.3	0.3	0.3	-4.9
Desktop	1.9	1.7	1.7	1.6	1.5	1.4	1.3	-5.0
Deskside	5.1	3.8	3.7	3.6	3.5	3.5	3.4	-2.1

NM = Not Meaningful
Source: Dataquest (October 1992)

Table 2-4
Worldwide PC Forecast, by Bus Type (Thousands of Unit Shipments)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
PC XT	1,925	520	261	0	0	0	0	-100.0
AT	11,058	13,149	13,575	13,289	12,122	10,139	8,056	-9.3
MCA (16 Bit)	1,450	1,204	1,163	815	255	0	0	-100.0
MCA (32 Bit)	889	827	990	1,513	2,295	2,856	3,233	31.3
EISA	272	474	646	825	981	1,148	1,297	22.3
Others	8,342	8,812	10,076	13,394	18,121	24,984	30,062	27.8
Total	23,936.00	24,986.00	26,711.00	29,836.00	33,774.00	39,127.00	42,648.00	11.3

Source: Dataquest (October 1992)

Table 2-5
Worldwide PC Forecast, by Microprocessor Type (Thousands of Unit Shipments)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
8088/8086	3,307	1,134	1,033	1,307	1,357	1,299	805	-6.6
80286	7,301	3,917	1,259	452	222	106	0	-100.0
80386 SX/SL	4,377	7,843	8,894	7,519	8,208	8,204	8,155	0.8
80386 DX	3,663	4,880	5,154	3,526	2,052	1,298	560	-35.1
80486 SX/SL	0	447	2,917	8,665	12,237	16,213	21,065	116.1
80486 DX/DX2	241	1,948	2,700	3,125	3,629	4,524	5,184	21.6
80586 (P5)	0	0	5	350	1,001	1,995	2,001	NM
68XXX	3,550	3,798	4,332	4,730	4,966	5,436	4,830	4.9
Others	1,497	1,020	416	162	101	53	49	-45.5
Total	23,936	24,987	26,710	29,836	33,773	39,128	42,649	11.3

NM = Not meaningful
Source: Dataquest (October 1992)

Table 2-6
Worldwide Non-PC Computer Systems Market Share, Estimated Unit Shipments

	Market Share (%)	
	1990	1991
Supercomputer Vendors		
Teradata	16.9	18.8
Convex Computer	20.6	18.4
AMT	7.5	9.9
Cray Research	6.4	9.4
Intel	8.3	7.8
Maspar Computer	3.0	5.3
Alliant Computer	9.9	5.2
Digital Equipment	4.2	4.2
Ncube	3.2	4.0
IBM	2.8	2.8
FPS Computing	5.2	1.7
Others	12.5	12.4
Total	100.0	100.0
Mainframe Vendors		
IBM	29.6	33.7
Fujitsu	12.9	16.6
NEC	12.9	13.0
Hitachi	14.5	11.7
Siemens Nixdorf	6.4	6.1
Unisys	8.6	5.2
Groupe Bull	4.3	4.0
Mitsubishi	2.4	2.3
Digital Equipment	0.7	1.3
Amdahl	1.4	1.2
Others	6.3	4.8
Total	100.0	100.0

(Continued)

Table 2-6 (Continued)
Worldwide Non-PC Computer Systems Market Share, Estimated Unit Shipments

	Market Share (%)	
	1990	1991
Midrange Vendors		
NEC	10.0	15.6
IBM	14.4	14.7
Fujitsu	9.8	12.2
Unisys	15.0	10.5
Digital Equipment	6.8	7.2
Groupe Bull	5.2	5.2
Hewlett-Packard	2.7	3.0
Siemens Nixdorf	2.8	2.6
NCR	2.1	1.9
Hitachi	3.3	1.6
Others	27.8	25.4
Total	100.0	100.0
Workstation Vendors		
Sun Microsystems	35.6	35.6
Hewlett-Packard	14.7	15.7
Digital Equipment	16.6	12.3
IBM	5.8	8.7
NeXT	1.0	3.6
Silicon Graphics	2.5	2.7
Hitachi	3.3	2.6
Sony	2.9	1.9
Omron	1.1	1.2
Toshiba	0.1	0.9
Others	26.4	14.7
Total	100.0	100.0

Source: Dataquest (October 1992)

Table 2-7
Worldwide PC Market Share, Estimated Unit Shipments

	Market Share (%)	
	1990	1991
All PC Vendors		
IBM	12.5	11.4
Apple	7.5	9.0
Commodore	7.1	8.3
NEC	5.6	5.8
Compaq	3.9	4.0
Packard Bell	2.2	2.5
Toshiba	3.7	2.0
Atari	3.1	2.0
Tandy	2.6	1.9
Groupe Bull	1.8	1.9
Olivetti	1.9	1.7
AST Research	1.1	1.6
Epson	2.5	1.2
Samsung	1.2	1.1
Hewlett-Packard	1.2	1.1
Hyundai	1.1	1.1
Dell Computer Corp.	0.6	1.0
Amstrad	1.3	1.0
MiTAC	0.8	0.7
Tandon	0.9	0.7
Others	37.4	40.0
Total	100.0	100.0
Desktop PC Vendors		
IBM	13.5	12.0
Apple	8.8	10.5
Commodore	8.5	10.4
NEC	4.9	4.7
Compaq	3.4	3.5
Packard Bell	2.4	2.7
Atari	2.7	2.1
Olivetti	2.2	2.0
AST Research	1.4	1.7
Tandy	2.7	1.7
Others	49.4	48.6
Total	100.0	100.0

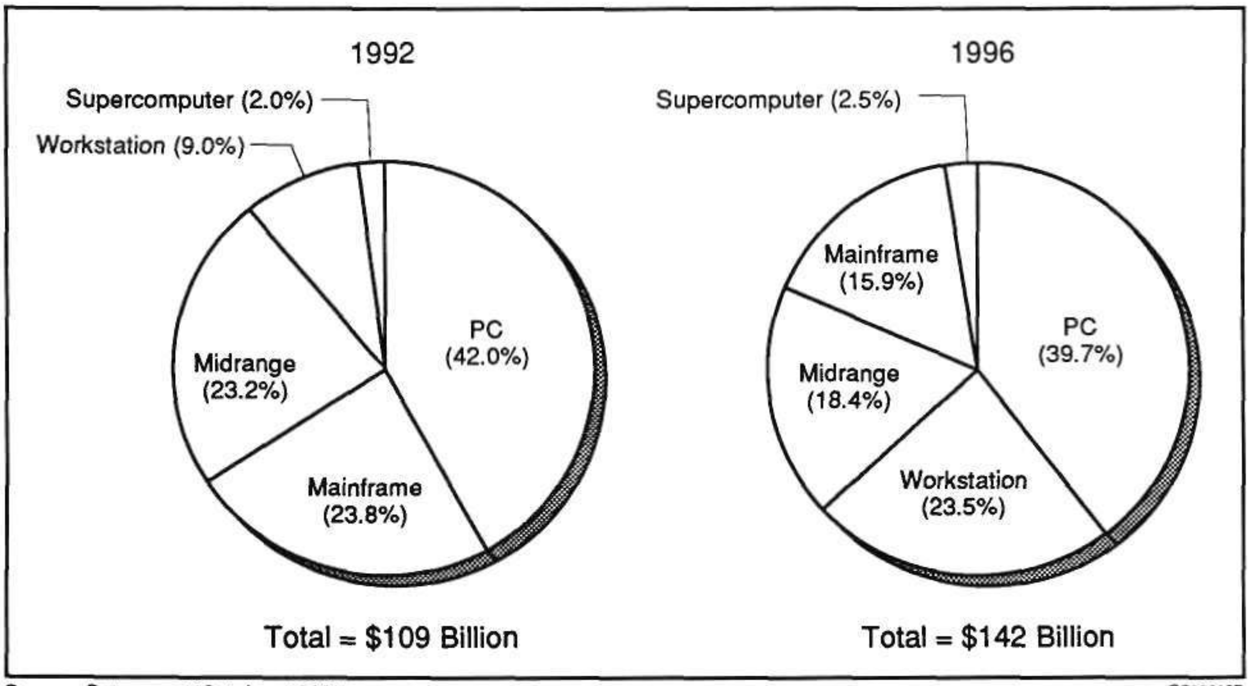
(Continued)

Table 2-7 (Continued)
Worldwide PC Market Share, Estimated Unit Shipments

	Market Share (%)	
	1990	1991
Laptop DC/Pen-Based Computer Vendors		
NEC	13.8	18.3
Toshiba	28.4	15.2
Sharp	0.8	8.0
Compaq	2.8	6.7
ZDS-Groupe Bull	7.0	4.8
Epson	4.2	3.0
Tandy	3.8	2.9
IBM	0.1	2.7
GRiD	1.7	2.5
Amstrad	1.0	1.9
Commodore	0.2	1.4
Packard Bell	1.3	1.3
Apple	1.8	1.2
Others	33.1	37.3
Total	100.0	100.0
Notebook/Hand-Held Computer Vendors		
Atari	30.9	7.2
Compaq	29.6	5.9
AST Research	0.0	5.4
IBM	0.0	5.3
Groupe Bull	0.0	4.9
Epson	5.3	3.9
Texas Instruments	2.5	3.0
Fujitsu	0.2	3.0
Sharp	10.7	2.5
Compuadd	0.8	1.5
Samsung	1.2	1.3
Others	18.8	56.1
Total	100.0	100.0

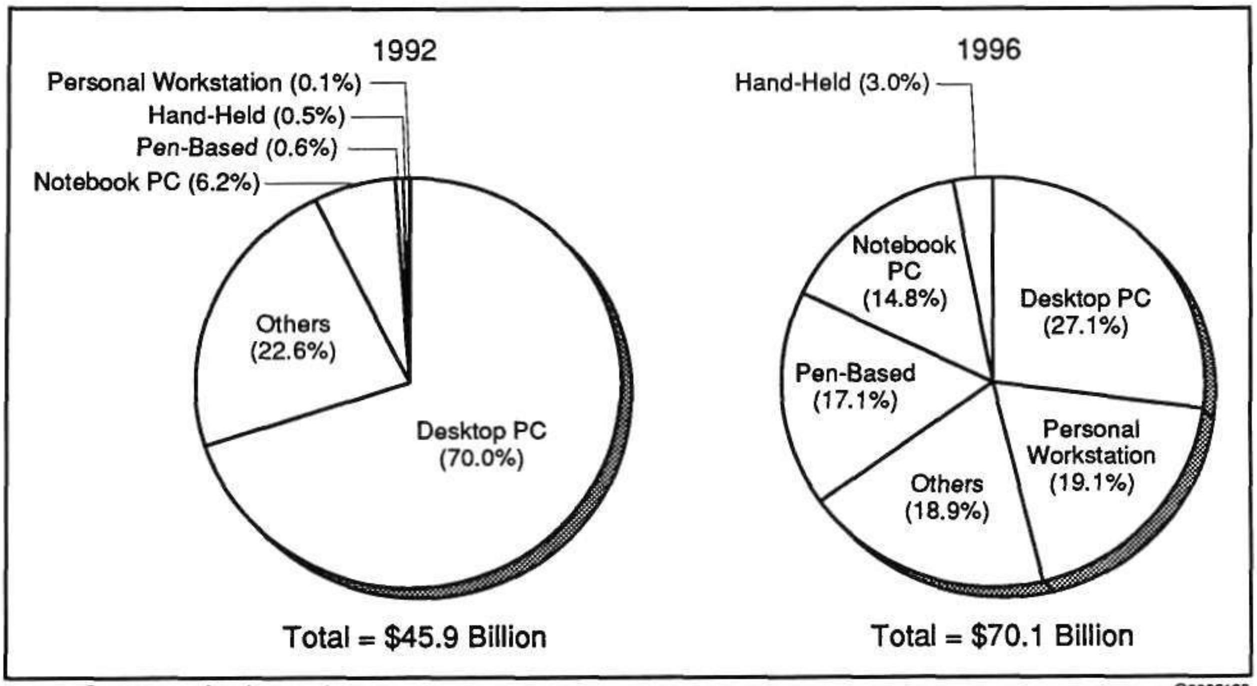
Source: Dataquest (October 1992)

Figure 2-3
Worldwide Computer Systems Market Mix



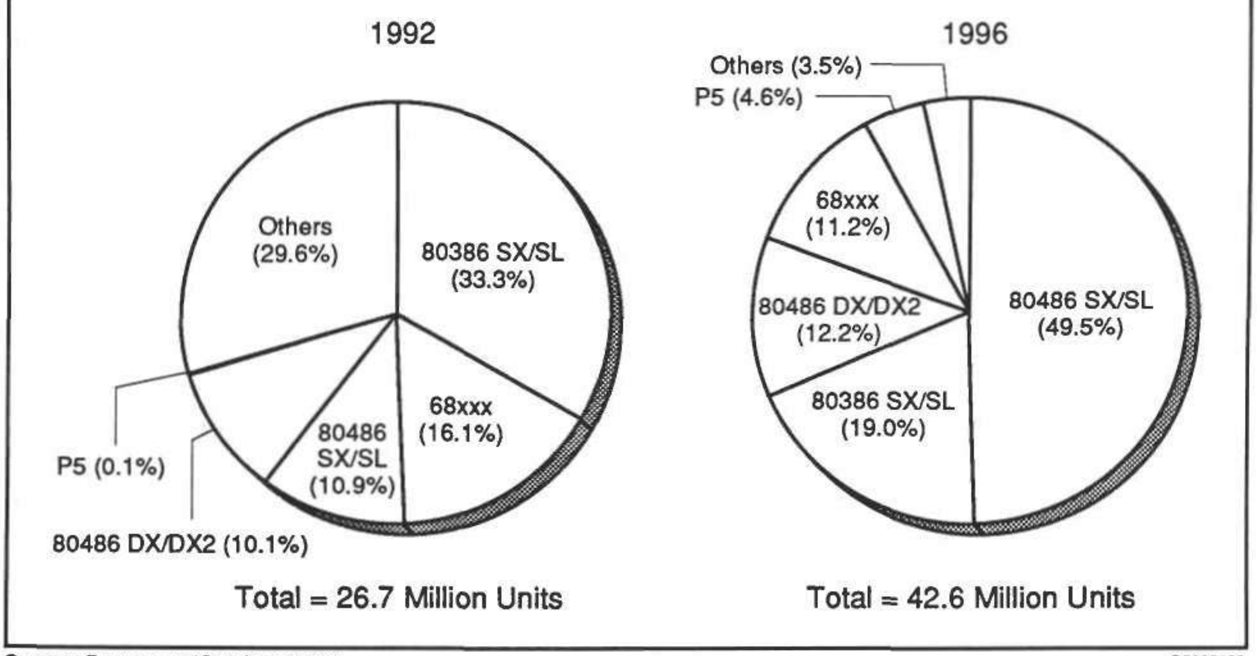
Source: Dataquest (October 1992) G2002137

Figure 2-4
Worldwide PC and Personal Workstation Market Mix



Source: Dataquest (October 1992) G2002138

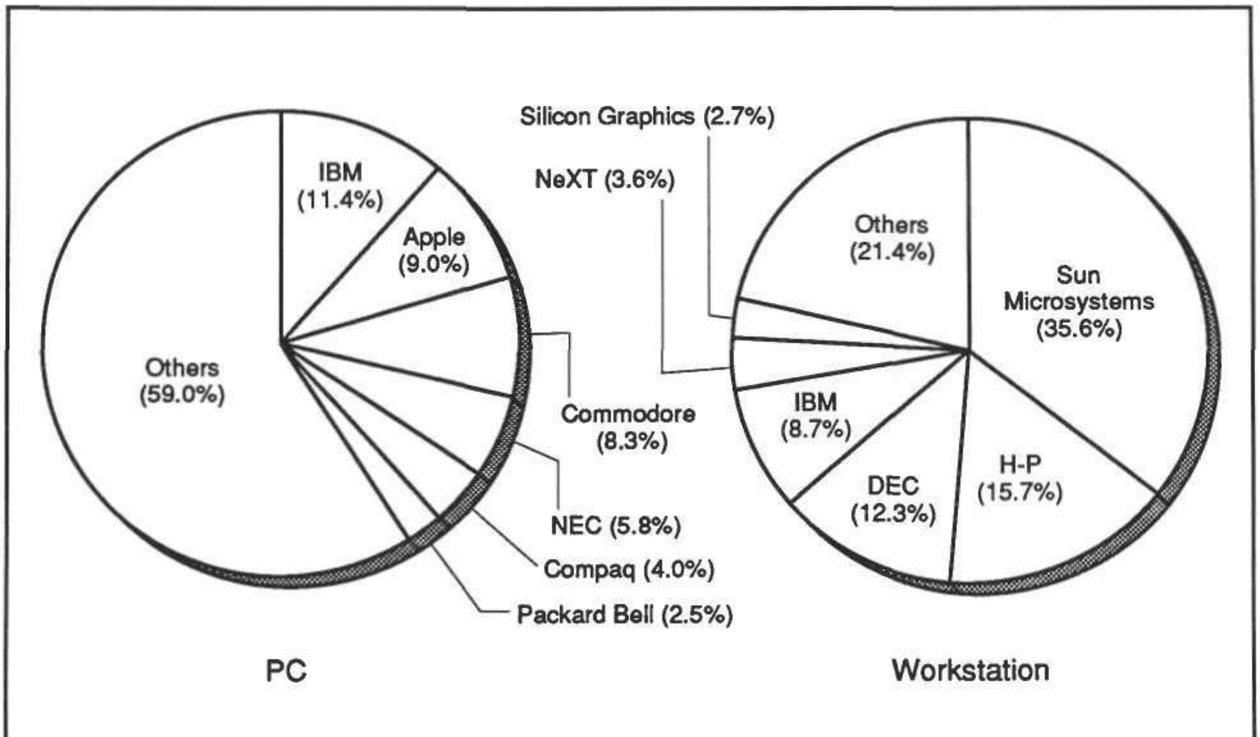
Figure 2-5
Worldwide PC Forecast, by Microprocessor Mix



Source: Dataquest (October 1992)

G2002139

Figure 2-6
1991 PC and Workstation Market Share, Unit Basis



Source: Dataquest (October 1992)

G2002140

Mass Storage

Tables 2-8 through 2-16 and Figures 2-7 through 2-10 present Dataquest's outlook for the worldwide computer storage systems markets. Key trends to note include the following:

- Magnetic rigid disk drives (RDDs) will remain the dominant computer mass storage system.
- 3.5-inch will continue to dominate the RDD widths with growing but modest presence from 2.5-inch and smaller versions.
- More than half of the 3.5-inch RDDs will ship with densities greater than 200MB by 1996.
- CD-ROM will remain the largest optical drive category as factory prices head toward $60. Usage is coming from multimedia title publishing and software application program shipment.
- 3.5-inch rewritable optical drives are expected to ramp up in volume as prices drop toward $100 because they offer an attractive mix of low price per bit and rewritability.

Table 2-8
Worldwide Rigid Disk Drive Forecast, by Width

	Thousands of Units							CAGR (%)
	1990	1991	1992	1993	1994	1995	1996	1992-1996
1.8 Inch	0	4.2	332.0	1,410.0	4,793.0	6,072.0	7,394.0	117.2
2.5 Inch	713.6	3,378.0	5,672.4	9,660.0	12,060.0	13,260.0	14,800.0	27.1
3.5 Inch	21,741.9	25,421.6	28,416.0	31,332.0	33,960.0	39,020.0	46,960.0	13.4
5.25 Inch	6,877.0	3,154.4	2,584.0	1,714.0	1,070.4	840.0	574.0	-31.3
8-10 Inch	376.6	466.3	421.3	382.0	286.0	212.0	94.0	-31.3
14 Inch	237.4	79.8	39.2	10.0	1.2	0	0	NM
Total	29,946.5	32,504.3	37,464.9	44,508.0	52,170.6	59,404.0	69,822.0	16.8
	Average Selling Price (Dollars)							CAGR (%)
	1990	1991	1992	1993	1994	1995	1996	1992-1996
1.8 Inch	0	340.0	271.2	222.1	142.6	128.9	108.0	-20.6
2.5 Inch	262.6	241.7	202.8	224.5	235.0	240.3	220.3	2.1
3.5 Inch	233.4	222.8	229.5	237.5	296.2	295.9	293.7	6.4
5.25 Inch	482.8	772.0	885.9	861.1	874.7	1,049.6	979.1	2.5
8-10 Inch	12,131.9	18,711.5	19,929.2	20,081.4	18,000.0	15,745.3	14,648.9	-7.4
14 Inch	21,934.3	23,062.9	24,126.5	21,744.0	22,000.0	0	0	NM
Total	35,045.0	43,350.9	45,645.1	43,370.6	41,548.5	17,460.0	16,250.0	-22.8
	Factory Revenue (Millions of Dollars)							CAGR (%)
	1990	1991	1992	1993	1994	1995	1996	1992-1996
1.8 Inch	0	1.4	90.0	313.2	683.5	782.4	798.9	72.6
2.5 Inch	187.4	816.4	1,150.4	2,169.0	2,834.1	3,186.0	3,260.0	29.7
3.5 Inch	5,073.9	5,663.6	6,520.9	7,440.7	10,060.6	11,547.0	13,790.4	20.6
5.25 Inch	3,320.1	2,435.3	2,289.2	1,476.0	936.2	881.7	562.0	-29.6
8-10 Inch	4,568.8	8,724.8	8,396.2	7,671.1	5,148.0	3,338.0	1,377.0	-36.4
14 Inch	5,207.1	1,840.1	945.8	217.4	26.4	0	0	NM
Total	18,357.3	19,481.6	19,392.5	19,287.4	19,688.8	19,735.1	19,788.3	0.5

NM = Not meaningful
Source: Dataquest (October 1992)

Table 2-9
Worldwide Rigid Disk Drive Forecast, by Capacity

	1991	1996	CAGR (%) 1991-1996
1.8 Inch			
0-30MB	4.2	12.0	NM
31-60MB	0	2,400.0	NM
61-100MB	0	4,800.0	NM
101-200MB	0	120.0	NM
201-500MB	0	60.0	NM
501-1,000MB	0	2.0	NM
Total	4.2	7,394.0	NM
2.5 Inch			
0-30MB	630.0	0	NM
31-60MB	1,955.0	200.0	-47.1
61-100MB	793.0	2,000.0	-4.5
101-200MB	0	3,400.0	63.1
201-500MB	0	8,000.0	659.8
501-1,000MB	0	1,200.0	NM
Total	3,378.0	14,800.0	27.1
3.5 Inch			
0-30MB	474.0	0	NM
31-60MB	12,816.0	60.0	-69.8
61-100MB	4,572.2	800.0	-41.9
101-200MB	5,197.9	12,000.0	8.7
201-500MB	2,223.3	16,000.0	37.3
501-1,000MB	137.0	10,200.0	80.5
1-2GB	1.0	6,000.0	165.9
2+GB	0	1,900.0	NM
Total	25,421.4	46,960.0	13.4
5.25 Inch			
0-30MB	205.1	0	-100.0
31-60MB	517.8	0	-100.0
61-100MB	236.0	0	-100.0
101-200MB	323.5	0	-100.0
201-500MB	640.6	0	-100.0
501-1,000MB	823.7	12.0	-67.1
1-2GB	405.1	12.0	-63.0
2+GB	2.6	550.0	54.7
Total	3,154.4	574.0	-31.3

NM = Not meaningful
Source: Dataquest (October 1992)

Table 2-10
Worldwide Rigid Disk Drive Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
1.8 Inch	
Integral Peripherals	100.0
Total	100.0
2.5 Inch	
Conner Peripherals	54.8
JVC	14.8
IBM	11.3
Toshiba	6.2
Western Digital	4.2
Others	8.7
Total	100.0
3.5 Inch	
Seagate Technology	26.4
Conner Peripherals	18.3
Quantum Corp.	15.7
IBM	11.4
Western Digital	8.3
Maxtor Corp.	8.1
Others	11.8
Total	100.0
5.25 Inch	
Seagate Technology	46.0
IBM	12.7
Maxtor Corp.	11.6
Fujitsu Ltd.	5.4
Hewlett-Packard	4.5
Others	19.8
Total	100.0

Source: Dataquest (October 1992)

Table 2-11
Worldwide Optical Disk Forecast (Thousands of Units)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
All Versions								
Units	397.1	1,067.6	1,985.7	3,286.7	5,304.1	6,629.7	8,008.6	41.7
CD-ROM								
Units	240.0	936.0	1,498.0	2,246.0	3,617.0	4,228.0	4,990.0	35.1
ASP($)	248.0	207.0	145.0	102.0	80.0	68.0	60.0	-19.8
Factory Revenue ($M)	27.3	225.5	217.2	229.1	289.4	287.5	299.4	8.4
5.25-Inch WORM								
Units	52.0	46.6	64.9	89.2	123.9	156.9	200.0	32.5
ASP($)	1,200.0	1,020.0	747.6	681.8	623.2	571.9	515.4	-8.9
Factory Revenue ($M)	62.4	47.5	48.6	60.8	77.2	89.7	103.0	20.7
12-Inch WORM								
Units	10.0	11.5	13.8	17.5	21.2	24.8	27.6	18.9
ASP($)	6,480.0	6,480.0	5,832.0	5,249.0	4,724.0	4,488.0	4,200.0	-7.9
Factory Revenue ($M)	64.8	74.6	80.5	91.8	100.0	111.4	115.9	9.5
3.5-Inch Rewritable								
Units	0	22.0	160.0	544.0	984.0	1,440.0	1,900.0	85.6
ASP($)	0	780.0	515.0	340.0	224.0	148.0	124.0	-30.0
Factory Revenue ($M)	0	17.2	82.4	185.0	220.4	213.1	235.6	30.0
5.25-Inch Rewritable								
Units	95.1	51.5	249.0	390.0	558.0	780.0	891.0	37.5
ASP ($)	2,000.0	1,600.0	1,280.0	1,024.0	819.0	655.0	524.0	-20.0
Factory Revenue ($M)	160.0	193.9	318.7	399.3	457.0	510.9	466.9	10.0

Source: Dataquest (October 1992)

Table 2-12
1991 Worldwide Optical Disk Drive Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
CD-ROM	
Sony	40.1
Hitachi	19.2
NEC	11.8
Toshiba	10.1
Panasonic	6.4
Others	12.4
Total	100.0
5.25-Inch WORM	
Panasonic	32.6
Pioneer	15.7
Ricoh	15.0
LMSI	8.7
ISi	8.5
Others	19.5
Total	100.0
12-Inch WORM	
Sony	31.3
Hitachi	20.9
LMSI	20.0
Toshiba	10.4
Others	17.4
Total	100.0
3.5-Inch Rewritable	
Sony	44.1
IBM	27.3
Panasonic	22.7
Others	5.9
Total	100.0
5.25-Inch Rewritable	
Sony	47.7
Ricoh	19.0
Panasonic	12.4
Maxoptix	8.3
Canon	5.8
Others	6.8
Total	100.0

Source: Dataquest (October 1992)

Table 2-13
Worldwide Flexible Disk Drive Forecast

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Units (K)	35,900.0	43,055.0	43,900.0	46,200.0	49,300.0	52,000.0	53,800.0	5.2
ASP ($)	46.6	42.5	42.0	41.4	40.6	39.4	38.0	-2.5
Factory Revenue ($M)	1,671.2	1,831.1	1,843.8	1,911.5	2,000.8	2,047.0	2,041.8	2.6

Source: Dataquest (October 1992)

Table 2-14
1991 Worldwide Flexible Disk Drive Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
Teac	25.4
Panasonic	15.8
Sony	14.6
Chinon	11.3
Citizen	9.7
Mitsubishi	7.2
Y-E Data	6.2
Seiko Epson	2.3
Toshiba	0.5
Others	7.0
Total	100.0

Source: Dataquest (October 1992)

Table 2-15
Worldwide Tape Drive Forecast

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Units (K)	1,704.9	2,334.9	2,694.7	3,057.3	3,308.4	3,463.8	3,607.2	7.6
ASP ($)	1,108.1	874.9	786.1	724.1	678.1	662.6	637.4	-5.1
Factory Revenue ($M)	1,889.2	2,042.9	2,188.3	2,213.7	2,243.4	2,295.2	2,299.3	1.2

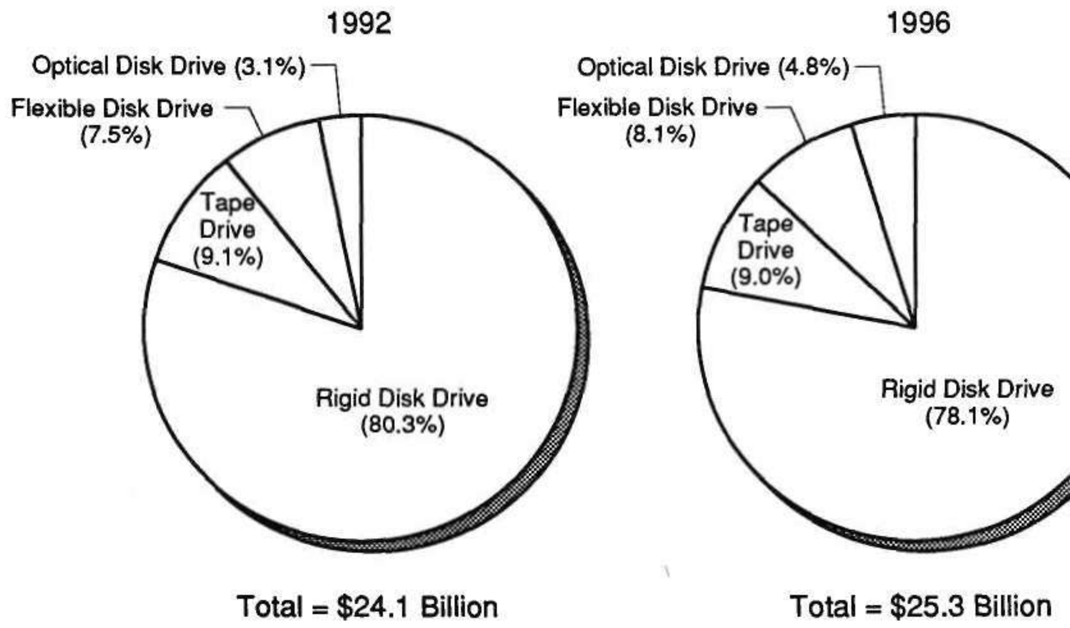
Source: Dataquest (October 1992)

Table 2-16
1991 Worldwide Tape Drive Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
Archive	30.3
Rexon (Wangtek/Wangdat)	15.3
Colorado Memory Systems	15.1
Tandberg	9.6
Teac	6.8
Exabyte	6.0
Hewlett-Packard	3.5
DEC	2.0
Fujitsu	1.1
Others	10.3
Total	100.0

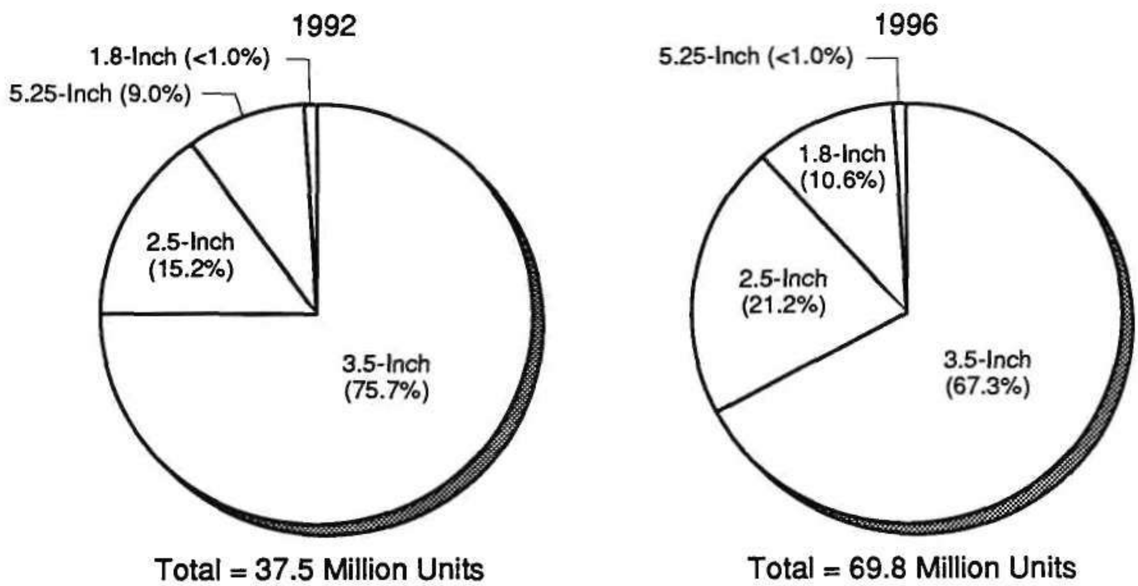
Source: Dataquest (October 1992)

Figure 2-7
Worldwide Storage Market



Source: Dataquest (October 1992) G2002141

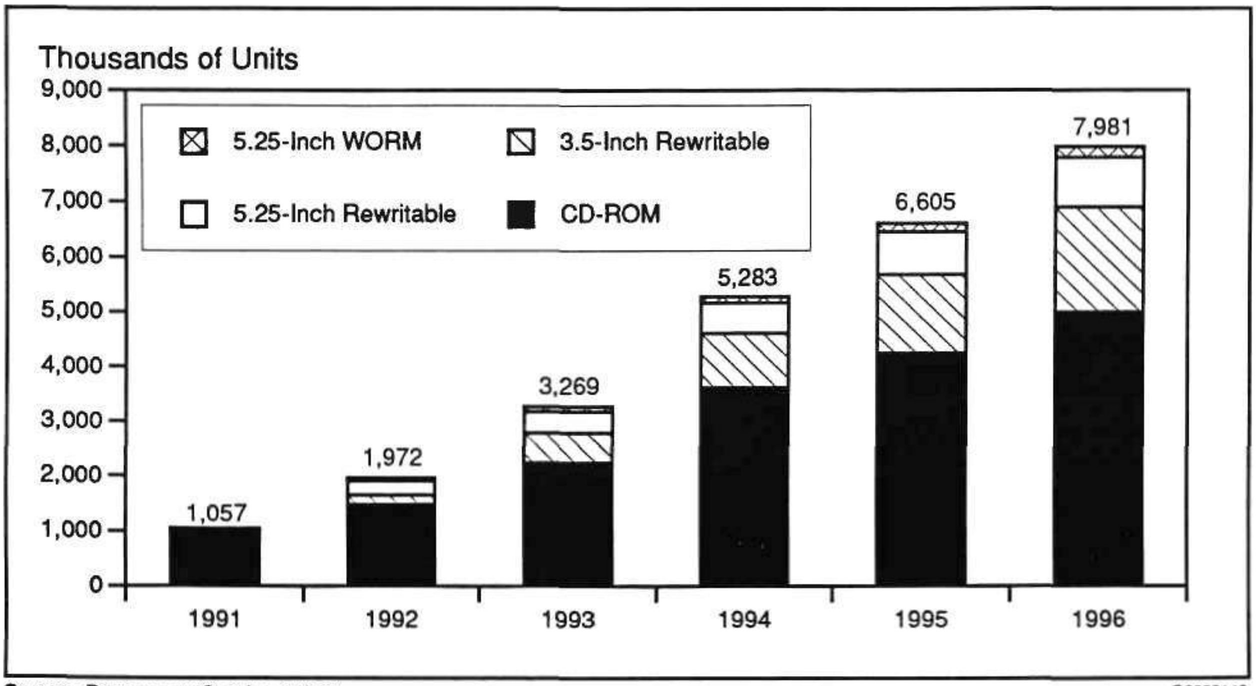
Figure 2-8
Worldwide Digital Disk Drive Forecast, by Width



Note: Segments may not add to 100 percent because of rounding.

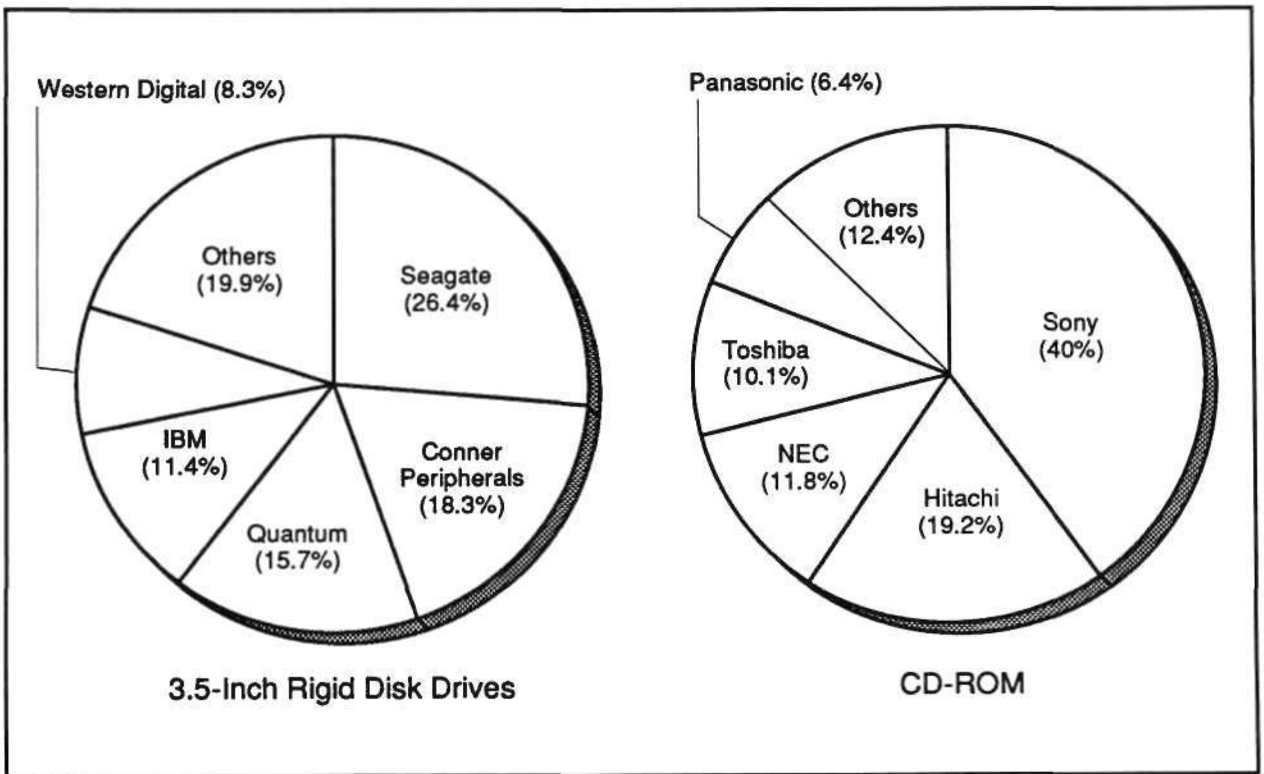
Source: Dataquest (October 1992) G2002142

Figure 2-9
Worldwide Optical Disk Drive Forecast



Source: Dataquest (October 1992) G2002143

Figure 2-10
1991 Worldwide Mass Storage Market Share, Unit Basis (Selected)



Source: Dataquest (October 1992) G2002144

Other Peripherals

Tables 2-17 through 2-22 and Figure 2-11 present Dataquest's forecast of selected computer peripherals including monitors, terminals, and printers. Key trends to note include the following:

- Monitors will continue to grow at the rate of desktop systems shipments with continual migration to finer dot pitch (for SVGA and workstations) and multisynch versions (variable up to 72Hz).
- Networked X Window terminals will continue to be used as an office alternative as volumes approach 900,000 units by 1996. NCD, Digital Equipment Corporation, HP, and IBM will account for 70 percent of the market.
- Traditional dot matrix serial printers will continue to be displaced by laser and ink jet printers. By 1996 laser and ink jet printers will each rival dot matrix in unit size in the North American and European markets. HP and Epson will be the largest printer companies in the world, with about a third of the market between them.

Table 2-17
Worldwide Display Terminal and Monitor Forecast (Thousands of Units)

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Display Terminals	6,123.0	5,542.0	5,736.0	5,925.0	6,076.0	6,187.0	6,228.0	2.1
Monitors	24,764.0	23,193.6	24,194.4	25,842.8	27,201.1	28,612.8	29,830.3	5.4

Source: Dataquest (October 1992)

Table 2-18
1991 Worldwide Display Terminal and Monitor Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
Display Terminals	
IBM	18.2
Wyse	10.4
Memorex Telex	6.0
Digital	4.1
Siemens	3.6
Others	57.7
Total	100.0
Monitors	
IBM	7.9
Philips	5.6
Apple	4.8
Commodore	4.7
Samsung Information Systems	2.8
Compaq	2.8
Olivetti	2.6
Packard Bell	2.6
Tatung	2.3
NEC	2.1
Others	61.8
Total	100.0

Source: Dataquest (October 1992)

Table 2-19
Worldwide X Window Terminal and Monitor Forecast

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Units (K)	69.0	111.1	226.8	407.2	587.5	722.5	880.0	40.3
ASP ($)	2,608.0	2,400.5	2,059.1	1,592.6	1,361.8	1,211.1	1,079.5	-14.9
Factory Revenue ($M)	180.0	266.7	467.0	648.5	800.0	875.0	950.0	19.4

Source: Dataquest (October 1992)

Table 2-20
1991 Worldwide X Window Terminal Market Share, Estimated Unit Shipments

Vendor	Market Share (%)
NCD	28.3
Digital	15.8
Hewlett-Packard	17.9
IBM	12.2
Tektronix	8.1
Visual Technology	3.1
HDS	3.2
Others	11.4
Total	100.0

Source: Dataquest (October 1992)

Table 2-21
North America and Europe Printer Forecast: 1991-1996

	All Printers						CAGR (%)
	1991	1992	1993	1994	1995	1996	1992-1996
North America							
Units (K)	8,346.7	8,462.0	8,690.7	8,818.2	8,885.4	8,919.6	1.3
End-User ASP ($)	1,007.6	1,000.0	1,017.0	1,031.0	1,036.2	1,040.5	0.6
End-User Revenue ($M)	8,410.0	8,460.7	8,838.8	9,092.0	9,207.0	9,281.0	2.0
Europe							
Units (K)	7,381.1	7,914.5	8,553.7	9,037.3	9,545.9	9,836.1	5.9
End-User ASP ($)	1,310.0	1,230.0	1,180.0	1,160.0	1,140.0	1,130.0	-2.9
End-User Revenue ($M)	9,642.7	9,706.7	10,073.4	10,454.5	10,885.5	11,122.8	2.9
	Serial Printers						CAGR (%)
	1991	1992	1993	1994	1995	1996	1992-1996
North America							
Units (K)	5,686.6	5,827.5	5,794.6	5,735.4	5,638.6	5,542.3	-0.5
End-User ASP ($)	480.6	483.1	496.6	496.0	489.2	480.5	0
End-User Revenue ($M)	2,820.2	2,815.2	2,877.6	844.8	2,758.6	2,663.2	-1.1
Europe							
Units (K)	5,843.5	6,077.5	6,376.0	6,533.3	6,759.1	6,795.9	3.1
End-User ASP ($)	78.0	72.0	69.0	68.0	67.0	67.0	-3.0
End-User Revenue ($M)	4,554.7	4,404.1	4,395.3	4,419.2	4,544.3	4,530.4	-0.1

(Continued)

Table 2-21 (Continued)
North America and Europe Printer Forecast: 1991-1996

	Line Printers						CAGR (%)
	1991	1992	1993	1994	1995	1996	1992-1996
North America							
Units (K)	94.0	95.5	99.8	103.0	107.2	110.4	3.3
End-User ASP ($)	8,859.0	9,000.0	8,968.0	8,990.0	8,830.0	9,705.0	1.8
End-User Revenue ($M)	832.4	859.5	895.6	916.7	946.1	970.5	3.1
Europe							
Units (K)	48.0	48.0	49.2	50.2	51.7	53.4	2.2
End-User ASP ($)	1,157.0	1,102.0	1,046.0	1,000.0	961.0	919.0	-4.5
End-User Revenue ($M)	555.6	528.9	514.3	501.4	496.9	490.7	-2.5
	Page Printers						CAGR (%)
	1991	1992	1993	1994	1995	1996	1992-1996
North America							
Units (K)	2,384.1	2,539.0	2,796.3	2,979.8	3,139.6	3,266.9	6.5
End-User ASP ($)	1,995.3	1,884.9	1,811.5	1,788.9	1,752.6	1,728.7	-2.8
End-User Revenue ($M)	4,757.2	4,785.9	5,065.5	5,330.4	5,502.4	5,647.3	3.5
Europe							
Units (K)	1,489.6	1,788.9	2,128.5	2,453.8	2,735.1	2,986.7	14.9
End-User ASP ($)	3,040.0	2,670.0	2,430.0	2,260.0	2,140.0	2,040.0	-7.7
End-User Revenue ($M)	4,532.4	4,773.6	5,163.8	5,533.8	5,844.2	6,101.7	6.1

(Continued)

Table 2-21 (Continued)
North America and Europe Printer Forecast: 1991-1996

	Non-Impact, Serial, Ink-Jet Printers						CAGR (%)
	1991	1992	1993	1994	1995	1996	1992-1996
North America							
Units (K)	721.4	1,011.5	1,193.6	1,383.4	1,582.6	1,788.3	19.9
End-User ASP ($)	622.5	674.0	710.0	684.8	638.5	595.0	-0.9
End-User Revenue ($M)	449.1	681.8	848.6	947.4	1,010.5	1,064.0	18.8
Europe							
Units (K)	1,348.9	1,945.4	2,525.8	2,982.2	3,370.3	3,650.9	22.0
End-User ASP ($)	750.0	670.0	630.0	620.0	630.0	640.0	-3.1
End-User Revenue ($M)	1,014.1	1,301.9	1,593.4	1,847.7	2,122.1	2,331.4	18.0

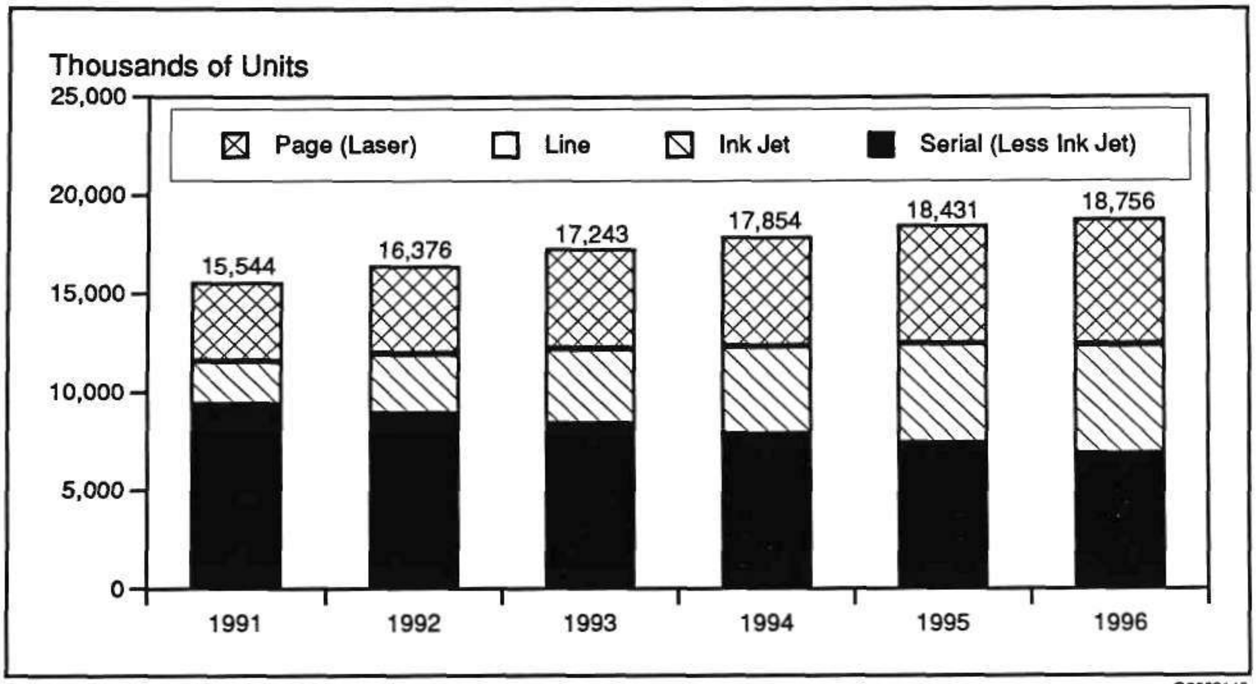
Source: Dataquest (October 1992)

Table 2-22
1991 Worldwide Printer Market Share (North America and Europe Combined), Estimated Unit Shipments

Vendor	Market Share (%)
Hewlett-Packard	17.7
Epson	16.5
Panasonic	8.9
Okidata	7.1
Canon	3.9
Apple	3.7
IBM	3.2
Others	39.1
Total	100.0

Source: Dataquest (October 1992)

Figure 2-11
North America and Europe Printer Market Forecast



Source: Dataquest (October 1992)

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Chapter 3
Communications Equipment: North America

Tables 3-1 through 3-18 present market forecast and market share information on selected communication markets tracked by Dataquest in North America. Figure 3-1 ranks the highest-growth communications equipment markets. Key trends to note include the following:

- High-performance networking is expected to witness robust growth over the coming decade. In particular FDDI network interface cards (NICs) will grow, as will wiring center equipment such as hubs, and assorted internetworking equipment linking networks along with high-bandwidth backbones.
- Ethernet and token ring NICs and internetworking equipment (bridges, routers, hubs, and gateways) will continue robust growth on a unit basis but competitive pricing pressure will limit revenue growth.
- ISDN line (basic rate 2B + D) shipments in North America are expected to start in earnest past the midway point of the decade.
- Central office and PBX switching systems are expected to continue following replacement market economics with steady, low growth. Unstandardized asynchronous transfer mode (ATM) technology is being broadly supported as a means of upgrading switches and multiplexers for point-to-point multimedia capability.
- Conversion to fiber-optic transmission based on the SONET standard will continue throughout the decade. Fiber to the curb and house are some of the potential developments as the regional Bells are cleared to offer "video" dial tones.
- Cellular systems will continue expanding demand as they convert to digital processing and compression techniques (TDMA). New microcell-based systems called personal communications networks (PCNs) will start to emerge in 1994 to 1995.
- Voice messaging and interactive response systems will continue finding expanded use with some competitive pressures factoring in by middecade.
- Video teleconferencing, systems, both room and low-cost desktop versions based on CCITT standards, will continue expanding into corporate use.

Table 3-1
Revenue and Shipments of ACD Systems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	3.2	4.5	4.9	5.4	5.7	16.2
Average End-User Price ($K)	83.9	85.9	118.6	92.9	92.1	2.3
End-User Revenue ($M)	264.6	388.2	577.3	497.2	528.5	18.9
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	6.2	6.9	7.7	8.6	9.6	11.4
Average End-User Price ($K)	90.3	88.9	87.6	87.6	87.8	-0.7
End-User Revenue ($M)	560.3	610.6	675.3	754.3	839.6	10.6

Source: Dataquest (October 1992)

Table 3-2
Revenue from Facsimile Equipment Placed in the United States
(Millions of U.S. Dollars)

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Total Fax Equipment	998.8	1,779.6	2,231.3	2,086.5	1,638.9	13.2
Total Group 3	994.0	1,772.6	2,218.3	2,078.5	1,630.9	13.2
Total Group 4	4.8	7.0	13.0	8.0	8.0	13.6
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Total Fax Equipment	2,026.6	2,575.5	2,808.8	2,812.0	2,699.4	7.4
Total Group 3	2,013.6	2,556.7	2,776.9	2,756.7	2,625.0	6.9
Total Group 4	13.0	18.8	31.9	55.3	74.4	54.7

Note: New segmentation scheme in 1991 further segmented Group 3 into plain paper by printing method and retained thermal by price segment.
Source: Dataquest (October 1992)

Table 3-3
Revenue and Placements of Group 3 Facsimile Products in the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Placements (K)	NA	1,039.2	1,435.7	1,404.3	1,673.1	-
Average End-User Price ($)	NA	1,706.0	1,545.0	1,480.0	975.0	-
End-User Revenue ($M)	NA	1,772.7	2,218.4	2,078.5	1,630.9	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Placements (K)	1,734.0	1,804.0	1,876.0	1,951.0	2,029.0	4.0
Average End-User Price ($)	1,161.0	1,417.0	1,480.0	1,413.0	1,294.0	2.7
End-User Revenue ($M)	2,013.6	2,556.7	2,776.9	2,756.7	2,625.0	6.9

NA = Not available
Note: New segmentation scheme in 1991 further segmented Group 3 into plain paper by printing method and retained thermal by price segment.
Source: Dataquest (October 1992)

Table 3-4
Revenue and Placements of Group 4 Facsimile Equipment in the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Placements (K)	NA	0.6	1.2	0.7	0.8	-
Average End-User Price ($K)	NA	11.7	10.8	11.2	10.4	-
End-User Revenue ($M)	NA	7.0	13.0	8.0	8.0	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Placements (K)	1.3	2.0	3.5	6.5	9.3	63.5
Average End-User Price ($K)	10.0	9.4	9.1	8.5	8.0	-5.4
End-User Revenue ($M)	13.0	18.8	31.9	55.3	74.4	54.7

NA = Not Available
Source: Dataquest (October 1992)

Table 3-5
Revenue and Shipments of Voice Response Systems to the United States

	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Shipments (K)	8.6	10.0	11.8	13.8	16.1	17.0
Average End-User Price ($K)	74.5	79.6	83.6	86.5	87.5	4.1
End-User Revenue ($M)	641.1	799.8	989.0	1,190.0	1,410.7	21.8

Source: Dataquest (October 1992)

Table 3-6
Revenue and Shipments of Key Telephone Systems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	481.0	476.4	472.6	479.0	462.6	-1.0
Average End-User Price ($K)	4.9	4.6	4.3	4.2	4.2	-3.8
End-User Revenue ($M)	2,354.8	2,184.3	2,055.7	2,011.5	1,940.6	-4.7
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	467.2	476.5	486.0	495.7	505.6	2.0
Average End-User Price ($K)	4.2	4.1	4.1	4.0	3.9	-1.5
End-User Revenue ($M)	1,944.0	1,957.1	1,969.8	1,982.1	1,997.1	0.6

Source: Dataquest (October 1992)

Table 3-7
Revenue from LANs Shipped to the United States
(Millions of U.S. Dollars)

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Network Interface Cards	NA	NA	998.0	1,123.7	1,153.2	-
Ethernet NIC	NA	NA	418.0	514.8	533.5	-
Token-Ring NIC	NA	NA	479.0	516.5	533.1	-
Other NIC	NA	NA	101.0	92.4	86.6	-
Network Operating Software	NA	NA	NA	688.0	729.6	-
1-10 User NOS	NA	NA	NA	276.5	306.6	-
11-34 User NOS	NA	NA	NA	244.1	262.4	-
35+ User NOS	NA	NA	NA	167.4	160.7	-
Wiring Center	NA	NA	NA	381.4	519.4	-
Ethernet	NA	NA	NA	314.1	418.0	-
Token-Ring	NA	NA	NA	47.7	96.9	-
FDDI Network Interface Cards	NA	NA	NA	16.1	20.3	-
PC	NA	NA	NA	0.7	1.3	-
Workstation	NA	NA	NA	10.2	15.0	-
Host	NA	NA	NA	5.2	4.1	-
FDDI Internetworking	NA	NA	NA	26.6	55.5	-
Bridges	NA	NA	NA	11.6	11.7	-
Routers	NA	NA	NA	15.0	43.8	-
FDDI Wiring Centers	NA	NA	NA	2.6	1.8	-

(Continued)

Table 3-7 (Continued)
Revenue from LANs Shipped to the United States
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Network Interface Cards	1,198.8	1,276.7	1,368.8	1,417.3	1,429.5	4.5
Ethernet NIC	546.3	559.1	571.9	559.6	542.6	-0.2
Token-Ring NIC	575.2	647.9	734.7	802.7	838.8	9.9
Other NIC	77.3	69.7	62.2	55.0	48.1	-11.2
Network Operating Software	734.8	748.5	753.1	769.6	787.2	1.7
1-10 User NOS	333.1	320.8	313.0	318.8	324.1	-0.7
11-34 User NOS	237.3	255.2	258.9	256.6	250.3	1.3
35+ User NOS	164.4	172.5	181.2	194.2	212.7	6.7
Wiring Center	585.5	685.2	763.1	857.5	954.2	13.0
Ethernet	438.9	503.6	547.7	591.3	637.4	9.8
Token-Ring	141.6	176.5	210.4	261.2	311.9	21.8
FDDI Network Interface Cards	59.5	164.5	310.0	607.7	772.4	89.8
PC	9.0	43.5	90.0	162.9	221.2	122.7
Workstation	28.0	75.0	150.0	360.0	466.2	102.0
Host	22.5	46.0	70.0	84.8	85.0	39.4
FDDI Internetworking	76.4	90.2	96.6	100.1	103.3	7.8
Bridges	11.3	10.0	10.5	10.3	9.5	-4.1
Routers	65.1	80.2	86.1	89.8	93.8	9.5
FDDI Wiring Centers	21.1	66.5	173.3	322.6	495.0	120.2

NA = Not available
Source: Dataquest (October 1992)

Table 3-8
Revenue and Shipments of Network Interface Cards to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	NA	NA	2,511.0	3,216.0	4,093.7	-
Average End-User Price ($)	NA	NA	397.0	349.0	282.0	-
End-User Revenue ($M)	NA	NA	998.0	1,123.7	1,153.2	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	5,098.9	6,080.5	6,902.9	7,335.2	7,599.4	10.5
Average End-User Price ($)	235.0	210.0	198.0	193.0	188.0	-5.4
End-User Revenue ($M)	1,198.8	1,276.7	1,368.8	1,417.3	1,429.5	4.5

NA = Not available
Source: Dataquest (October 1992)

Table 3-9
Revenue and Shipments of Ethernet NICs to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	NA	NA	1,202.0	1,846.3	2,505.4	-
Average End-User Price ($)	NA	NA	348.0	279.0	213.0	-
End-User Revenue ($M)	NA	NA	418.0	514.8	533.5	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	3,206.9	3,816.3	4,197.9	4,323.8	4,367.0	8.0
Average End-User Price ($)	170.0	147.0	136.0	129.0	124.0	-7.6
End-User Revenue ($M)	546.3	559.1	571.9	559.6	542.6	-0.2

NA = Not available
Source: Dataquest (October 1992)

Table 3-10
Revenue and Shipments of Token-Ring NICs to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	NA	NA	764.0	832.0	1,064.5	-
Average End-User Price ($)	NA	NA	627.0	621.0	501.0	-
End-User Revenue ($M)	NA	NA	479.0	516.5	533.1	-
	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Shipments (K)	1,383.8	1,771.3	2,231.8	2,566.6	2,823.2	19.5
Average End-User Price ($)	416.0	366.0	329.0	313.0	297.0	-8.1
End-User Revenue ($M)	575.2	647.9	734.7	802.7	838.8	9.9

NA = Not available
Source: Dataquest (October 1992)

Table 3-11
Revenue and Shipments of Other NIC Protocols to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	NA	NA	545.0	537.7	523.8	-
Average End-User Price ($)	NA	NA	185.0	172.0	165.0	-
End-User Revenue ($M)	NA	NA	101.0	92.4	86.6	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	508.2	492.9	473.2	444.8	409.2	-5.3
Average End-User Price ($)	152.0	141.0	131.0	124.0	118.0	-6.2
End-User Revenue ($M)	77.3	69.7	62.2	55.0	48.1	-11.2

NA = Not available
Source: Dataquest (October 1992)

Table 3-12
Revenue and Shipments of Wiring Center Access Parts to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	NA	NA	NA	1,269.8	2,162.9	-
Average End-User Price ($)	NA	NA	NA	300.0	240.0	-
End-User Revenue ($M)	NA	NA	NA	381.4	519.4	-
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	3,144.3	4,271.7	5,387.3	6,338.1	7,351.0	23.7
Average End-User Price ($)	186.0	160.0	142.0	135.0	130.0	-8.6
End-User Revenue ($M)	585.5	685.2	763.1	857.5	954.2	13.0

NA = Not available
Source: Dataquest (October 1992)

Table 3-13
Revenue and Shipments of Modems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	2156.1	2446.5	2915.5	3049.2	2853.4	7.3
Average End-User Price ($)	603.0	516.0	381.0	333.0	300.0	-16.0
End-User Revenue ($M)	1300.1	1262.4	1110.8	1015.4	856.0	-9.9
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	2724.1	2535.7	2370.4	2173.1	1760.0	-10.3
Average End-User Price ($)	290.0	280.0	270.0	260.0	250.0	-3.6
End-User Revenue ($M)	790.0	710.0	640.0	565.0	440.0	-13.6

Source: Dataquest (October 1992)

Table 3-14
Revenue and Shipments of V.32 Modems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	20.0	48.0	100.0	234.7	427.4	115.0
Average End-User Price ($)	1,500.0	1,388.0	1,100.0	900.0	695.0	-17.5
End-User Revenue ($M)	30.0	66.6	110.0	211.2	297.0	77.4
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	400.0	350.0	320.0	300.0	270.0	-9.4
Average End-User Price ($)	550.0	400.0	360.0	250.0	200.0	-22.3
End-User Revenue ($M)	220.0	140.0	115.2	75.0	54.0	-29.6

Source: Dataquest (October 1992)

Table 3-15
Revenue and Shipments of PBX Systems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	30.6	32.2	30.9	26.7	24.3	-5.6
Average End-User Price ($K)	101.5	96.8	94.0	99.4	98.9	-1.4
End-User Revenue ($M)	3,103.0	3,119.2	2,903.8	2,652.6	2,423.2	-6.0
	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
Shipments (K)	23.4	24.2	25.4	26.0	26.5	3.2
Average End-User Price ($K)	100.5	100.3	99.1	99.4	99.2	-0.3
End-User Revenue ($M)	2,370.9	2,447.9	2,542.9	2,620.1	2,666.4	3.0

Source: Dataquest (October 1992)

Table 3-16
Revenue and Shipments of PBX Lines to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	5,301.1	5,615.0	5,266.7	5,050.1	4,736.9	-2.8
New	4,330.0	4,404.0	4,157.5	3,847.4	3,526.7	-5.0
Add-On	971.0	1,211.0	1,109.2	1,202.6	1,209.1	5.6
Average End-User Price ($)	717.0	708.0	698.0	689.0	687.0	-1.0
End-User Revenue ($M)	3,103.0	3,119.2	2,903.8	2,652.6	2,423.2	-6.0
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	4,665.8	4,829.1	5,022.2	5,172.8	5,276.2	3.1
New	3,485.3	3,607.3	3,751.5	3,864.0	3,941.3	3.1
Add-On	1,180.5	1,221.8	1,270.7	1,318.8	1,334.9	3.1
Average End-User Price ($)	680.0	679.0	678.0	678.0	677.0	-0.1
End-User Revenue ($M)	2,370.9	2,447.9	2,542.9	2,620.1	2,666.4	3.0

Source: Dataquest (October 1992)

Table 3-17
Revenue and Shipments of T-1 Multiplexers to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	6.7	8.4	11.4	12.7	14.8	21.9
Average End-User Price ($K)	46.0	46.2	39.2	34.1	28.1	-11.6
End-User Revenue ($M)	308.8	388.0	445.5	433.9	416.3	7.8
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	17.5	20.6	23.1	26.7	29.8	14.2
Average End-User Price ($K)	22.8	18.9	15.9	12.7	10.4	-17.8
End-User Revenue ($M)	400.0	390.0	368.0	340.0	310.0	-6.2

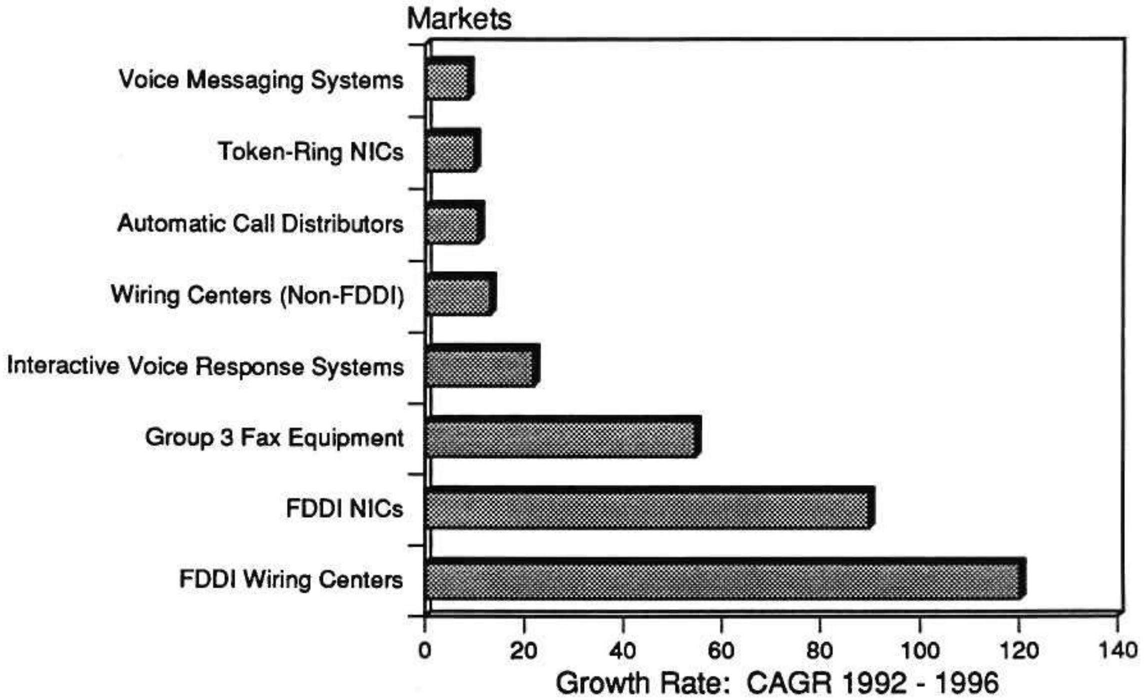
Source: Dataquest (October 1992)

Table 3-18
Revenue and Shipments of Voice Messaging Systems to the United States

	1987	1988	1989	1990	1991	CAGR (%) 1987-1991
Shipments (K)	7.0	13.6	20.5	22.7	25.9	38.5
Average End-User Price ($K)	40.5	31.7	27.5	34.4	34.3	-4.1
End-User Revenue ($M)	284.8	431.5	562.8	781.7	887.3	32.9
	1992	**1993**	**1994**	**1995**	**1996**	**CAGR (%) 1992-1996**
Shipments (K)	29.3	32.2	35.3	38.2	42.1	9.5
Average End-User Price ($K)	34.6	34.1	33.6	33.5	33.4	-0.8
End-User Revenue ($M)	1,012.2	1,099.6	1,188.2	1,280.9	1,406.7	8.6

Source: Dataquest (October 1992)

Figure 3-1
High-Growth Communications Markets in North America



Source: Dataquest (October 1992)

G2002146

The suppliers of automatic call distributors have the following market share:

- AT&T—29 percent
- Northern Telecom—23 percent
- IBM/ROLM—14 percent
- Others—34 percent

The suppliers of facsimile equipment have the following market share:

- Sharp—22 percent
- Murata/Muratec—18 percent
- Canon—12 percent
- Panasonic Co.—10 percent
- Toshiba—9 percent
- Others—29 percent

The suppliers of interactive voice response systems have the following market share:

- AT&T—9 percent
- InterVoice—6 percent
- Syntellect—6 percent
- Perception Tech.—4 percent
- Others—75 percent

The suppliers of key telephone systems have the following market share:

- AT&T—29 percent
- Northern Telecom—11 percent
- Nitsuko/TIE—9 percent
- Executone—7 percent
- Toshiba—7 percent
- Others—37 percent

The suppliers of network interface cards have the following market share:

- IBM—19 percent
- SMC/Western Digital—20 percent
- 3Com—16 percent
- Anthem—6 percent
- Others—39 percent

The suppliers of modems have the following market share:

- Codex (Motorola)—12 percent
- UDS (Motorola)—11 percent
- Hayes—10 percent
- U.S. Robotics—8 percent
- Racal-Datacom—8 percent
- Others—51 percent

The suppliers of PBX systems have the following market share:

- AT&T—28 percent
- Northern Telecom—23 percent
- ROLM—15 percent
- NEC—6 percent

- Others—28 percent

The suppliers of T-1 multiplexers have the following market share:

- Ascom/Timeplex—22 percent
- NET—20 percent
- Newbridge—15 percent
- Tellabs—11 percent
- Others—32 percent

The suppliers of voice messaging systems have the following market share:

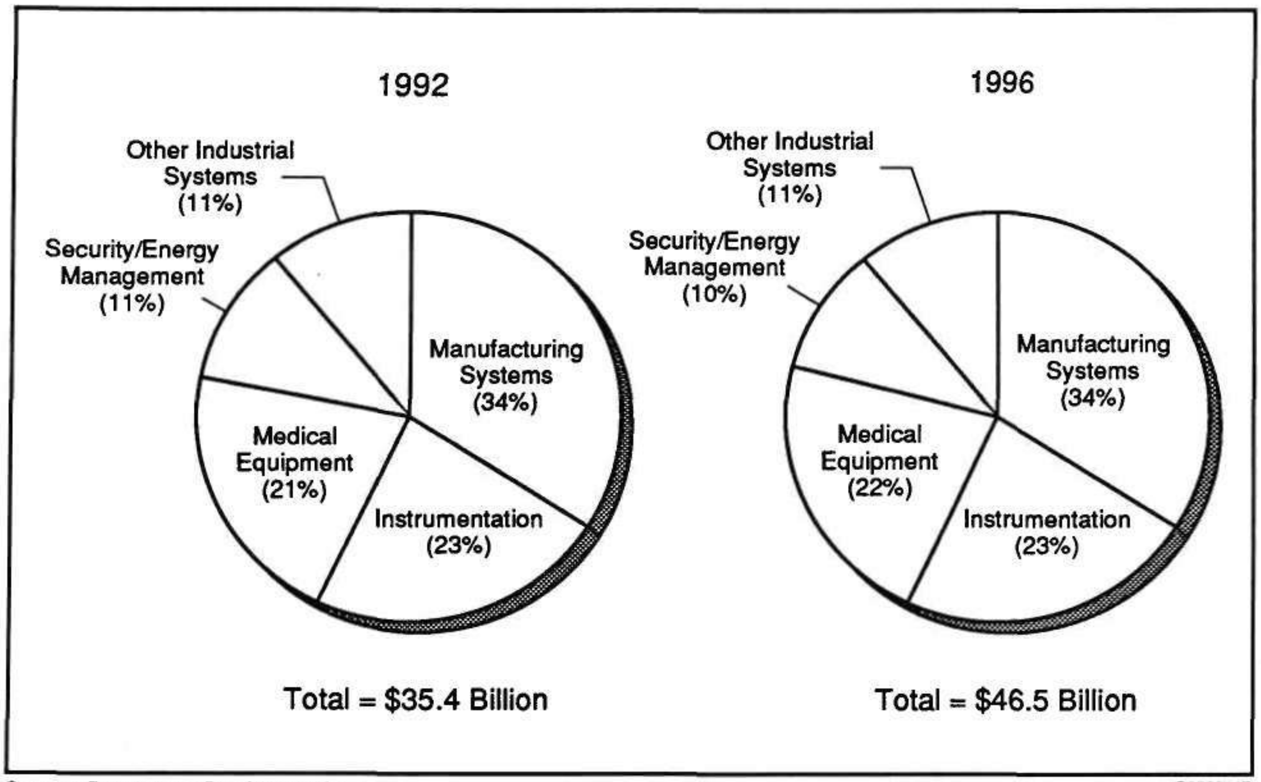
- Octel—18 percent
- AT&T—14 percent
- Northern Telecom—14 percent
- VMX—9 percent
- Others—45 percent

Chapter 4
Industrial Electronics: North America

This chapter profiles the production of industrial electronic equipment and identifies major companies involved.

Figure 4-1 shows the breakdown of the major system groups in the industrial electronic equipment market. Tables 4-1 and 4-2 present historical and forecast production and Tables 4-3 through 4-13 show the estimated historical total value of equipment production for each category. Some columns do not add to totals shown because of rounding.

Figure 4-1
Norht American Industrial Electronics Production



Source: Dataquest (October 1992) G2002147

Table 4-1
Revenue from North American Industrial Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Industrial			
Security/Energy Management			
Alarm Systems			
Intrusion Detection	804	875	904
Fire Detection	477	532	550
Total Alarm Systems	1,281	1,407	1,454
Energy Management Systems	2,209	2,284	2,327
Total Security/Energy Management	3,490	3,691	3,781
Manufacturing Systems			
Semiconductor Production	1,696	1,691	1,691
Controllers & Actuators	3,895	3,985	3,880
Sensor Systems	1,640	1,765	1,710
Management Systems	3,569	3,683	3,790
Robotics	256	275	295
Total Manufacturing Systems	11,056	11,399	11,365
Instrumentation			
ATE-Semiconductor Equipment	570	597	610
ATE-Other	1,517	1,547	1,488
Oscilloscopes & Waveform Analyzers	785	836	801
Nuclear Instruments	606	651	617
Electrical Test Instruments	1,003	1,029	972
Other Test & Measurement	3,295	3,509	3,391
Total Instrumentation	7,776	8,168	7,879

(Continued)

Table 4-1 (Continued)
Revenue from North American Industrial Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Medical Equipment			
X-Ray	1,725	1,756	1,846
Ultrasonic & Scanning	320	329	349
Blood & Body Fluid Analyzers	605	618	654
Patient Monitoring Equipment	305	313	331
Other Diagnostic & Therapeutic	3,400	3,664	4,002
Total Medical Equipment	6,355	6,680	7,182
Other Industrial Systems	3,625	3,749	3,702
Total Industrial	32,302	33,687	33,909

Source: Dataquest (October 1992)

Table 4-2
Revenue from North American Industrial Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Industrial						
Security/Energy Management						
Alarm Systems						
Intrusion Detection	947	1,023	1,102	1,170	1,242	6.6
Fire Detection	577	608	641	676	713	5.3
Total Alarm Systems	1,524	1,631	1,743	1,846	1,955	6.1
Energy Management Systems	2,405	2,513	2,634	2,761	2,894	4.5
Total Security/Energy Management	3,929	4,144	4,377	4,607	4,849	5.1
Manufacturing Systems						
Semiconductor Production	1,521	1,690	2,001	2,302	2,620	9.2
Controllers & Actuators	4,024	4,321	4,615	4,938	5,284	6.4
Sensor Systems	1,866	2,028	2,193	2,379	2,588	8.6
Management Systems	3,907	4,024	4,137	4,249	4,355	2.8
Robotics	325	359	395	432	474	9.9
Total Manufacturing Systems	11,643	12,422	13,341	14,300	15,321	6.2
Instrumentation						
ATE-Semiconductor Equipment	537	584	679	774	885	7.7
ATE-Other	1,533	1,692	1,826	1,912	2,019	6.3
Oscilloscopes & Waveform Analyzers	862	920	982	1,046	1,114	6.8
Nuclear Instruments	656	686	728	774	823	5.9
Electrical Test Instruments	1,030	1,068	1,110	1,151	1,194	4.2
Other Test & Measurement	3,676	3,954	4,233	4,558	4,908	7.7
Total Instrumentation	8,294	8,904	9,558	10,215	10,943	6.8

(Continued)

Table 4-2 (Continued)
Revenue from North American Industrial Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Medical Equipment						
X-Ray	1,922	1,966	2,005	2,043	2,082	2.4
Ultrasonic & Scanning	368	385	402	422	443	4.9
Blood & Body Fluid Analyzers	686	712	736	763	791	3.9
Patient Monitoring Equipment	346	354	361	369	377	2.6
Other Diagnostic & Therapeutic	4,332	4,804	5,288	5,848	6,467	10.1
Total Medical Equipment	7,653	8,220	8,791	9,444	10,160	7.2
Other Industrial Systems	3,964	4,269	4,481	4,830	5,206	7.1
Total Industrial	35,482	37,958	40,547	43,395	46,479	6.5

Source: Dataquest (October 1992)

Table 4-3
Revenue from North American Security/Energy Management Equipment Production (Millions of Dollars)

Equipment	1983	1984	1985	1986	1987	1988	1989	1990	1991
Intrusion Detection	516	568	590	679	781	752	804	875	904
Fire Detection	364	477	431	427	436	413	477	532	550
Alarm Systems Subtotal	880	1,045	1,021	1,106	1,217	1,165	1,281	1,407	1,454
Energy Management	1,894	1,870	1,878	1,964	2,093	2,168	2,209	2,284	2,327
Total	2,774	2,915	2,899	3,070	3,310	3,333	3,490	3,691	3,781

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-4
Revenue from North American Manufacturing Systems Equipment Production
(Millions of Dollars)

Equipment	1983	1984	1985	1986	1987	1988	1989	1990	1991
Semiconductor Production	908	1,461	1,258	1,077	1,105	1,541	1,696	1,691	1,691
Controls and Actuators	2,776	3,347	3,152	3,258	3,346	3,655	3,895	3,985	3,880
Sensor Systems	1,055	1,211	1,339	1,241	1,350	1,511	1,640	1,765	1,710
Management Systems	2,356	2,736	2,919	3,178	3,197	3,405	3,569	3,683	3,790
Robotics	231	281	345	346	284	229	256	275	295
Total	7,326	9,036	9,013	9,100	9,282	10,341	11,056	11,399	11,365

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-5
Revenue from North American Controls and Actuators Equipment Production
(Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
AC Full-Voltage Starters	372	326	350	314	386	401	383	557	573	558
Motor Control Centers	215	242	251	282	262	243	252	337	355	345
Starters and Contactors for Motors	66	81	47	50	50	44	52	130	118	115
Pilot Circuit Devices	214	200	306	271	324	363	425	419	403	392
Push Buttons, Rheostats, and Resist	243	267	319	282	301	305	341	376	256	347
Crane and Hoist Controls	29	20	28	27	20	26	37	38	45	44
Adjustable-Speed Drives	270	246	321	353	382	441	523	617	670	652
Numerical Controls	55	599	910	844	816	741	803	822	922	897
Other Controls*	1,046	1,412	1,602	1,522	1,534	1,684	1,735	1,920	1,873	1,822
Total	2,511	3,392	4,134	3,945	4,074	4,248	4,550	5,213	5,215	5,173

*Revised
Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-6
Revenue from North American Sensor Systems Equipment Production (Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Temperature	119	97	131	138	129	181	175	575	560	542
Pressure, Draft, and Vacuum	141	128	155	169	169	185	204	386	415	402
Flow and Liquid Level	548	508	585	624	594	629	694	804	891	863
Humidity Instruments	17	16	19	19	19	24	29	21	25	24
Continuous-Process Gas and Liquid Analysis	219	221	230	273	233	238	276	327	341	331
Instruments for Other Variables (Speed, Viscosity, Position, Density, Specific Gravity)	96	84	92	117	99	93	116	113	120	116
Total	1,139	1,055	1,211	1,339	1,241	1,350	1,495	2,226	2,352	2,278

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-7
Revenue from North American Management Systems Equipment Production (Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Electronic Systems (Unified Architecture Type)										
Controllers	131	145	109	92	105	106	127	153	167	162
Recorders	73	66	76	77	71	92	74	76	80	78
Indicators	33	33	27	41	35	37	42	48	44	43
Electronic Systems (Nonunified Architecture Type)	519	441	652	706	690	778	860	1,039	1,118	1,083
Multifunction Process Computers	175	171	144	135	154	178	178	182	188	182
Pneumatic Systems	63	79	62	66	61	60	64	57	52	51
Annunciators	33	13	21	37	39	22	26	26	20	19
Physical Properties Testing and Inspection Equipment	371	365	395	409	494	534	547	577	800	775
Kinematic Test and Measuring Equipment	141	129	164	113	130	149	149	177	169	164
Automatic Regulating Devices	495	505	508	622	609	515	606	897	984	953
Other Process Instruments	510	410	579	622	792	727	681	587	613	594
Total	2,544	2,356	2,736	2,919	3,178	3,197	3,353	3,820	4,235	4,103

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-8
Revenue from North American Robotic Equipment Production
(Millions of Dollars)

Equipment	1984	1985	1986	1987	1988	1989	1990	1991
Servo-Controlled Robots								
Point-to-Point Type	119	142	157	136	71	73	72	77
Continuous-Path Type	87	113	99	67	67	63	67	72
Nonservo-Controlled	16	18	16	8	17	20	15	16
Other Robots, Including Educational, Hobby, and Experimental	3	3	3	9	-	-	-	-
Robot Accessories, Subassemblies, Components, and Parts Sold Separately	40	52	57	49	56	85	99	106
Sensors	15	18	15	16	18	21	22	24
Total	281	345	346	284	229	261	275	294

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-9
Revenue from North American Instrumentation Equipment Production
(Millions of Dollars)

Equipment	1983	1984	1985	1986	1987	1988	1989	1990	1991
ATE-Semiconductor	247	476	470	460	565	581	570	597	610
ATE-Other	941	940	954	994	1,379	1,379	1,517	1,547	1,488
Oscilloscopes and Waveform Analyzers	678	739	744	679	658	714	785	836	801
Nuclear Instruments	490	480	519	560	601	616	606	651	617
Electrical Test Instruments	1,197	1,450	1,268	1,251	1,074	980	1,003	1,029	972
Other Test and Measurement	2,524	3,157	3,094	2,875	2,938	3,075	3,295	3,509	3,391
Total	6,077	7,242	7,049	6,819	7,215	7,345	7,776	8,168	7,879

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-10
Revenue from North American Electric Test Instruments Equipment Production (Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Voltage, Current, and Resistance Measuring Equipment	209	229	270	276	261	302	284	291	275	266
Multimeters	105	104	127	133	127	136	132	149	147	142
Power and Energy Measuring Equipment	19	54	59	80	101	98	79	86	95	92
Frequency Measuring	98	109	114	137	27	112	104	113	100	96
Signal-Generating Equipment	279	328	351	315	325	357	279	297	295	285
Field Strength and Intensity Measuring	129	155	211	249	231	-	-	-	-	-
Impedance and Standing Wave Ratio Measuring	50	36	54	44	49	48	49	43	40	39
X-Y Plotters	168	183	263	34	34	19	16	8	5	5
Total	1,056	1,197	1,450	1,268	1,154	1,074	943	987	956	926

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-11
Revenue from North American Other Test and Measurement Equipment Production (Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
AC Watt-Hour Meters	143	179	181	197	186	183	157	176	175	169
Combined Watt-Hour and Demand Meters and Time-Switches	70	75	85	94	103	101	119	124	122	118
Other Integrating Meters and Instruments and Parts	127	104	152	111	114	116	112	102	94	91
Standards and Calibration	134	133	131	184	145	186	196	186	166	161
Microwave Test	121	34	36	34	35	47	54	45	39	38
Communications Test	-	39	178	263	259	363	446	436	443	429
Internal Combustion Engine Analyzer	221	232	307	312	296	274	281	273	343	332
Associated Devices for Testing and Measuring	78	118	225	NA	NA	NA	NA	NA	NA	NA
Other Test, Measuring, and Analyzer	962	1,225	1,379	1,379	1,214	1,063	1,080	1,244	1,221	1,183
Geophysical and Meteorological	224	224	315	332	319	358	414	454	NA	NA
Survey and Drafting Instruments	162	162	167	188	204	247	279	331	NA	NA
Total	2,240	2,524	3,157	3,094	2,875	2,938	3,138	3,370	2,601	2,520

NA = Not available
Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-12
Revenue from North American Medical Equipment Production
(Millions of Dollars)

Equipment	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
X-ray	1,342	1,544	1,758	1,675	1,522	1,571	1,696	1,745	1,862	2,001
Ultrasonic and Scanning	300	376	294	172	244	337	417	567	659	709
Blood and Body Fluid Analyzers	641	744	715	632	572	617	-	-	-	-
Other Diagnostic	539	476	511	588	565	935	1,196	1,182	1,276	1,371
Diagnostic Subtotal	2,821	3,140	3,278	3,067	2,903	3,459	3,309	3,494	3,797	4,081
Patient-Monitoring Equipment	713	762	706	842	815	859	919	1,166	1,215	1,306
Other Therapeutic	806	778	919	818	830	871	1,029	1,150	1,339	1,439
Therapeutic subtotal	1,518	1,540	1,626	1,660	1,645	1,730	1,948	2,316	2,553	2,744
Total	4,339	4,680	4,904	4,727	4,547	5,189	5,257	5,810	6,350	6,826

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 4-13
Revenue from North American Other Industrial Systems Equipment Production (Millions of Dollars)

Year	Revenue ($M)
1983	2,625
1984	2,746
1985	2,575
1986	2,622
1987	3,266
1988	3,384
1989	3,625
1990	3,748
1991	3,702

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Key trends to note include the following:

- The bulk of this heterogeneous category is affected by capital spending outlays by business and government. This expenditure is expected to continue recovering at a slow pace throughout 1992 and 1993.
- In general these systems are converting to digital-based processing of the real-world data they encounter.
- A corollary trend is toward industrial equipment that can be networked to, and for coordination by a computer system.
- Security and energy management systems continue diffusing into almost every structure or premise. Stiffer fire codes and rising crime rates are positively affecting demand for security, fire, and intrusion systems. Energy management is being positively affected by energy conservation measures.
- Electronics-based manufacturing systems continue to be employed and updated for productivity improvement purposes. Many of these systems are becoming architecturally anchored on industrial buses such as VME and even networks of PCs and workstations. As economics warrant, sensors and actuators are converting to solid-state semiconductor technology.
- Driven by R&D, maintenance, and manufacturing requirements, instrumentation continues to have new demands placed on it. Besides the trend to being digital microprocessor-based, much instrumentation is becoming portable.
- Medical equipment is greatly affected by insurance reimbursement policies that, in general, are becoming more restrictive as soaring health costs become a political issue. However, the need for better imaging systems, low-cost doctor office/home equipment, and

personal medical electronics for blood monitoring and other uses will mitigate the negative factor already mentioned.

Security/Energy Management OEMs

The following sections identify major companies participating in the security/energy management systems arena.

Companies participating in security include the following:

- Alarm Device Manufacturing
- Cerberus Pyronics
- EyeDefinately Inc.
- Honeywell Inc.
- Johnson Controls Inc.
- Simplex Time Recorder Co.
- Wells Fargo Alarm Services

Companies participating in energy are as follows:

- 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

Manufacturing Systems OEMs

The following sections identify major companies participating in the manufacturing systems market.

Companies participating in semiconductor production, along with their areas of focus, include the following:

- Anelva (sputtering, dry etch, molecular beam epitaxy, evaporation, LPCVD, PECVD, ECR, CVD)
- Applied Materials (dry etch, silicon epitaxy, APCVD, PECVD, LPCVD, ion implantation)
- ASM Lithography (steppers, direct write and maskmaking)
- ASM International (diffusion, LPCVD, PECVD, silicon epitaxy)
- Cannon (projection aligners, steppers, contact/proximity, resist processing equipment, optical CD/wafer inspection)

- Dainippon Screen (resist processing equipment, wet process, rapid thermal processing)
- Eaton (ion implantation, resist processing equipment, dry etch, dry strip, diffusion)
- General Signal (steppers, resist processing equipment, dry etch, dry strip, diffusion, LPCVD, APCVD, sputtering)
- Hitachi (direct write and maskmaking, steppers, dry etch, dry strip, ion implantation, optical CD/wafer inspection, APCVD)
- Lam Research (dry etch, silicon epitaxy)
- Nikon (steppers, optical CD/wafer inspection)
- Silicon Valley Group (resist processing equipment, diffusion, LPCVD)
- Tokyo Electron Limited (resist processing equipment, diffusion, LPCVD, dry etch, metalorganic CVD, rapid thermal processing)
- Ulvac (sputtering, evaporation, ion implantation, molecular beam epitaxy, PECVD, LPCVD, dry etch, dry strip, metalorganic CVDE)
- Varian Associates (sputtering, ion implantation, molecular beam epitaxy, dry etch, LPCVD, rapid thermal processing, direct write and mask making)

Companies participating in other manufacturing systems, along with their areas of focus, include the following:

- Allen-Bradley (data acquisition, manufacturing process controls, programmable controls, machine tools/presses, inspection equipment)
- Bailey Controls Company (manufacturing process controls, other manufacturing control systems)
- Cincinnati Milacron (manufacturing process controls, programmable controls for machine and factory process, FMS materials handling equipment, machine tool accessories/tools)
- Fisher Controls (manufacturing process controls)
- Fisher & Porter Co. (manufacturing process controls)
- General Electric (data acquisition/ID equipment, manufacturing process controls, programmable controls for machines and factory processes)
- Johnson Controls (manufacturing process controls)
- Leeds & Northrup Co. (manufacturing process controls, programmable controls for machines, other material handling/shipping equipment)
- Measurex (sensor systems)
- Modicon (data acquisition/ID equipment, manufacturing process controls for machines, programmable controls for machines and factory processes)

- Texas Instruments (manufacturing process controls)
- Westinghouse (data acquisition/ID equipment, manufacturing process controls, other manufacturing control systems, machine tools/presses)

Companies participating in robotics include the following:

- 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.

Instrumentation OEMs

The following is a sample of the major companies participating in the electronic instrumentation category:

Companies participating in automatic test equipment include the following:

- Advantest
- Asia Electronics
- Credence
- GenRad
- Hewlett-Packard
- LTX
- Megatest
- Minato
- Schlumerger
- Tektronix
- Teradyne

Companies participating in electrical test instruments include the following:

- Analogic Corporation (oscilloscopes)
- Ametek Inc. (infrared analyzers, calibrators, data logging/ acquisition, flow measuring equipment, level measuring equipment)

- EG&G (data recorders, oscilloscopes, detection equipment, seismograph measuring equipment, geophysical measuring equipment, flow measuring equipment, frequency measuring equipment, spectrometers)
- Fisher Controls (electronic function controls)
- Gould (computer-related analyzers, oscilloscopes, data logging/acquisition equipment, data recorders, waveform analyzers)
- Hewlett-Packard (oscilloscopes, bar code readers, analyzers, counters/timers, data recorders, multimeters, power measuring equipment, spectrophotometers)
- John Fluke (oscilloscopes, analyzers, counters/timers, voltmeters)
- LeRoy Corporation (oscilloscopes)
- IFR Systems (oscilloscopes)
- Millipore/Chromatography Division (scientific instruments, counters/recorders)
- Nicolet (oscilloscopes, mass spectrometers)
- Schlumerger (indicators, power measuring equipment, electrical measuring equipment, geophysical measuring equipment, oscilloscopes, analyzers, data logging/acquisition equipment)
- Teledyne (chemical/physical analyzers, infrared analyzers, other analyzers, calibrators, energy fuel retrieval equipment, geophysical equipment, seismograph measuring equipment, voltmeters)
- Tektronix (oscilloscopes, analyzers, calibrators)
- Tracor Inc. (analyzers, data recorders, detection equipment, spectroscopy equipment, spectrophotometers)
- Westinghouse (data recorders, detection equipment, electronic function controls)

Medical Electronics OEMs

The following is a sample of major companies participating in the medical electronics arena:

- Abbot Laboratories
- Acuson
- Bard (CR)
- Baxter International
- Becton, Dickenson
- Diasonics
- Eli Lilly
- Medtronic

- General Electric
- GEC, U.K.
- Siemens
- Philips
- Hitachi
- Toshiba

Chapter 5
Consumer Electronics: North America

This chapter provides market statistics of the consumer electronic equipment market in North America.

The 1980s saw the introduction of a new generation of consumer electronics gear—VCRs and compact disc players—made possible by new and more powerful integrated circuits, and mass marketing and manufacturing. In the 1990s, products such as interactive television, multimedia computing, and digital compact cassette recorders are expected to change and fine-tune the home entertainment, communications, and educational possibilities available in North America and the world.

Demographics and Economics

Population and population growth play an important long-run role (but by no means a sufficient role) in determination of the size and growth potential of the consumer electronics market. Working-age population and population growth for the Group of Seven (G7) industrialized economies are in Table 5-1.

The growth in the value of a country's production is an important short- and long-run indicator of overall economic performance, and therefore an indicator of consumer market potential. Real gross domestic product (GDP) growth for the G7 countries is in Table 5-2 (effects of changing relative values of currencies are corrected by measuring GDP levels in local currencies.)

A related measure of economic performance is per-capita real GDP (see Table 5-3). (Note that the levels and growth rates in Table 5-3 assume purchasing power parity exchange rates, a statistical adjustment that ensures that the purchasing power in terms of goods for each currency is the same regardless of where the currency is used to buy goods.)

Housing starts and per-capita disposable personal income are also important indicators of consumer electronics market potential. Table 5-4 has U.S. estimates for these statistics.

Table 5-1
Working Age Population in G7 Countries

	Population, 15-64 Years (Thousands)					
Country	1980	1981	1982	1983	1984	1985
Canada	16,231	16,499	16,692	16,845	16,986	17,110
France	34,320	34,796	35,278	35,703	36,081	36,328
Germany	40,828	41,427	41,973	42,390	42,655	42,740
Italy	37,121	37,351	37,879	38,375	39,000	39,286
Japan	78,700	78,180	79,860	80,670	81,550	82,310
United Kingdom	36,078	36,302	36,498	36,763	37,104	37,163
United States	150,751	152,566	154,203	155,661	157,224	158,811
	Percentage Rate of Change					
Country	1980	1981	1982	1983	1984	1985
Canada	1.83	1.65	1.17	0.92	0.84	0.73
France	1.05	1.39	1.39	1.20	1.06	0.68
Germany	1.34	1.47	1.32	0.99	0.63	0.20
Italy	0.26	0.62	1.41	1.31	1.63	0.73
Japan	0.94	-0.66	2.15	1.01	1.09	0.93
United Kingdom	0.61	0.62	0.54	0.73	0.93	0.16
United States	1.54	1.20	1.07	0.95	1.00	1.01

(Continued)

Table 5-1 (Continued)
Working Age Population in G7 Countries

Country	Population, 15-64 Years (Thousands)					
	1986	1987	1988	1989	1990	1991
Canada	17,246	17,403	17,580	17,764	17,977	18,110
France	36,480	36,663	36,856	37,032	37,144	37,270
Germany	42,798	42,826	42,960	43,258	43,782	43,864
Italy	39,405	39,396	39,823	39,609	39,737	39,752
Japan	83,120	83,930	84,760	85,510	86,100	86,460
United Kingdom	37,281	37,368	37,422	37,458	37,502	37,484
United States	160,438	161,687	162,847	163,864	165,052	166,372
	Percentage Rate of Change					
Country	1986	1987	1988	1989	1990	1991
Canada	0.79	0.91	1.02	1.05	1.20	0.74
France	0.42	0.50	0.53	0.48	0.30	0.34
Germany	0.14	0.07	0.31	0.69	1.21	0.19
Italy	0.30	-0.02	1.08	-0.54	0.32	0.04
Japan	0.98	0.97	0.99	0.88	0.69	0.42
United Kingdom	0.32	0.23	0.14	0.10	0.12	-0.05
United States	1.02	0.78	0.72	0.62	0.72	0.80

Source: Organization of Economic Cooperation and Development, Dataquest (October 1992)

Table 5-2
Real Gross Domestic Product (Percentage Change in Local Currencies)

Country	1980	1981	1982	1983	1984	1985
Canada	1.1	3.4	-3.2	3.2	6.3	4.8
France	1.6	1.2	2.6	0.7	1.3	1.9
Germany	1.0	0.1	-1.1	1.9	3.1	1.8
Italy	1.0	0.6	0.2	1.0	2.7	2.6
Japan	3.5	3.4	3.4	2.8	4.3	5.2
United Kingdom	-1.7	-1.0	1.5	3.5	2.2	3.6
United States	-0.5	1.8	-2.2	3.9	6.2	3.2
Country	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Canada	3.3	4.2	4.7	2.5	0.5	-1.5
France	2.5	2.3	4.5	4.1	2.3	1.3
Germany	2.2	1.5	3.7	3.8	4.5	3.1
Italy	2.9	3.1	4.1	2.9	2.2	1.4
Japan	2.6	4.3	6.2	4.8	5.2	4.5
United Kingdom	3.9	4.8	4.3	2.3	1.0	-2.2
United States	2.9	3.1	3.9	2.5	1.0	-0.7

Source: Organization of Economic Cooperation and Development, Dataquest (October 1992)

Table 5-3
Per-Capita Real Gross Domestic Product at Purchasing Power Parity Exchange Rates (1990 U.S.$)

Country	1980	1981	1982	1983	1984	1985
Canada	16,671	17,070	16,359	16,738	17,658	18,362
France	13,224	13,305	13,569	13,601	13,725	13,927
Germany	13,446	13,445	13,327	13,582	14,017	14,317
Italy	12,235	12,284	12,281	12,359	12,656	12,952
Japan	12,226	12,572	12,882	13,140	13,613	14,205
United Kingdom	12,058	11,927	12,097	12,552	12,733	13,169
United States	18,077	18,240	17,608	18,089	19,175	19,676
			Percentage Rate of Change			
Country	1980	1981	1982	1983	1984	1985
Canada	0.23	2.39	-4.17	2.32	5.50	3.99
France	1.11	0.61	1.98	0.24	0.91	1.47
Germany	0.73	-0.01	-0.88	1.91	3.20	2.14
Italy	4.00	0.40	-0.02	0.64	2.40	2.34
Japan	2.82	2.83	2.47	2.00	3.60	4.35
United Kingdom	-2.09	-1.09	1.43	3.76	1.44	3.42
United States	-1.32	0.90	-3.46	2.73	6.00	2.61

(Continued)

Table 5-3 (Continued)
Per-Capita Real Gross Domestic Product at Purchasing Power Parity Exchange Rates (1990 U.S.$)

Country	1986	1987	1988	1989	1990
Canada	18,830	19,390	20,014	20,352	20,257
France	14,220	14,478	15,015	15,528	15,895
Germany	14,626	14,831	15,280	15,619	16,079
Italy	13,309	13,699	14,229	14,639	14,894
Japan	14,490	15,011	15,875	16,540	17,406
United Kingdom	13,654	14,245	14,763	14,999	15,064
United States	20,060	20,583	21,284	21,598	21,571
			Percentage Rate of Change (%)		
Country	1986	1987	1988	1989	1990
Canada	2.55	2.97	3.22	1.69	-0.47
France	2.10	1.81	3.71	3.42	2.36
Germany	2.16	1.40	3.03	2.22	2.95
Italy	2.76	2.93	3.87	2.88	1.74
Japan	2.01	3.60	5.76	4.19	5.24
United Kingdom	3.68	4.33	3.64	1.60	0.43
United States	1.95	2.61	3.41	1.48	-0.13

Source: Organization of Economic Cooperation and Development, Dataquest (October 1992)

Table 5-4
Consumer Electronics' Potential Indicators in the United States, New Housing Starts and Per-Capita Disposable Personal Income

	1980	1981	1982	1983	1984	1985
New Housing Starts (Thousands of Units)	12,004	12,156	12,146	12,348	13,029	13,258
Per-Capita Disposable Personal Income (1982 Dollars)	1,300	1,096	1,057	1,705	1,766	1,741
	1986	**1987**	**1988**	**1989**	**1990**	**1991**
New Housing Starts (Thousands of Units)	13,552	13,545	13,889	14,006	14,068	13,886
Per-Capita Disposable Personal Income (1982 Dollars)	1,812	1,631	1,488	1,382	1,206	1,015

Source: U.S. Department of Commerce, Dataquest (October 1992)

International Trade

Highlights of international trade include the following:

- Imports of consumer electronics to the United States were $14.9 billion in 1991, an increase of 1.3 percent from 1990. Videocassette recorders/players accounted for about 32 percent of the import dollar volume. Total audiotape equipment accounted for the second largest category with imports of more than $2.9 billion, while color television imports totaled $1.6 billion. Total dollar values of key import categories are in Table 5-5.
- Total 1991 exports of consumer electronics amounted to $2.7 billion, a 13 percent increase over 1990. Exports of color televisions accounted for nearly 18 percent of the dollar value of total exports. This represented growth of over 16 percent from exports of color televisions in 1990. Exports of automobile radios also showed strong growth, rising 9 percent to $277 million. Total dollar values of key export categories are in Table 5-5.
- In total, consumer electronics imports exceeded exports by $12.1 billion in 1991, a decline of 1.1 percent from 1990's $12.3 billion net import position.

Production Outlook

As is usually the case, production of consumer electronic equipment has borne the brunt of the recent downturn in business conditions. North American production is expected to rebound in 1993 as household budget constraints are relaxed in response to the expected income growth (see Tables 5-6 and 5-7). Figure 5-1 shows the distribution of consumer electronics production in North America.

Table 5-5
1991 U.S. Consumer Electronics Trade Estimates (Millions of Dollars)

Product	Exports	less	Imports	equals	Net Exports
Audio Equipment	227		1,024		-797
Color TVs	492		1,603		-1,111
Monochrome TVs	57		89		-32
Home Radios	63		736		-673
VCRs	0		4,763		-4,763

Source: Electronic Industries Association, U.S. Department of Commerce, Dataquest (October 1992)

Table 5-6
Revenue from North American Consumer Electronic Equipment Production, 1989-1996 (Millions of Dollars)

Equipment	1989	1990	1991	1992	1993	1994	1995	1996
Audio								
Compact Disc Players	8	9	9	9	9	9	9	9
Radio	228	233	205	212	219	227	235	243
Stereo Components	208	207	204	214	227	238	248	260
Musical Instruments	235	240	235	238	253	265	277	289
Tape Recorders	19	18	18	17	17	17	17	17
Total Audio	698	707	671	690	725	756	786	818
Video								
VTRs, VCRs	245	265	266	272	290	309	329	350
Videodisk Players	1	1	1	0	0	0	0	0
Color Televisions	3,160	3,110	3,115	3,193	3,337	3,487	3,644	3,808
Total Video	3,406	3,376	3,382	3,465	3,627	3,796	3,973	4,158
Personal Electronics								
Games	301	316	335	347	359	371	384	398
Cameras	25	25	24	24	25	26	27	28
Watches	100	90	82	75	70	65	60	55
Clocks	53	50	48	48	49	49	49	49
Total Personal Electronics	479	481	489	494	503	511	520	530

(Continued)

Table 5-6 (Continued)
Revenue from North American Consumer Electronic Equipment Production, 1989-1996
(Millions of Dollars)

Equipment	1989	1990	1991	1992	1993	1994	1995	1996
Appliances								
Air Conditioners	1,846	1,935	1,683	1,758	1,855	1,957	2,065	2,168
Microwave Ovens	619	531	478	500	527	556	587	616
Washers and Dryers	2,981	3,032	2,973	3,106	3,277	3,457	3,648	3,830
Refrigerators	4,024	3,923	3,962	4,141	4,368	4,609	4,862	5,105
Dishwashers	979	981	971	1,015	1,071	1,130	1,192	1,251
Range and Ovens	982	956	966	1,009	1,065	1,123	1,185	1,244
Total Appliances	11,431	11,358	11,033	11,529	12,163	12,832	13,539	14,214
Other Consumer								
Automatic Garage Door Openers	255	263	260	272	284	297	310	324
Other Consumer Equipment, NEC	813	810	825	862	914	969	1,027	1,083
Total Other Consumer	1,068	1,073	1,085	1,134	1,198	1,266	1,337	1,407
Total Consumer	17,082	16,995	16,660	17,312	18,216	19,161	20,155	21,127

Source: Dataquest (October 1992)

Table 5-7
Revenue Growth from North American Consumer Electronic Equipment Production, 1989-1996 (Percentage Change)

Equipment	1989	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Audio									
Compact Disc Players	166.7	12.5	0	0	0	0	0	0	0
Radio	-9.2	2.2	-12.0	3.4	3.3	3.7	3.5	3.4	3.5
Stereo Components	1.0	-0.5	-1.4	4.9	6.1	4.8	4.2	4.8	5.0
Musical Instruments	4.4	2.1	-2.1	1.3	6.3	4.7	4.5	4.3	4.2
Tape Recorders	5.6	-5.3	0	-5.6	0	0	0	0	-1.1
Total Audio	-0.7	1.3	-5.1	2.8	5.1	4.3	4.0	4.1	4.0
Video									
VTRs, VCRs	-7.5	8.2	0.4	2.3	6.6	6.6	6.5	6.4	5.6
Videodisk Players	-88.9	0	0	0	0	0	0	0	-100.0
Color Televisions	22.0	-1.6	0.2	2.5	4.5	4.5	4.5	4.5	4.1
Total Video	18.9	-0.9	0.2	2.5	4.7	4.7	4.7	4.7	4.2
Personal Electronics									
Games	32.6	5.0	6.0	3.6	3.5	3.3	3.5	3.6	3.5
Cameras	8.7	0	-4.0	0	4.2	4.0	3.8	3.7	3.1
Watches	0	-10.0	-8.9	-8.5	-6.7	-7.1	-7.7	-8.3	-7.7
Clocks	-3.6	-5.7	-4.0	0	2.1	0	0	0	0.4
Total Personal Electronics	18.3	0.4	1.7	1.0	1.8	1.6	1.8	1.9	1.6

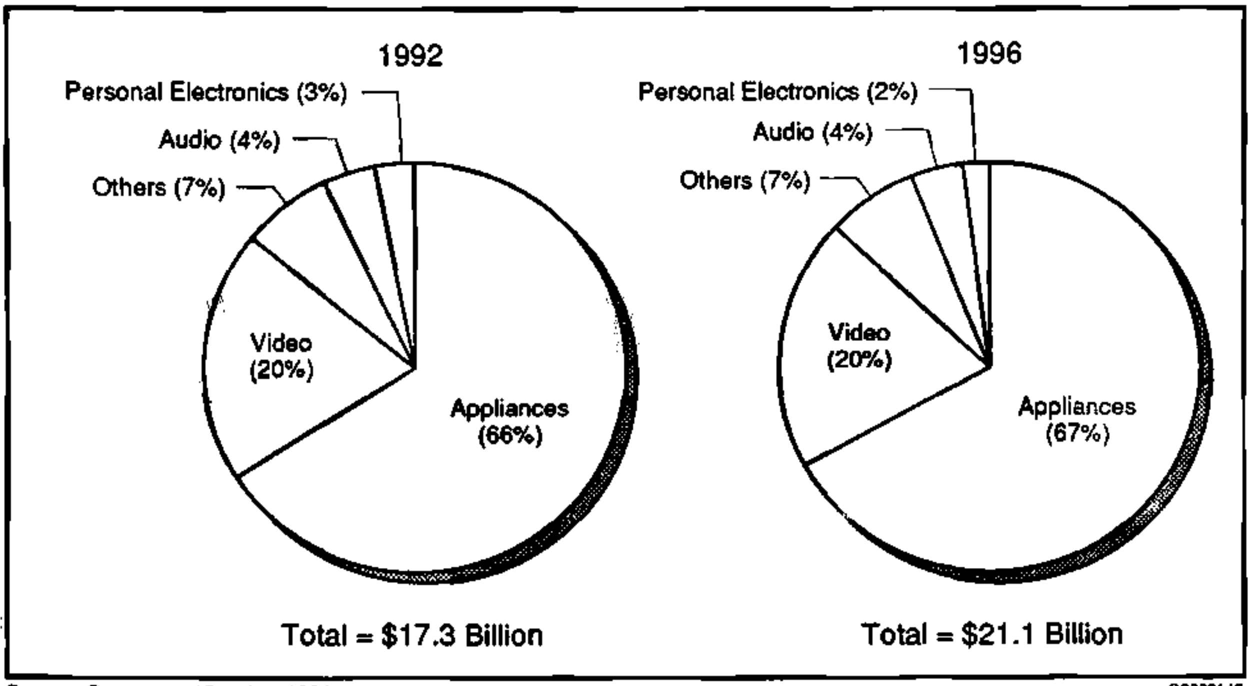
(Continued)

Table 5-7 (Continued)
Revenue Growth from North American Consumer Electronic Equipment Production, 1989-1996
(Percent Change)

Equipment	1989	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Appliances									
Air Conditioners	6.8	4.8	-13.0	4.5	5.5	5.5	5.5	5.0	5.2
Microwave Ovens	-13.5	-14.2	-10.0	4.6	5.4	5.5	5.6	4.9	5.2
Washers and Dryers	3.2	1.7	-1.9	4.5	5.5	5.5	5.5	5.0	5.2
Refrigerators	20.8	-2.5	1.0	4.5	5.5	5.5	5.5	5.0	5.2
Dishwashers	11.1	0.2	-1.0	4.5	5.5	5.5	5.5	4.9	5.2
Range and Ovens	4.7	-2.6	1.0	4.5	5.6	5.4	5.5	5.0	5.2
Total Appliances	9.1	-0.6	-2.9	4.5	5.5	5.5	5.5	5.0	5.2
Other Consumer									
Automatic Garage Door Openers	-3.8	3.1	-1.1	4.6	4.4	4.6	4.4	4.5	4.5
Other Consumer Equipment, NEC	10.5	-0.4	1.9	4.5	6.0	6.0	6.0	5.5	5.6
Total Other Consumer	6.7	0.5	1.1	4.5	5.6	5.7	5.6	5.2	5.3
Total Consumer	10.5	-0.5	-2.0	3.9	5.2	5.2	5.2	4.8	4.9

Source: Dataquest (October 1992)

Figure 5-1
North American Consumer Electronics Production



Source: Dataquest (October 1992)
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Manufacturing

Table 5-8 lists major consumer electronics equipment and appliance manufacturers with manufacturing facilities in the United States.

Audio Equipment

Digital audio is setting higher standards for fidelity than ever before. The trend continues toward multiroom systems and secondary systems in rooms other than the main room for home entertainment listening or viewing.

Table 5-9 lists unit shipments of audio equipment to the United States in 1991. Also noted, where data are available, are the household saturation rates (for 1990, the latest estimates available at the time of publication) and unit replacements. (Saturation is defined as the percentage of U.S. households with a particular type of appliance, and does not reflect households with more than one of a particular appliance.)

Table 5-8
Major Consumer Electronic Manufacturers with U.S. Facilities

Manufacturer	Products
Emerson Radio	Audio
General Electric	Appliances
Kodak	Personal electronics
Litton Industries	Appliances
Matsushita Electric	Video
Mitsubishi Electric	Video
North American Philips	Video
Pioneer Electronics	Audio
Poloroid	Personal electronics
Raytheon	Appliances
Sanyo	Video, audio
Sharp	Video
Sony	Video
Tandy	Audio, personal electronics
Texas Instruments	Personal electronics
Thomson	Video
Toshiba	Video, audio
White Consolidated Industries	Appliances
Whirlpool	Appliances
Zenith	Video

Source: *Appliance*, Dataquest (October 1992)

Video Equipment

Current technology emphasizes the steady emergence of advanced television and new uses for the television screen. Digital high fidelity and multichannel sound for video are reviving a wave of interest in audio and leading to the integration of audio and video in products such as laser disk audio/video combination players, which play both compact audio disks and laser videodisks.

The complex combination of audio and video is perhaps best demonstrated by the increasingly popular home theater concept. The mix of mutlidimensional surround sound and theater-quality video creates a heretofore unachievable home entertainment environment.

Table 5-10 lists unit shipments of video equipment to the United States in 1991. Also noted, where data are available, are the household saturation rates (for 1990, the latest estimates available at the time of publication) and unit replacements.

Table 5-9
1991 Shipments of Audio Equipment to the United States (Thousands of Units)

	Shipments	1990 Penetration* (%)	Replacements
Total Audio Equipment			
Portable Audio Equipment	39,669	NA	NA
Players Only	4,986	NA	NA
Recorders/Players	5,831	NA	NA
Radio/Tape/CD Combinations	28,852	NA	NA
Home Radios	18,530	98.0	NA
Clock Radios	10,958	NA	NA
Portable Radios	7,374	NA	NA
Table Radios	198	NA	NA
Audio Hi-Fi Systems			
Compact Systems	3,139	62.0	1,659
Component Systems	6,959	64.0	NA
Amps and Preamps	338	NA	NA
Cassette Decks	695	NA	NA
Compact Disc Players	3,422	28.0	NA
Equializers	192	NA	NA
Receivers	2,109	NA	1,4402
Tuners	203	NA	NA

*1990 penetration rates are latest estimates at time of publication.
NA = Not available
Source: *Appliance,* Electronics Industry Association, Dataquest (October 1992)

Table 5-11 lists the top three companies' share of total unit shipments of video equipment to the United States in 1990. Estimates represent the approximate 1990 percentage of products produced by each manufacturer for the U.S. video equipment market (including private brands).

Home Appliances

Table 5-12 lists unit shipments of home appliances to the United Sates in 1991. Also noted, where data are available, are the household saturation rates (for 1990, the latest estimates available at the time of publication) and unit replacements.

Table 5-10
1991 Shipments of Video Equipment to the United States
(Thousands of Units)

	Shipments	1990 Penetration* (%)	Replacements
Total Video Equipment	37,091	NA	NA
Color Receivers	22,109	97.2	13,939
Consoles	1,526	NA	NA
LCD TVs	500	7.0	NA
Projection TVs	398	7.0	770
Table and Portable	19,023	NA	NA
TV/VCR Combined	662	3.0	NA
Videocassette Recorders	13,688	NA	NA
VCR Decks	10,809	72.0	4,091
Camcorders	2,879	15.0	NA
Monochrome Receivers	784	42.0	5,765
Satellite Earth Stations	310	3.0	NA
Videodisk Players	200	6.6	NA

*1990 penetration rates are latest estimates at time of publication.
NA = Not available
Source: *Appliance*, Electronics Industry Association, Dataquest (October 1992)

Table 5-11
1990 Top Three Companies' Share of Total Unit Shipments of Video Equipment to the United States (Percentage)

Company	Market Share (%)
Camcorders	
Sony	18
Thomson	18
Matsushita	14
Color TVs	
Thomson	21
Philips	13
Zenith	12
VCRs	
Matsushita	21
Thomson	15
Emerson	9
Videodisk Players	
Pioneer	40
Sony	35
Matsushita	7

Source: *Appliance*, Electronic Industry Association, Dataquest (October 1992)

Table 5-13 lists the top three companies' share of total unit shipments of home appliances to the United States in 1990. Estimates represent the approximate 1990 percentage of products produced by each manufacturer for the United States appliance market (including private brands.)

Table 5-12
1991 Shipments of Appliances to the United States (Millions of Units)

	Shipments	1990 Penetration* (%)	Replacements
Total Appliances	89,454	NA	NA
Electric Housewares	38,690	NA	NA
Irons	14,690	89.5	10,797
Coffeemakers	14,000	72.6	15,488
Smoke Detectors	10,000	NA	6,970
Major Appliances	36,057	NA	NA
Microwave Ovens	8,335	83.7	3,585
Refrigerators	7,237	99.9	4,577
Ranges	5,779	59.0	5,297
Dryers	4,581	45.0	3,610
Washers	6,555	72.8	4,812
Dishwashers	3,571	51.8	2,484
Air Conditioners	6,103	32.0	5,336

*1990 penetration rates are latest estimates at time of publication.
NA = Not available
Source: *Appliance*, Dataquest (October 1992)

Table 5-13
1990 Top Three Companies' Share of Total Unit Shipments of Appliances to the United States (Percentage)

Company	Market Share (%)
Air Conditioners	
Fedders	23
Electrolux	19
Whirlpool	19
Dishwashers	
GE	40
Whirlpool	32
Maytag	20
Dryers	
Whirlpool	51
GE	17
Maytag	15
Microwave Ovens	
Sharp	18
Samsung	17
Matsushita	15
Ranges	
GE	40
Electrolux	20
Whirlpool	17
Refrigerators	
GE	34
Whirlpool	23
Electrolux	20
Washers	
Whirlpool	51
Maytag	18
GE	16

Source: *Appliance*, Dataquest (October 1992)

Chapter 6
Military and Civil Aerospace Electronics: North America

Tables 6-1 through 6-8 and Figures 6-1 and 6-2 present key data and Dataquest's forecast for the military and civil aerospace electronics market. Key trends to note include the following:

- Overall decline for defense spending will continue across the board from the NATO countries in response to the ending of the cold war.
- Demand will be weaker for military wares out of traditional export markets in the Middle East; demand will grow with the Asia/Pacific countries such as Taiwan and South Korea.
- Remaining 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. New systems will be required for this role including portable communication, satellite surveillance and communication, and small-scale C^3I systems.
- Civil space programs will continue to flourish as they receive some funds diverted from the military programs.
- The space station Freedom will be the single largest space project over the next decade, requiring an estimated $15 billion in electronics systems in space and on the ground.
- There are at least a half dozen proposals to launch arrays of satellites to provide global and local cellular communication to areas such as Asia, Africa, and Eastern Europe. There also are several direct broadcast satellite (DBS) systems planned to provide interactive services and HDTV reception.
- There are ongoing decade-long projects to upgrade the world's air traffic control systems.

Table 6-1
Revenue from North American Military/Civil Aerospace Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Military/Civil Aerospace			
Military Aerospace			
Radar/Sonar	9,326	9,000	7,182
Missile-Weapon	6,461	6,280	6,085
Space	5,552	5,608	5,022
Communication/Navigation	6,546	6,317	5,230
Electronic Warfare	5,571	5,627	4,628
Aircraft Systems	4,312	4,204	3,390
Computer Systems	2,308	2,421	2,430
Simulation	845	946	1,004
Misc. Equipment, NEC	10,806	10,698	9,662
Total Military Aerospace	51,727	51,101	44,633
Civil Aerospace			
Radar	2,080	2,288	2,495
Space	2,818	3,114	3,343
Communication/Navigation	808	990	1,165
Flight Systems	2,198	2,791	3,291
Simulation	245	285	330
Total Civil Aerospace	8,149	9,468	10,624
Total Military/Civil Aerospace	59,876	60,569	55,257

Source: Dataquest (October 1992)

Table 6-2
Revenue from North American Military/Civil Aerospace Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Military/Civil Aerospace						
Military Aerospace						
Radar/Sonar	6,643	6,411	6,186	5,970	5,761	-4.3
Missile-Weapon	6,420	6,709	7,010	7,326	7,656	4.7
Space	4,595	4,687	4,781	4,805	4,757	-1.1
Communication/Navigation	4,969	4,919	4,870	4,821	4,676	-2.2
Electronic Warfare	4,420	4,353	4,332	4,288	4,203	-1.9
Aircraft Systems	3,237	3,205	3,173	3,189	3,125	-1.6
Computer Systems	2,527	2,628	2,733	2,843	2,956	4.0
Simulation	1,054	1,107	1,162	1,220	1,281	5.0
Misc. Equipment, NEC	9,324	8,904	8,459	7,952	7,395	-5.2
Total Military Aerospace	43,189	42,923	42,706	42,414	41,810	-1.3
Civil Aerospace						
Radar	2,695	2,897	3,114	3,301	3,466	6.8
Space	3,711	4,397	5,277	6,332	7,598	17.8
Communication/Navigation	1,270	1,371	1,467	1,570	1,680	7.6
Flight Systems	3,702	4,073	4,460	4,839	5,080	9.1
Simulation	370	407	439	468	498	8.6
Total Civil Aerospace	11,748	13,145	14,757	16,510	18,322	11.5
Total Military/Civil Aerospace	54,937	56,068	57,463	58,924	60,132	1.7

Source: Dataquest (October 1992)

Table 6-3
Long-Range U.S. Defense Budget, Fiscal Years
(Billions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Military Personnel	79	78.3	77.1	72.3	71.9	73.6	-1.4
Operations and Maintenance	86	85.8	86.5	83.7	85.4	88.1	0.5
Procurement	64.1	64.7	54.4	58.8	63.3	61.5	-0.8
RTD&E	34.6	38	38.8	39.7	37.9	36.8	1.2
Construction	5	4.9	6.2	9	7.2	6	3.7
Housing	3.3	3.6	4	3.9	3.7	3.7	2.3
Other	1	3	1.5	1.4	1.3	1.4	7.0
Total	273	278.3	268.5	268.8	270.7	271.1	-0.1

Source: U.S. Department of Defense

Table 6-4
Major U.S. Defense Program Spending (Procurement and RTD&E), Fiscal Years (Billions of Dollars)

	1991	1992	1993
Aircraft Programs			
AH-64 Helicopter	88.4	209.9	170.3
RAH-66 Comache	333.7	538.8	443
UH-60L Blackhawk	152.4	507.5	428.5
AX Attack Aircraft	137.5	0	165.6
EA-6B Remanufacture	368.2	128.1	617.9
CH/MH-53 Super Stallion	342.6	511.1	527.5
F/A 18 C-F	1901	2661	3035
F-14D Remanufacture	1239	317	244
B-2 Stealth Bomber	4144	4369	4028
C-17 Airlift	1021	2260	3140
E-8A JSTARS	216.1	467.4	743.7
F-15E Eagle	2275	918	91.5
F-16 Falcon	2155	1404	900.9
F-22 ATF	943.5	1621.1	2224.3
Missile Programs			
AAWS-M Javelin	75.9	119.8	109.7
ATACMS Tactical Missile	241.9	176.4	188.2
Avenger	117.6	186.1	164.9
Patriot	1048.7	194	67.8
MLRS	615.8	206.5	230.9
TOW-2	338.5	273.9	183.1
AMRAAM	852	794	915.1
Standard	341.6	376.9	297.5
Tomahawk	1097.4	470.8	422.6
Trident II	1665.8	1259.7	1054.9
Navy Vessels			
CVN-68 Aircraft Carrier	15.8	168.2	859.2
DDG-51 AEGIS Destroyer	3276.7	4244.7	3591.6
Space Systems			
FLTSATCOM Satellites	244.4	283.1	326
DMSP Satellites	197.2	135	55.9
DSP Satellites	607.8	122.5	371.5
Medium Launch Vehicle	500.7	288.1	302.1
Milstar	955.6	1375.7	1533.9

(Continued)

Table 6-4 (Continued)
Major U.S. Defense Program Spending (Procurement and RTD&E), Fiscal Years (Billions of Dollars)

	1991	1992	1993
Navstar (GPS)	282.6	396.8	419.7
Unmanned Aerial Vehicles	132	205.3	278
Strategic Defense Initiative	2703.3	3286.9	4364.9
Miscellaneous			
M-I Tank	805.9	136.2	87.2
Bradley Fighting Vehicle	667.3	108.6	112.9
Lonbow	197	232.2	281.8
SINCGARS Radio	265.6	340.2	283.2

Source: U.S. Department of Defense

Table 6-5
1990 Defense Electronics Revenue of Top Companies
(Billions of Dollars)

GM Hughes Electronics	6.7
Thomson-CSF	5.5
General Electric	5.4
Raytheon	5.0
GEC	3.5
Lockheed	3.4
Westinghouse	2.9
Martin-Marietta	2.9
Unisys	2.2
Deutsche Aerospace	2.2
Texas Instruments	2.1
Loral	2.0
IBM	1.9
Litton Industries	1.9
GTE	1.8
ITT	1.6
British Aerospace	1.6
Boeing	1.6
E-Systems	1.5
Selenia	1.5
Mitsubishi Electric	1.4
Rockwell International	1.3
Allied Signal	1.3
Textron	1.3
TRW	1.2
Siemens	1.1
Aerospatiale	1.1
Matra	1.1
Teledyne	1.0
Northrop	0.9
NEC	0.8

Source: *Defense Electronics*

Table 6-6
Principal Military/Aerospace Electronic Equipment 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
GE	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	
Martin Marietta	X			X	X	X		
Rockwell	X			X	X	X	X	X
Texas Instruments	X			X		X		X
Litton				X		X	X	X
Honeywell			X	X	X	X	X	X
Westinghouse	X	X	X	X	X		X	X
IBM	X		X		X			
ITT		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	
Loral/Ford	X			X	X		X	X
GTE							X	X
Ferranti	X	X			X	X		

(Continued)

Table 6-6 (Continued)
Principal Military/Aerospace Electronic Equipment Producers

Company	Airborne	Radar Ship/Ground	Sonar	Missile Weapon	Space	Navigation	Communication	Electronic Warfare
Boeing	X			X	X			X
British Aerospace				X	X	X	X	X
Allied-Signal	X			X	X	X	X	
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)

Table 6-6 (Continued)
Principal Military/Aerospace Electronic Equipment Producers

Company	Electro-Optic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
GM Hughes Electronics	X	X	X	X	X	Semicond., microwave subsys.
Thomson-CSF	X	X	X	X	X	Semicond., microwave, CCD
GE	X	X	X	X	X	Semiconductors
Raytheon			X			Semiconductors
GEC Plessey	X	X	X	X	X	Semicond., microwave subsys.
Lockheed	X	X	X	X	X	Semicond., microwave subsys.
TRW	X	X	X	X		Semicond., microwave subsys.
Unisys		X	X	X		
Martin Marietta	X					
Rockwell	X	X	X		X	Semiconductors
Texas Instruments	X		X		X	Semicond., microwave subsys.
Litton	X		X			Microwave subsys.
Honeywell	X	X	X	X		Semiconductors
Westinghouse	X	X	X			Semiconductors
IBM		X	X	X		Semiconductors
ITT	X	X				Semicond., microwave subsys.
Deutsche Aerospace	X					
E-Systems				X		
Northrop	X	X			X	

(Continued)

Table 6-6 (Continued)
Principal Military/Aerospace Electronic Equipment Producers (Continued)

Company	Electro-Optic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
General Dynamics		X		X	X	
Harris		X	X	X		Semicond., microwave subsys.
Loral/Ford	X	X	X	X	X	Semicond., microwave subsys.
GTE	X					
Ferranti	X	X				
Boeing	X	X		X	X	
British Aerospace	X	X	X	X	X	
Allied-Signal		X			X	Semiconductors
Philips						Semiconductors
Thorn-EMI	X		X	X		Semiconductors
Mitsubishi		X		X	X	Semiconductors
Motorola		X	X		X	Semiconductors
AT&T	X	X	X			Semicond., microwave subsys.
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

(Continued)

Table 6-6 (Continued)
Principal Military/Aerospace Electronic Equipment Producers (Continued)

Company	Electro-Optic	Aircraft Systems	Computer	Simulat. Trainers	Test	Other
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 (October 1992)

Table 6-7
U.S. Aircraft and Ship Inventory (Units)

	1991	1992	1993
Navy Vessels			
Aircraft Carriers	15	15	14
Surface Combatants	159	134	127
Mine Warfare Ships	9	11	15
Attack Submarines	87	87	90
Others	256	227	216
Total	526	474	462
Tactical Aircraft			
A-6	210	232	210
AV-8	160	160	160
A-10	423	249	159
F-4	156	66	30
F-14	294	300	268
F-15	462	408	396
F-15E	72	108	144
F-16	882	996	1,164
F/A-18	479	474	472
Others	474	324	111
Total	3,612	3,317	3,114

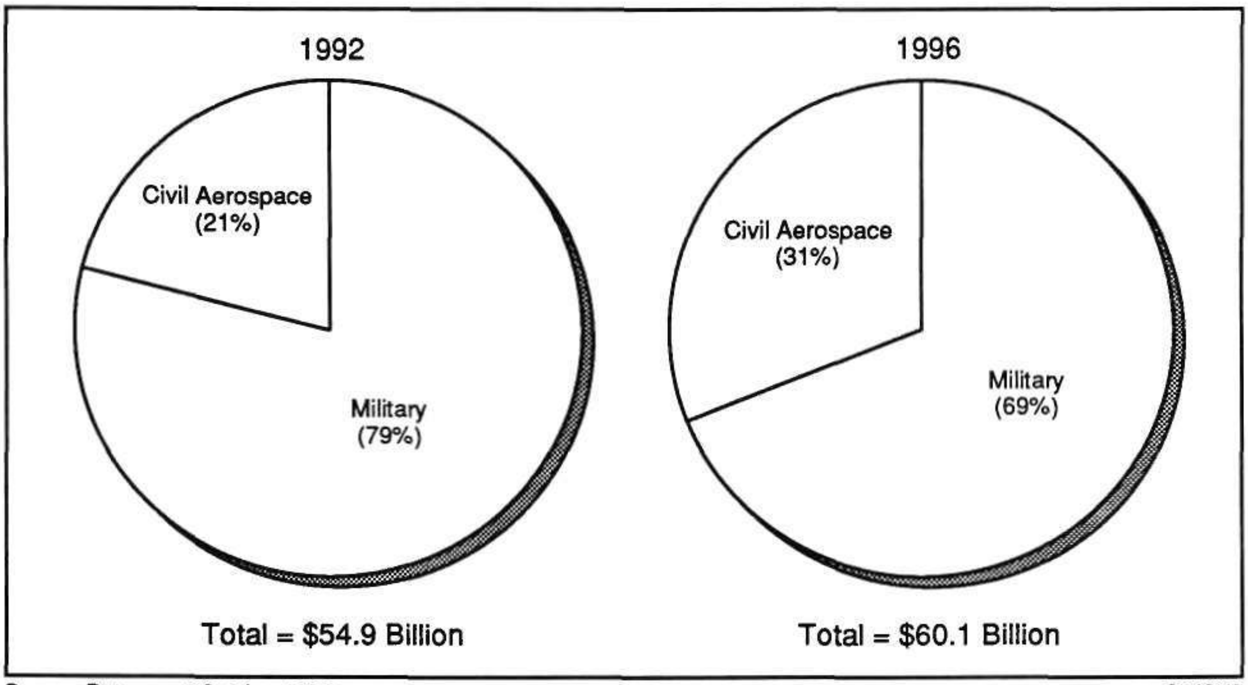
Source: U.S. Deptartment of Defense

Table 6-8
Proposed Small Satellite Systems

System	Sponsor	No. of Satellites	Service
Low Earth Orbit			
Iridium	Motorola	77	Worldwide cellular
Orbcomm	Orbital Sciences	20-24	Messaging—United States
Ellipso	Ellipsat	24	Worldwide cellular
GlobeStar	Loral/Qualcomm	24-48	Voice, data, position
SmartCar	Leosat	24	Vehicle messaging
Aries	Constellation Communications	48	Voice, data, position
Vita	Volunteers in Technical Assistance	2	Communication
Medium Earth Orbit			
Odyssey	TRW	12	Cellular, data, RDSS
Geostationary Earth Orbit			
Tritium	Hughes	3	Worldwide mobile communication
Unicom	Unicom Satellite Corporation	4	Voice, data
Afrispace	Afrispace	1	Direct broadcast radio
Project 21	INMARSAT	NA	Telephony

NA = Not available
Source: U.S. Department of Commerce

Figure 6-1
North American Military and Civil Aerospace Electronics Production



Source: Dataquest (October 1992)

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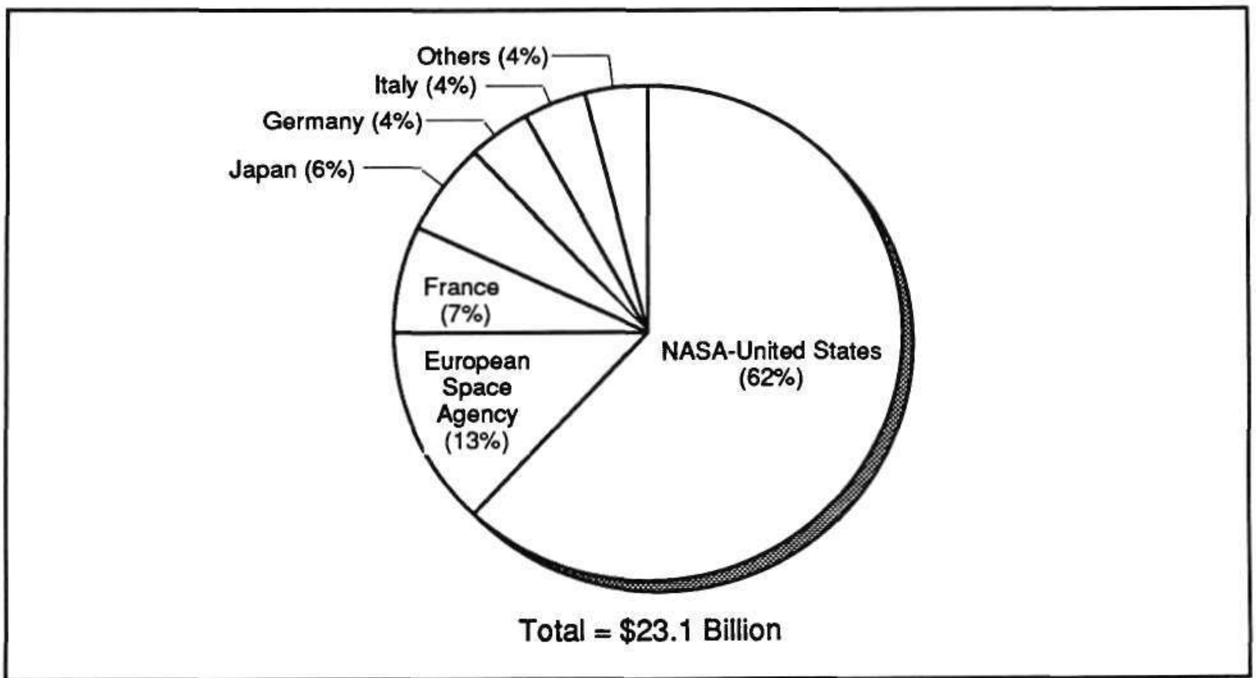
Figure 6-2
1991 Worldwide Government Civil Space Spending



Source: American Institute for Aeronautics and Astronautics

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Chapter 7
Transportation Electronics: North America

Tables 7-1 through 7-8 and Figure 7-1 present key data and Dataquest's forecast for transportation electronics. Key trends to note include the following:

- There is continuing penetration of various electronic subsystems and controls into cars and trucks.
- In the drive train area, a new class of controls for integrated engine and transmission management is emerging, stimulated by efficiencies needed for even higher corporate fuel economy requirements imposed by the U.S. Congress.
- Electronic-intensive antilock brakes and air bags continue their penetration of vehicle shipments. Antilock braking is emerging from its traditional use on trucks (two wheels) to high-end cars (four wheels). Driver-side air bags are becoming standard equipment on almost every vehicle. Passenger-side air bag versions are now entering the market.
- Electronic suspension and steering are beginning to appear on some models as the market and vendors evaluate the future of these systems.
- Keyless entry and other security features are proving to be popular options.
- Multiplex wiring, or a vehicle communications bus, appears to be at least five years off from broad-scale use.
- Intelligent vehicles that employ navigation aids and collision avoidance systems, and communicate with the highway system to optimize traffic flow, remain at least a decade off from broad-scale use.

Table 7-1
Revenue from North American Transportation Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Transportation			
Entertainment	490	442	403
Vehicle Controls	397	463	481
Body Controls	57	74	78
Driver Information	710	705	645
Powertrain	2,073	1,875	1,704
Safety and Convenience	426	556	570
Total Transportation	4,153	4,115	3,881

Source: Dataquest (October 1992)

Table 7-2
Revenue from North American Transportation Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Transportation						
Entertainment	429	446	458	466	475	3.3
Vehicle Controls	566	737	846	966	1,051	16.9
Body Controls	82	85	88	91	118	8.6
Driver Information	710	749	777	800	817	4.8
Powertrain	1,806	1,889	1,945	1,977	2,019	3.5
Safety and Convenience	659	788	882	965	1,036	12.7
Total Transportation	4,252	4,694	4,996	5,265	5,516	7.3

Source: Dataquest (October 1992)

Table 7-3
North American Auto and Light Truck Production (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Automobiles	7,972	7,164	6,509	6,717	7,154	7,476	7,700	7,854	3.8
Light Trucks/Vans	4,749	4,630	4,284	4,820	5,109	5,287	5,436	5,517	5.2
Total	12,721	11,794	10,793	11,537	12,263	12,763	13,136	13,371	4.4

Source: Dataquest (October 1992)

Table 7-4
Estimated Electronic Value of the Average North American Vehicle (Dollars)

Year	Value ($)
1989	326
1990	349
1991	360
1992	369
1993	383
1994	391
1995	401
1996	413
1991-1996 CAGR (%)	2.8

Source: Dataquest (October 1992)

Table 7-5
North American Auto and Light Truck Electronics Production (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Transportation									
Entertainment	490	442	403	429	446	458	466	475	3.3
Vehicle Controls	397	463	481	566	737	846	966	1,051	16.9
Body Controls	57	74	78	82	85	88	91	118	8.6
Driver Infomation	710	705	645	710	749	777	800	817	4.8
Power Train	2,073	1,875	1,704	1,806	1,889	1,945	1,977	2,019	3.5
Safety and Convenience	426	556	570	659	788	882	965	1,036	12.7
Total Transportation	4,153	4,115	3,881	4,252	4,694	4,996	5,265	5,516	7.3

Source: Dataquest (October 1992)

Table 7-6
North American Auto and Light Truck Vehicle Production (Percentage of Total Production)

	1987	1988	1989	1990	1991
General Motors	46.4	44.1	41.8	41.1	41.3
Ford	29.7	30.2	30.0	27.9	27.3
Chrysler	15.8	16.7	15.6	14.0	14.2
Honda	2.6	3.2	3.4	4.6	5.3
Toyota	NM	NM	1.3	2.4	2.4
Nissan	1.7	1.6	1.8	2.0	2.5
NUMMI	1.5	1.0	1.5	1.7	2.0
Mazda	NM	1.2	1.7	1.5	1.6
Others	2.3	2.0	2.9	4.8	3.4

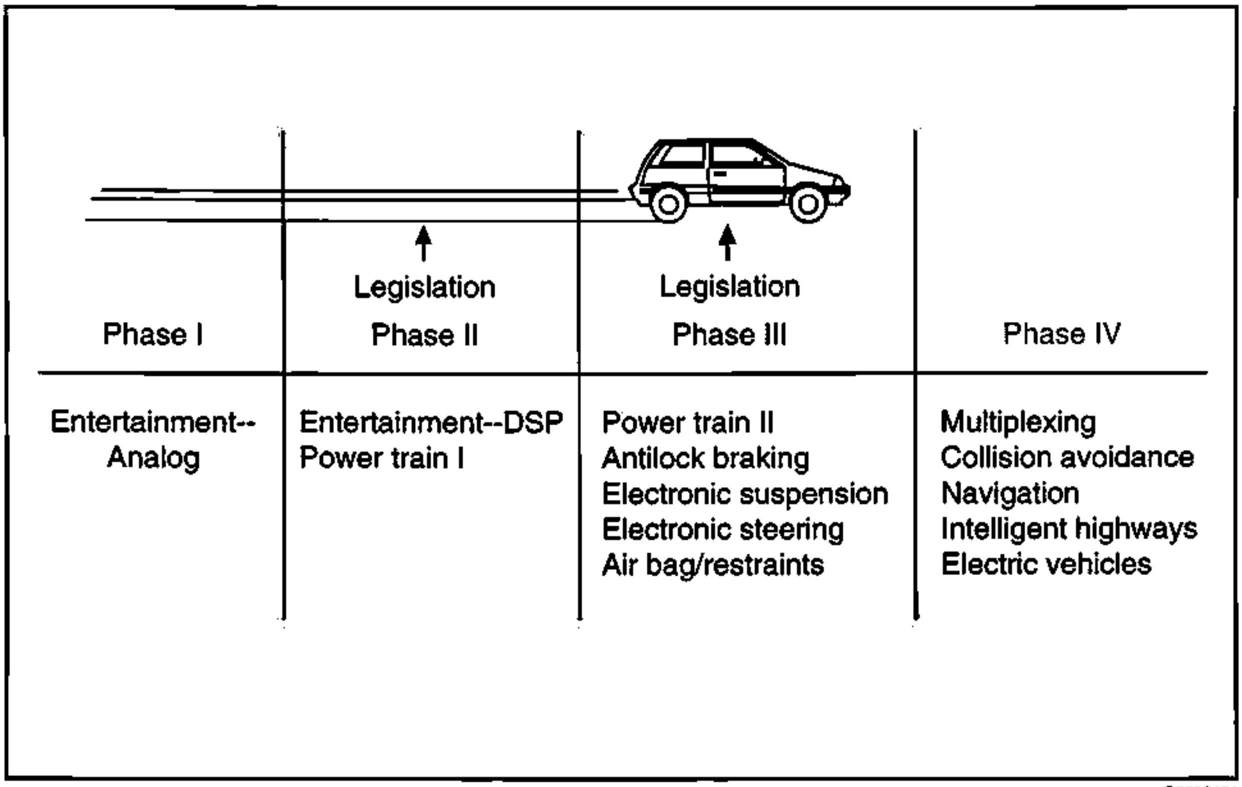
NM = Not meaningful
Source: *Automotive News*, Dataquest (October 1992)

Table 7-7
Primary North American Manufacturers of Vehicle Electronic Systems

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-EED	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
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 (October 1992)

Figure 7-1
Automotive Electronics



Source: Dataquest (October 1992) G2002151

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The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Offices in
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Market Statistics

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Worldwide Semiconductor Consumption by Application Market

October 19, 1992

Source: Dataquest

Market Statistics

Semiconductor Application Markets *Worldwide*

SAWW-SVC-MS-9203

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Worldwide Semiconductor Consumption by Application Markets

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Worldwide Semiconductor Consumption by Application Markets

Table of Contents

Note: All tables show estimated data.

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Table		Page

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Worldwide Semiconductor Consumption by Application Markets

Introduction

This document contains detailed information on Dataquest's view of worldwide semiconductor consumption in electronic equipment. Included in this document are the following:

- 1989-1991 historical data
- 1992-1996 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 usage of particular semiconductor categories, such as MOS memory, across the various electronic equipment areas?

The electronic equipment forecast contained in this document is the aggregate of Dataquest's regional electronic equipment production forecasts. The regional forecasts may be found in their entirety and in greater detail in the companion Source: Dataquest volumes, *Worldwide and North American Electronic Equipment Forecast, Europe Electronic Equipment Forecast, Japanese Electronic Equipment Forecast,* and *Asia/Pacific-Rest of World Electronic Equipment Forecast.*

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety and by region in Source Dataquest: *Semiconductor Consumption and Shipment Forecast.* Estimates in this document may differ slightly from the aforementioned documents because of rounding.

The tables in this document are organized as follows:

- Tables 1 through 3 cover total electronic equipment production
- Tables 4 through 42 cover the data processing application market and the data processing equipment system groups
- Tables 43 through 77 cover the communications application market and the communications equipment system groups
- Tables 78 through 108 cover the industrial application market and the industrial equipment system groups
- Tables 109 through 144 cover the consumer application market and the industrial equipment system groups
- Tables 145 through 150 cover the military/civil aerospace application market
- Tables 151 through 156 cover the transportation application market

The following six table types are associated with each application market or equipment system group:

- Revenue from equipment production, and revenue from associated semiconductor shipments, 1989-1991
- Revenue from equipment production, and revenue from associated semiconductor shipments, 1992-1996
- Revenue growth from equipment production, and revenue growth from associated semiconductor shipments, 1989-1991
- Revenue growth from equipment production, and revenue growth from associated semiconductor shipments, 1992-1996
- Input/output ratios, 1989-1991
- Input/output ratios, 1992-1996

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 *Dataquest Research and Forecast Methodology* document located in the Source: Dataquest binder. For a complete listing of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

Electronic Equipment Segmentation

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 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
  - Terminals
  - Input/Output Devices
  - Dedicated Systems
- 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 optoelectronic 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
      - Bipolar Memory
      - Bipolar Logic
    - MOS Digital
      - MOS Memory
      - MOS Microcomponents
      - MOS Logic
    - Analog
  - Total Discrete
  - Total Optoelectronic

Definitions

The following two 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. 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 Share Survey Guide.*

Electronic Equipment Definitions

Electronic systems groups comprise the following specific electronic equipment types.

Computer Systems: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers.

Data Storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.

Terminals: Includes alphanumeric terminals and graphics terminals (for example, X terminals).

Input/Output Devices: Includes printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, voice recognition/synthesizer equipment, mouse, keyboard, and digitizers.

Dedicated Systems: Includes electronic copiers, electronic calculators, smart 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.

Premise Telecom Equipment: Includes image and text communication, such as facsimile and video teleconferencing; data communications equipment such as modems, statistical multiplexers, T-1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area networks, internetworking, network management, and packet data switching/wide area networks; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, call accounting, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay 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, mobile radios, and mobile radio base station equipment; 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 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.

Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems, and energy management systems.

Manufacturing Systems and Instrumentation: Includes semiconductor production equipment, controllers and actuators, sensor systems, management systems, and robotics; and semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and waveform analyzers, nuclear instruments, and other test and measurement equipment.

Medical Equipment: Includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analyzers, patient monitoring equipment, and other diagnostic and therapeutic equipment.

Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

(Consumer) Audio Equipment: Includes compact disc players, radios, stereo components, musical instruments, and tape recorders.

(Consumer) Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, and color and monochrome TVs.

Personal Electronics: Includes electronic games and toys, 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: Includes military electronics, such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, computer systems, simulation systems, and military electronics not elsewhere classified; and civilian aerospace electronics, such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

Transportation Electronics: Includes entertainment systems, vehicle controls, body controls, driver information systems, power train systems, and safety and convenience systems.

Semiconductor Device Definitions

Semiconductor device categories comprise the following specific types of semiconductor devices:

Total Semiconductor (IC + Discrete + Optoelectronic). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide) 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 Monolithic IC). An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. In a monolithic IC, discrete circuits are integrated onto a small number of dice.

Bipolar Digital (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.

Bipolar Memory. Defined as a bipolar digital semiconductor product in which binary data are stored and electronically retrieved. Includes ECL random access memory (RAM), read-only memory (ROM), programmable ROM (PROM), first-in/first-out (FIFO) memory.

Bipolar Logic (Bipolar Application-Specific IC + Other Bipolar Logic IC + Bipolar Digital Microcomponent). Defined as a bipolar digital semiconductor product in which more than 50 percent of the die area performs logic functions. Includes bipolar digital microcomponent ICs.

MOS Digital (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 some MOS technology is employed.

MOS Memory (DRAM + SRAM + EPROM + Other Nonvolatile MOS Digital Memory + Other MOS Digital Memory). Defined as an MOS digital IC in which binary data are stored and electronically retrieved.

MOS Microcomponents (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral). Defined as an MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both CISC and RISC.

MOS Digital Logic (MOS Digital Application-Specific IC + Other MOS Logic IC). Defined as an MOS digital semiconductor product in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC. Defined as monolithic analog ICs plus hybrid ICs. (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 a semiconductor product that consists 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. Note that hybrid digital ICs are reported in this category, and not under the earlier category of monolithic digital ICs. 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 + Solar Cell). 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.

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 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.

Semiconductor Device Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its goods. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data exclude 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.

1989 and 1990 revenue estimates have been restated from previous publication to reflect modifications in Dataquest's data.

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
- Various government agencies' estimates of manufacturers' shipments
- Trade association data
- 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 input/output (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* guide.

The electronic equipment forecast contained in this document is the aggregate of Dataquest's regional electronic equipment production forecasts. The regional forecasts may be found in their entirety and in greater detail in the companion Source: Dataquest volumes, *Worldwide and North American Electronic Equipment Forecast, Europe Electronic Equipment Forecast, Japanese Electronic Equipment Forecast,* and *Asia/Pacific-Rest of World Electronic Equipment Forecast.*

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. 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 are, in general, comprised of 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 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 five-year revenue forecasts for the aggregate semiconductor market during the second and fourth quarters of each year. 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* guide.

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 four-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 uses a decomposition time series model to generate forecasts of regional total semiconductor sales. The model assumes that sales are affected by factors such as long-run trends, short-run aggregate economic and industry-specific conditions, and seasonality. The forecast is made by using statistical methods to analyze each of the components separately, then combining them into a single aggregate. The model is especially useful for assessing market fluctuations about the trend growth path.

Third, Dataquest's worldwide Semiconductor service and its Semiconductor Equipment, Manufacturing, and Materials service, in conjunction with its various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-range trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the short-range forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12- to 24-month time frame. Semiconductor fab facilities and long-term 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-term trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The input/output (or 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, with modeled semiconductor consumption. The semiconductor content analyses are typically performed on equipment that sells in high volume or otherwise impacts the semiconductor market. These analyses include personal computers, disk drives, printers, and cellular mobile radios.

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 aggregate semiconductor 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 total semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Further, 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 total semiconductor market than 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 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 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 the electronic equipment markets. By construction, then, the I/O ratios tend to reflect this difference in volatility. Users of the I/O ratios are therefore cautioned to focus on long-run trends in the I/O ratios, rather than the year-to-year movements in their values.

Forecast Assumptions

The following three sections discuss the assumptions that underlie the forecasts in this document. The first section gives the assumptions of the economic outlook. The second section gives the assumptions of the electronic equipment forecast. The third section gives the assumption of the semiconductor consumption forecast.

Economic Outlook Assumptions

The worldwide economy is expected to show mixed results in 1992. The Dun & Bradstreet Corporation forecast the following outlook for the Group of Seven (G7) countries:

- The U.S., Canada, and U.K. economies are expected to recover from the recession in 1992. Real gross domestic product (GDP) is expected to expand 2.1, 1.6, and 0.5 percent, respectively, in 1992. (These economies contracted at rates of 0.7, 1.5, and 2.4 percent, respectively, in 1991.) Though modest in comparison to historical rates of expansion during recovery periods, the benefit is that inflationary pressures will likely be held in check, sustaining the expansion's duration. Expansion should accelerate to 2.5, 4.0, and 2.2 percent, respectively, in 1993.
- Real GDP growth is expected to accelerate in France and Italy from 0.9 percent in 1991 to 2.1 percent in 1992, and from 1.4 percent in 1991 to 1.5 percent in 1992, respectively. The pace of growth should pick up in 1993 to 2.7 and 2.2 percent, respectively.
- Real GDP growth is expected to decelerate in Germany and Japan from 3.2 percent in 1991 to 1.1 percent in 1992, and from 4.4 percent in 1991 to 2.0 percent in 1992, respectively. Moderating these countries' short-term growth prospects are the cost burden of Germany's reunification and the rise in Japan's cost of capital and recent bout of asset deflation. The respective economies are expected to reaccelerate to 2.8 percent and 3.3 percent growth in 1993.

Electronic Equipment Forecast Assumptions

Overall, worldwide electronic systems production is expected to expand 3.1 percent in 1992, slightly faster than the 2.4 percent rate of growth in 1991. Expansion is expected to accelerate further in 1993 to 7.6 percent as the worldwide economic climate improves. In 1992, however, the value of worldwide production will be constrained by two important influences:

- A moderate—in contrast to booming—rate of recovery from recession
- An abundance of productive capacity, combined with further proliferation of product and technology standards, both placing pressure on costs and prices

From a semiconductor application-market perspective, the forecast carries assumptions detailed in the following paragraphs.

Data processing production will begin to make a moderate 2.6 percent recovery in 1992, after a depressing 2.2 percent decline in 1991. In North America, recovery will continue into 1993 as economic conditions continue to improve and stabilize. Japanese production will remain hemmed in for the remainder of 1992, as business and households adjust downward their spending plans in response to the lackluster business climate. The year 1993 and beyond should, however, find Japan back on the path of normal growth. Local content regulations are spurring the placement of production facilities in Europe, helping explain the boost of growth in 1993. Once facilities are in place, though, growth is expected to assume a more sustainable pace. Asia/Pacific-ROW production prospects remain upbeat as it increasingly becomes the region of choice for mass manufacturing of established technologies.

Communications production growth—the most stable-growing of the application markets, owing to its heterogeneous composition of personal wireless communications, premise voice, and data products, and large-scale, long-life investment in public telecommunications infrastructure—will decelerate slightly in 1992 to 6.1 percent from 7.3 percent in 1991. Investment in networking the existing stock of data processing equipment will help drive communications hardware growth through 1996.

As is usually the case, production of industrial and consumer equipment have borne the brunt of the recent downturn in business conditions, especially in North America and Japan. Europe and Asia/Pacific-ROW have been somewhat insulated from the recent cycle, owing to foreign investment spurred by local production factors and cost of production advantages, respectively. In North America and Japan, though, these application markets are forecast to rebound in 1993, with the expected relaxation of business and household budget constraints.

Military/civil aerospace electronics production was hit hard by Washington, D.C. budget cuts in 1991, declining 5.5 percent worldwide. Few positive opportunities remain for all but the most specialized niche players participating in simulation systems, dedicated military computer systems, and civil-space projects. Civil aerospace electronics production will remain the bright spot in this application market, fueled by replacement of aging jet airliners and upgrades of the worldwide air traffic control system.

Transportation electronics production growth is expected to accelerate from 4.8 percent growth in 1991 to 6.0 percent in 1992, and to 10.2 percent in 1993. Production was hurt by the recession, but growth prospects are relatively upbeat because of increased household spending, combined with increasing share of electronic systems' added value to new vehicles.

Semiconductor Forecast Assumptions

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 15.1 percent in 1992, up from a meager 2.7 percent in 1991. The market is clearly on target midway through the year: According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in July were 24.6 percent above year-earlier bookings, compared with 18.1 percent in June. Total semiconductor billings growth for the same period was 17.5 percent above year-earlier billings, compared with 14.8 percent in June.

Strength in the North American market owes itself largely to the recovery of the U.S. economy and the relaxation of household and business budget constraints for durable goods and capital equipment. In particular, however, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

Dataquest expects the Japanese market to decline 9.4 percent (dollar-based) in 1992, the first yearly decline since 1985. The latest market statistics support this outlook: The dollar value of total semiconductor billings for the three months ended in July were 7.2 percent below year-earlier billings. The bookings picture is even more bleak. Total semiconductor bookings for the same period were 8.0 percent below year-earlier levels.

Japan's situation is because of more than just weakness in its European export market. Other factors include a heightened level of international competition in chips and systems; a glut of worldwide DRAM fab capacity; rising cost of capital in Japan; and a dearth of new, high-volume consumer electronic systems. Dataquest does not expect an improvement in Japan's export market to alleviate these structural problems in 1992.

Dataquest forecasts the European market to grow 7.2 percent in 1992, up from 5.8 percent in 1991. Total semiconductor billings for the three months ended in July were 10.4 percent above year-earlier billings. Total semiconductor bookings for the same period were 14.5 percent above year-earlier levels. We believe that the European market will show more growth in the second half of 1992 than usual, as recovery in the U.S. market starts to pull through demand in Europe later in the year.

Recovery of the U.K. and French economies will help offset decelerating growth in Germany. PC manufacture in Ireland is strong, and much of the growth in the United Kingdom is related to multinational companies increasing their data processing and consumer equipment production. Investment in telecommunications infrastructure and the introduction of Groupe Spéciale Mobile mobile cellular phones also provide growth stimulus.

Dataquest forecasts the Asia/Pacific-Rest of World market to grow 21.6 percent in 1992. Again, the latest statistics support this outlook: Total semiconductor bookings growth for the three months ended in July was 25.8 percent above year-earlier bookings. Total semiconductor billings growth for the same period was 27.2 percent above year-earlier billings. Expansion continues to be driven by foreign investment and improvement in Western export markets.

Table 1
Revenue from Worldwide Total Electronic Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Electronic Equipment	587,616	621,707	640,635
Total Semiconductor	54,339	54,545	59,694
Total IC	44,613	44,459	48,855
Bipolar Digital	4,314	4,173	3,628
Bipolar Memory	460	431	356
Bipolar Logic	3,854	3,742	3,272
MOS Digital	31,140	30,152	34,315
MOS Memory	15,405	12,128	12,841
MOS Microcomponent	7,808	9,584	11,774
MOS Logic	7,927	8,440	9,700
Analog	9,159	10,134	10,912
Total Discrete	7,320	7,674	8,035
Total Optoelectronic	2,406	2,412	2,804

Source: Dataquest (October 1992)

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, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Electronic Equipment	664,073	713,332	758,637	805,230	857,288
Total Semiconductor	62,925	72,668	82,627	88,122	94,991
Total IC	52,074	60,902	70,002	74,609	80,720
Bipolar Digital	3,271	2,989	2,733	2,498	2,252
Bipolar Memory	339	274	209	185	176
Bipolar Logic	2,932	2,715	2,524	2,313	2,076
MOS Digital	37,287	45,007	53,063	56,540	61,713
MOS Memory	14,683	18,927	22,888	21,978	23,661
MOS Microcomponent	12,985	14,804	17,258	20,016	21,920
MOS Logic	9,619	11,276	12,917	14,545	16,132
Analog	11,516	12,907	14,206	15,571	16,754
Total Discrete	8,126	8,730	9,290	9,868	10,403
Total Optoelectronic	2,725	3,036	3,335	3,645	3,868

Source: Dataquest (October 1992)

Table 3
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, 1989-1991 (Percentage Change)

	1989	1990	1991
Total Electronic Equipment	NA	5.8	3.0
Total Semiconductor	NA	0.4	9.4
Total IC	NA	-0.3	9.9
Bipolar Digital	NA	-3.3	-13.1
Bipolar Memory	NA	-6.3	-17.4
Bipolar Logic	NA	-2.9	-12.6
MOS Digital	NA	-3.2	13.8
MOS Memory	NA	-21.3	5.9
MOS Microcomponent	NA	22.7	22.9
MOS Logic	NA	6.5	14.9
Analog	NA	10.6	7.7
Total Discrete	NA	4.8	4.7
Total Optoelectronic	NA	0.2	16.3

NA = Not available
Source: Dataquest (October 1992)

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, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Electronic Equipment	3.7	7.4	6.4	6.1	6.5	6.0
Total Semiconductor	5.4	15.5	13.7	6.7	7.8	9.7
Total IC	6.6	17.0	14.9	6.6	8.2	10.6
Bipolar Digital	-9.8	-8.6	-8.6	-8.6	-9.8	-9.1
Bipolar Memory	-4.9	-19.1	-23.7	-11.6	-4.9	-13.2
Bipolar Logic	-10.4	-7.4	-7.0	-8.4	-10.2	-8.7
MOS Digital	8.7	20.7	17.9	6.6	9.1	12.5
MOS Memory	14.3	28.9	20.9	-4.0	7.7	13.0
MOS Microcomponent	10.3	14.0	16.6	16.0	9.5	13.2
MOS Logic	-0.8	17.2	14.6	12.6	10.9	10.7
Analog	5.5	12.1	10.1	9.6	7.6	9.0
Total Discrete	1.1	7.4	6.4	6.2	5.4	5.3
Total Optoelectronic	-2.8	11.4	9.8	9.3	6.1	6.6

Source: Dataquest (October 1992)

Table 5
Input/Output Ratios of All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	9.2	8.8	9.3
Total IC	7.6	7.2	7.6
Bipolar Digital	0.7	0.7	0.6
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	0.7	0.6	0.5
MOS Digital	5.3	4.8	5.4
MOS Memory	2.6	2.0	2.0
MOS Microcomponent	1.3	1.5	1.8
MOS Logic	1.3	1.4	1.5
Analog	1.6	1.6	1.7
Total Discrete	1.2	1.2	1.3
Total Optoelectronic	0.4	0.4	0.4

Source: Dataquest (October 1992)

Table 6
Input/Output Ratios of All Semiconductors Shipped to the World for Use in All Electronic Equipment Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	9.5	10.2	10.9	10.9	11.1
Total IC	7.8	8.5	9.2	9.3	9.4
Bipolar Digital	0.5	0.4	0.4	0.3	0.3
Bipolar Memory	0.1	0	0	0	0
Bipolar Logic	0.4	0.4	0.3	0.3	0.2
MOS Digital	5.6	6.3	7.0	7.0	7.2
MOS Memory	2.2	2.7	3.0	2.7	2.8
MOS Microcomponent	2.0	2.1	2.3	2.5	2.6
MOS Logic	1.4	1.6	1.7	1.8	1.9
Analog	1.7	1.8	1.9	1.9	2.0
Total Discrete	1.2	1.2	1.2	1.2	1.2
Total Optoelectronic	0.4	0.4	0.4	0.5	0.5

Source: Dataquest (October 1992) .

Table 7
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Data Processing	181,637	188,936	188,409
Total Semiconductor	25,565	24,210	26,743
Total IC	23,668	22,345	24,716
Bipolar Digital	2,674	2,584	2,281
Bipolar Memory	333	333	282
Bipolar Logic	2,341	2,251	1,999
MOS Digital	19,550	18,173	20,754
MOS Memory	11,633	8,944	9,553
MOS Microcomponent	4,283	5,356	6,753
MOS Logic	3,634	3,874	4,447
Analog	1,444	1,587	1,682
Total Discrete	1,489	1,489	1,607
Total Optoelectronic	408	377	419

Source: Dataquest (October 1992)

Table 8
Revenue from Worldwide Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Data Processing	196,755	208,262	221,061	233,425	249,131
Total Semiconductor	28,684	33,890	39,260	40,794	43,667
Total IC	26,710	31,816	37,094	38,522	41,310
Bipolar Digital	2,096	1,939	1,793	1,650	1,502
Bipolar Memory	269	222	169	150	146
Bipolar Logic	1,827	1,717	1,625	1,500	1,357
MOS Digital	22,819	27,851	33,079	34,465	37,292
MOS Memory	11,046	14,479	17,687	16,730	17,907
MOS Microcomponent	7,386	8,311	9,633	11,238	12,264
MOS Logic	4,386	5,061	5,758	6,497	7,122
Analog	1,795	2,026	2,222	2,406	2,516
Total Discrete	1,514	1,564	1,612	1,658	1,709
Total Optoelectronic	460	509	555	614	648

Source: Dataquest (October 1992)

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, 1989-1991
(Percentage Change)

	1989	1990	1991
Total Data Processing	NA	4.0	-0.3
Total Semiconductor	NA	-5.3	10.5
Total IC	NA	-5.6	10.6
Bipolar Digital	NA	-3.4	-11.8
Bipolar Memory	NA	0.1	-15.4
Bipolar Logic	NA	-3.8	-11.2
MOS Digital	NA	-7.0	14.2
MOS Memory	NA	-23.1	6.8
MOS Microcomponent	NA	25.0	26.1
MOS Logic	NA	6.6	14.8
Analog	NA	9.9	6.0
Total Discrete	NA	0	8.0
Total Optoelectronic	NA	-7.7	11.3

NA = Not available
Source: Dataquest (October 1992)

Table 10
Revenue Growth from Worldwide Data Processing Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Processing Applications, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Data Processing	4.4	5.8	6.1	5.6	6.7	5.7
Total Semiconductor	7.3	18.1	15.8	3.9	7.0	10.3
Total IC	8.1	19.1	16.6	3.9	7.2	10.8
Bipolar Digital	-8.1	-7.5	-7.5	-8.0	-9.0	-8.0
Bipolar Memory	-4.7	-17.3	-23.9	-11.1	-3.1	-12.4
Bipolar Logic	-8.6	-6.0	-5.4	-7.6	-9.6	-7.5
MOS Digital	9.9	22.1	18.8	4.2	8.2	12.4
MOS Memory	15.6	31.1	22.2	-5.4	7.0	13.4
MOS Microcomponent	9.4	12.5	15.9	16.7	9.1	12.7
MOS Logic	-1.4	15.4	13.8	12.8	9.6	9.9
Analog	6.8	12.8	9.7	8.3	4.5	8.4
Total Discrete	-5.8	3.3	3.0	2.9	3.0	1.2
Total Optoelectronic	9.6	10.8	9.0	10.6	5.6	9.1

Source: Dataquest (October 1992)

Table 11
Inout/Output Ratios of All Semiconductors Shipped to the World for Use in Data Processing Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	14.1	12.8	14.2
Total IC	13.0	11.8	13.1
Bipolar Digital	1.5	1.4	1.2
Bipolar Memory	0.2	0.2	0.1
Bipolar Logic	1.3	1.2	1.1
MOS Digital	10.8	9.6	11.0
MOS Memory	6.4	4.7	5.1
MOS Microcomponent	2.4	2.8	3.6
MOS Logic	2.0	2.1	2.4
Analog	0.8	0.8	0.9
Total Discrete	0.8	0.8	0.9
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (October 1992)

Table 12
Inout/Output Ratios of All Semiconductors Shipped to the World for Use in Data Processing Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	14.6	16.3	17.8	17.5	17.5
Total IC	13.6	15.3	16.8	16.5	16.6
Bipolar Digital	1.1	0.9	0.8	0.7	0.6
Bipolar Memory	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	0.9	0.8	0.7	0.6	0.5
MOS Digital	11.6	13.4	15.0	14.8	15.0
MOS Memory	5.6	7.0	8.0	7.2	7.2
MOS Microcomponent	3.8	4.0	4.4	4.8	4.9
MOS Logic	2.2	2.4	2.6	2.8	2.9
Analog	0.9	1.0	1.0	1.0	1.0
Total Discrete	0.8	0.8	0.7	0.7	0.7
Total Optoelectronic	0.2	0.2	0.3	0.3	0.3

Source: Dataquest (October 1992)

Table 13
Revenue from Worldwide Computer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Computer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Computers	103,434	108,120	103,255
Total Semiconductor	15,853	14,584	16,230
Total IC	15,311	14,046	15,669
Bipolar Digital	2,080	2,018	1,781
Bipolar Memory	319	316	267
Bipolar Logic	1,761	1,702	1,514
MOS Digital	13,061	11,844	13,694
MOS Memory	8,432	6,334	6,885
MOS Microcomponent	2,725	3,478	4,503
MOS Logic	1,904	2,031	2,306
Analog	170	184	193
Total Discrete	444	443	457
Total Optoelectronic	97	94	105

Source: Dataquest (October 1992)

Table 14
Revenue from Worldwide Computer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Computer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Computers	108,940	114,088	121,892	129,438	139,599
Total Semiconductor	17,602	20,647	23,843	24,030	25,476
Total IC	17,039	20,054	23,229	23,377	24,801
Bipolar Digital	1,703	1,578	1,466	1,361	1,255
Bipolar Memory	254	211	161	143	139
Bipolar Logic	1,449	1,368	1,304	1,217	1,116
MOS Digital	15,131	18,242	21,507	21,731	23,216
MOS Memory	7,889	10,117	12,267	11,087	11,677
MOS Microcomponent	4,862	5,426	6,194	7,183	7,779
MOS Logic	2,380	2,698	3,047	3,461	3,760
Analog	205	233	256	286	331
Total Discrete	439	459	477	499	513
Total Optoelectronic	125	134	137	154	161

Source: Dataquest (October 1992)

Table 15
Revenue Growth from Worldwide Computer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Computer Applications, 1989-1991
(Percentage Change)

	1989	1990	1991
Total Computers	NA	4.5	-4.5
Total Semiconductor	NA	-8.0	11.3
Total IC	NA	-8.3	11.6
Bipolar Digital	NA	-3.0	-11.7
Bipolar Memory	NA	-1.0	-15.4
Bipolar Logic	NA	-3.4	-11.0
MOS Digital	NA	-9.3	15.6
MOS Memory	NA	-24.9	8.7
MOS Microcomponent	NA	27.6	29.5
MOS Logic	NA	6.7	13.5
Analog	NA	8.3	4.8
Total Discrete	NA	-0.2	3.0
Total Optoelectronic	NA	-3.0	11.3

NA = Not available
Source: Dataquest (October 1992)

Table 16
Revenue Growth from Worldwide Computer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Computer Applications, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Computers	5.5	4.7	6.8	6.2	7.9	6.2
Total Semiconductor	8.5	17.3	15.5	0.8	6.0	9.4
Total IC	8.7	17.7	15.8	0.6	6.1	9.6
Bipolar Digital	-4.4	-7.3	-7.1	-7.2	-7.8	-6.8
Bipolar Memory	-5.1	-17.0	-23.5	-11.1	-3.2	-12.3
Bipolar Logic	-4.3	-5.6	-4.6	-6.7	-8.3	-5.9
MOS Digital	10.5	20.6	17.9	1.0	6.8	11.1
MOS Memory	14.6	28.2	21.3	-9.6	5.3	11.1
MOS Microcomponent	8.0	11.6	14.1	16.0	8.3	11.6
MOS Logic	3.2	13.4	12.9	13.6	8.6	10.3
Analog	6.0	14.1	9.8	11.5	15.7	11.4
Total Discrete	-3.9	4.7	3.8	4.6	2.9	2.4
Total Optoelectronic	18.7	7.5	1.9	12.6	5.0	9.0

Source: Dataquest (October 1992)

Table 17
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Computer Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	15.3	13.5	15.7
Total IC	14.8	13.0	15.2
Bipolar Digital	2.0	1.9	1.7
Bipolar Memory	0.3	0.3	0.3
Bipolar Logic	1.7	1.6	1.5
MOS Digital	12.6	11.0	13.3
MOS Memory	8.2	5.9	6.7
MOS Microcomponent	2.6	3.2	4.4
MOS Logic	1.8	1.9	2.2
Analog	0.2	0.2	0.2
Total Discrete	0.4	0.4	0.4
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (October 1992)

Table 18
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Computer Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	16.2	18.1	19.6	18.6	18.2
Total IC	15.6	17.6	19.1	18.1	17.8
Bipolar Digital	1.6	1.4	1.2	1.1	0.9
Bipolar Memory	0.2	0.2	0.1	0.1	0.1
Bipolar Logic	1.3	1.2	1.1	0.9	0.8
MOS Digital	13.9	16.0	17.6	16.8	16.6
MOS Memory	7.2	8.9	10.1	8.6	8.4
MOS Microcomponent	4.5	4.8	5.1	5.5	5.6
MOS Logic	2.2	2.4	2.5	2.7	2.7
Analog	0.2	0.2	0.2	0.2	0.2
Total Discrete	0.4	0.4	0.4	0.4	0.4
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (October 1992)

Table 19
Revenue from Worldwide Data Storage/Subsystems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Data Storage/Subsystems	20,511	20,476	21,125
Total Semiconductor	3,044	3,138	3,276
Total IC	2,793	2,887	3,001
Bipolar Digital	203	183	167
Bipolar Memory	4	5	4
Bipolar Logic	200	178	162
MOS Digital	1,826	1,859	1,976
MOS Memory	650	545	562
MOS Microcomponent	604	713	771
MOS Logic	572	600	643
Analog	764	845	858
Total Discrete	219	222	244
Total Optoelectronic	32	29	31

Source: Dataquest (October 1992)

Table 20
Revenue from Worldwide Data Storage/Subsystems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Data Storage/Subsystems	21,703	23,457	23,756	24,433	25,237
Total Semiconductor	3,393	3,853	4,171	4,365	4,510
Total IC	3,110	3,555	3,862	4,044	4,183
Bipolar Digital	126	125	108	96	89
Bipolar Memory	4	3	2	2	2
Bipolar Logic	122	121	106	94	87
MOS Digital	2,075	2,418	2,686	2,841	2,999
MOS Memory	600	861	1,010	1,042	1,117
MOS Microcomponent	825	860	929	1,015	1,055
MOS Logic	650	697	747	784	828
Analog	909	1,012	1,068	1,106	1,095
Total Discrete	245	258	266	277	281
Total Optoelectronic	37	40	42	44	45

Source: Dataquest (October 1992)

Table 21
Revenue Growth from Worldwide Data Storage/Subsystems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1989-1991
(Percentage Change)

	1989	1990	1991
Total Data Storage/Subsystems	NA	-0.2	3.2
Total Semiconductor	NA	3.1	4.4
Total IC	NA	3.4	4.0
Bipolar Digital	NA	-9.9	-9.1
Bipolar Memory	NA	27.8	-12.0
Bipolar Logic	NA	-10.6	-9.0
MOS Digital	NA	1.8	6.3
MOS Memory	NA	-16.1	3.1
MOS Microcomponent	NA	18.0	8.1
MOS Logic	NA	5.0	7.1
Analog	NA	10.6	1.6
Total Discrete	NA	1.4	9.9
Total Optoelectronic	NA	-10.1	7.7

NA = Not available
Source: Dataquest (October 1992)

Table 22
Revenue Growth from Worldwide Data Storage/Subsystems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Data Storage/Subsystems	2.7	8.1	1.3	2.8	3.3	3.6
Total Semiconductor	3.6	13.6	8.3	4.7	3.3	6.6
Total IC	3.6	14.3	8.7	4.7	3.4	6.9
Bipolar Digital	-24.1	-1.3	-13.1	-11.2	-7.9	-11.8
Bipolar Memory	5.5	-21.3	-31.6	-13.4	-1.6	-13.5
Bipolar Logic	-24.8	-0.6	-12.6	-11.2	-8.0	-11.8
MOS Digital	5.0	16.5	11.1	5.8	5.6	8.7
MOS Memory	6.7	43.5	17.2	3.2	7.2	14.7
MOS Microcomponent	7.0	4.3	8.1	9.2	3.9	6.5
MOS Logic	1.1	7.2	7.2	5.1	5.5	5.2
Analog	5.9	11.3	5.6	3.6	-1.0	5.0
Total Discrete	0.7	5.2	3.3	4.0	1.5	2.9
Total Optoelectronic	19.7	7.7	4.2	4.9	3.5	7.8

Source: Dataquest (October 1992)

Table 23
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	14.8	15.3	15.5
Total IC	13.6	14.1	14.2
Bipolar Digital	1.0	0.9	0.8
Bipolar Memory	0	0	0
Bipolar Logic	1.0	0.9	0.8
MOS Digital	8.9	9.1	9.4
MOS Memory	3.2	2.7	2.7
MOS Microcomponent	2.9	3.5	3.6
MOS Logic	2.8	2.9	3.0
Analog	3.7	4.1	4.1
Total Discrete	1.1	1.1	1.2
Total Optoelectronic	0.2	0.1	0.1

Source: Dataquest (October 1992)

Table 24
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Data Storage/Subsystems Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	15.6	16.4	17.6	17.9	17.9
Total IC	14.3	15.2	16.3	16.5	16.6
Bipolar Digital	0.6	0.5	0.5	0.4	0.4
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.6	0.5	0.4	0.4	0.3
MOS Digital	9.6	10.3	11.3	11.6	11.9
MOS Memory	2.8	3.7	4.2	4.3	4.4
MOS Microcomponent	3.8	3.7	3.9	4.2	4.2
MOS Logic	3.0	3.0	3.1	3.2	3.3
Analog	4.2	4.3	4.5	4.5	4.3
Total Discrete	1.1	1.1	1.1	1.1	1.1
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (October 1992)

Table 25
Revenue from Worldwide Terminal Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Terminal Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Terminals	15,319	16,105	16,664
Total Semiconductor	2,388	2,318	2,463
Total IC	1,998	1,914	2,025
Bipolar Digital	141	142	137
Bipolar Memory	2	3	2
Bipolar Logic	139	139	135
MOS Digital	1,554	1,437	1,505
MOS Memory	885	676	627
MOS Microcomponent	331	392	460
MOS Logic	338	368	418
Analog	303	336	383
Total Discrete	349	361	391
Total Optoelectronic	42	43	47

Source: Dataquest (October 1992)

Table 26
Revenue from Worldwide Terminal Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Terminal Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Terminals	17,293	18,377	19,630	20,803	22,238
Total Semiconductor	2,427	2,887	3,472	3,956	4,207
Total IC	2,017	2,464	3,035	3,503	3,738
Bipolar Digital	106	97	94	87	72
Bipolar Memory	2	2	1	1	1
Bipolar Logic	103	96	92	86	71
MOS Digital	1,491	1,865	2,352	2,749	2,993
MOS Memory	647	834	1,065	1,211	1,304
MOS Microcomponent	471	567	751	925	1,000
MOS Logic	373	464	536	613	689
Analog	421	502	590	667	673
Total Discrete	356	363	369	376	388
Total Optoelectronic	54	60	68	76	81

Source: Dataquest (October 1992)

Table 27
Revenue Growth from Worldwide Terminal Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Terminal Applications, 1989-1991
(Percentage Change)

	1989	1990	1991
Total Terminals	NA	5.1	3.5
Total Semiconductor	NA	-2.9	6.2
Total IC	NA	-4.2	5.8
Bipolar Digital	NA	0.9	-3.5
Bipolar Memory	NA	52.9	-10.0
Bipolar Logic	NA	0.3	-3.4
MOS Digital	NA	-7.5	4.8
MOS Memory	NA	-23.6	-7.3
MOS Microcomponent	NA	18.4	17.3
MOS Logic	NA	9.0	13.6
Analog	NA	10.7	14.1
Total Discrete	NA	3.5	8.3
Total Optoelectronic	NA	2.6	9.3

NA = Not available

Source: Dataquest (October 1992)

Table 28
Revenue Growth from Worldwide Terminal Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Terminal Applications, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Terminals	3.8	6.3	6.8	6.0	6.9	5.9
Total Semiconductor	-1.5	19.0	20.2	13.9	6.4	11.3
Total IC	-0.4	22.1	23.2	15.4	6.7	13.0
Bipolar Digital	-22.9	-7.7	-3.7	-7.2	-17.0	-12.0
Bipolar Memory	-7.3	-16.1	-25.6	-4.2	1.1	-10.9
Bipolar Logic	-23.2	-7.5	-3.3	-7.3	-17.3	-12.0
MOS Digital	-0.9	25.1	26.1	16.9	8.9	14.7
MOS Memory	3.2	28.9	27.7	13.8	7.6	15.8
MOS Microcomponent	2.5	20.3	32.5	23.1	8.1	16.8
MOS Logic	-11.0	24.5	15.5	14.4	12.4	10.5
Analog	9.8	19.1	17.5	13.1	0.9	11.9
Total Discrete	-9.1	2.2	1.6	2.0	3.0	-0.2
Total Optoelectronic	16.2	10.7	12.4	12.9	6.8	11.8

Source: Dataquest (October 1992)

Table 29
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Terminal Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	15.6	14.4	14.8
Total IC	13.0	11.9	12.2
Bipolar Digital	0.9	0.9	0.8
Bipolar Memory	0	0	0
Bipolar Logic	0.9	0.9	0.8
MOS Digital	10.1	8.9	9.0
MOS Memory	5.8	4.2	3.8
MOS Microcomponent	2.2	2.4	2.8
MOS Logic	2.2	2.3	2.5
Analog	2.0	2.1	2.3
Total Discrete	2.3	2.2	2.3
Total Optoelectronic	0.3	0.3	0.3

Source: Dataquest (October 1992)

Table 30
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Terminal Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	14.0	15.7	17.7	19.0	18.9
Total IC	11.7	13.4	15.5	16.8	16.8
Bipolar Digital	0.6	0.5	0.5	0.4	0.3
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.6	0.5	0.5	0.4	0.3
MOS Digital	8.6	10.1	12.0	13.2	13.5
MOS Memory	3.7	4.5	5.4	5.8	5.9
MOS Microcomponent	2.7	3.1	3.8	4.4	4.5
MOS Logic	2.2	2.5	2.7	2.9	3.1
Analog	2.4	2.7	3.0	3.2	3.0
Total Discrete	2.1	2.0	1.9	1.8	1.7
Total Optoelectronic	0.3	0.3	0.3	0.4	0.4

Source: Dataquest (October 1992)

Table 31
Revenue from Worldwide Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Input/Output Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Input/Output Devices	22,929	25,209	27,252
Total Semiconductor	2,556	2,536	2,898
Total IC	2,148	2,134	2,452
Bipolar Digital	172	179	153
Bipolar Memory	5	6	5
Bipolar Logic	167	173	148
MOS Digital	1,856	1,821	2,151
MOS Memory	1,099	913	994
MOS Microcomponent	359	461	609
MOS Logic	398	447	547
Analog	120	134	148
Total Discrete	293	297	330
Total Optoelectronic	114	104	116

Source: Dataquest (October 1992)

Table 32
Revenue from Worldwide Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Input/Output Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Input/Output Devices	28,009	30,091	32,282	34,028	35,816
Total Semiconductor	3,352	4,329	5,303	5,798	6,627
Total IC	2,927	3,867	4,818	5,278	6,079
Bipolar Digital	128	119	109	91	74
Bipolar Memory	6	4	3	3	3
Bipolar Logic	122	115	106	89	71
MOS Digital	2,637	3,568	4,511	4,966	5,745
MOS Memory	1,315	1,907	2,457	2,492	2,846
MOS Microcomponent	763	917	1,133	1,390	1,647
MOS Logic	559	745	921	1,084	1,251
Analog	162	180	198	221	260
Total Discrete	307	321	325	334	349
Total Optoelectronic	118	142	161	186	199

Source: Dataquest (October 1992)

Table 33
Revenue Growth from Worldwide Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Input/Output Applications, 1989-1991
(Percentage Change)

	1989	1990	1991
Total Input/Output Devices	NA	9.9	8.1
Total Semiconductor	NA	-0.8	14.3
Total IC	NA	-0.7	14.9
Bipolar Digital	NA	3.8	-14.5
Bipolar Memory	NA	10.3	-14.6
Bipolar Logic	NA	3.6	-14.5
MOS Digital	NA	-1.9	18.1
MOS Memory	NA	-16.9	8.9
MOS Microcomponent	NA	28.5	32.2
MOS Logic	NA	12.3	22.4
Analog	NA	11.2	10.5
Total Discrete	NA	1.4	10.9
Total Optoelectronic	NA	-8.3	11.0

NA = Not available
Source: Dataquest (October 1992)

Table 34
Revenue Growth from Worldwide Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Input/Output Applications, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Input/Output Devices	2.8	7.4	7.3	5.4	5.3	5.6
Total Semiconductor	15.7	29.2	22.5	9.3	14.3	18.0
Total IC	19.4	32.1	24.6	9.6	15.2	19.9
Bipolar Digital	-16.5	-6.6	-8.9	-16.0	-18.9	-13.5
Bipolar Memory	24.4	-24.4	-34.8	-12.9	-1.2	-12.0
Bipolar Logic	-17.8	-5.8	-7.9	-16.1	-19.4	-13.6
MOS Digital	22.6	35.3	26.4	10.1	15.7	21.7
MOS Memory	32.2	45.0	28.8	1.4	14.2	23.4
MOS Microcomponent	25.2	20.1	23.6	22.7	18.5	22.0
MOS Logic	2.2	33.2	23.7	17.7	15.4	18.0
Analog	9.7	10.6	10.5	11.5	17.8	12.0
Total Discrete	-6.9	4.4	1.4	2.6	4.5	1.1
Total Optoelectronic	1.5	20.8	13.1	15.7	7.1	11.4

Source: Dataquest (October 1992)

Table 35
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Input/Output Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	11.1	10.1	10.6
Total IC	9.4	8.5	9.0
Bipolar Digital	0.8	0.7	0.6
Bipolar Memory	0	0	0
Bipolar Logic	0.7	0.7	0.5
MOS Digital	8.1	7.2	7.9
MOS Memory	4.8	3.6	3.6
MOS Microcomponent	1.6	1.8	2.2
MOS Logic	1.7	1.8	2.0
Analog	0.5	0.5	0.5
Total Discrete	1.3	1.2	1.2
Total Optoelectronic	0.5	0.4	0.4

Source: Dataquest (October 1992)

Table 36
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Input/Output Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	12.0	14.4	16.4	17.0	18.5
Total IC	10.5	12.9	14.9	15.5	17.0
Bipolar Digital	0.5	0.4	0.3	0.3	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.4	0.4	0.3	0.3	0.2
MOS Digital	9.4	11.9	14.0	14.6	16.0
MOS Memory	4.7	6.3	7.6	7.3	7.9
MOS Microcomponent	2.7	3.0	3.5	4.1	4.6
MOS Logic	2.0	2.5	2.9	3.2	3.5
Analog	0.6	0.6	0.6	0.6	0.7
Total Discrete	1.1	1.1	1.0	1.0	1.0
Total Optoelectronic	0.4	0.5	0.5	0.5	0.6

Source: Dataquest (October 1992)

Table 37
Revenue from Worldwide Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Dedicated Systems	19,444	19,026	20,113
Total Semiconductor	1,724	1,635	1,876
Total IC	1,418	1,363	1,569
Bipolar Digital	78	62	43
Bipolar Memory	3	4	3
Bipolar Logic	75	59	40
MOS Digital	1,254	1,213	1,427
MOS Memory	568	475	485
MOS Microcomponent	264	311	410
MOS Logic	422	427	533
Analog	86	88	99
Total Discrete	184	165	186
Total Optoelectronic	123	106	121

Source: Dataquest (October 1992)

Table 38
Revenue from Worldwide Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Dedicated Systems	20,810	22,248	23,500	24,723	26,241
Total Semiconductor	1,910	2,173	2,471	2,646	2,847
Total IC	1,617	1,877	2,149	2,320	2,508
Bipolar Digital	33	20	17	15	13
Bipolar Memory	2	2	1	1	1
Bipolar Logic	31	18	16	14	12
MOS Digital	1,485	1,758	2,023	2,179	2,339
MOS Memory	595	759	889	898	962
MOS Microcomponent	466	541	626	726	783
MOS Logic	424	457	508	555	594
Analog	99	100	109	126	156
Total Discrete	168	163	174	172	177
Total Optoelectronic	126	133	148	154	161

Source: Dataquest (October 1992)

Table 39
Revenue Growth from Worldwide Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1989-1991 (Percentage Change)

	1989	1990	1991
Total Dedicated Systems	NA	-2.1	5.7
Total Semiconductor	NA	-5.2	14.8
Total IC	NA	-3.9	15.1
Bipolar Digital	NA	-19.5	-31.7
Bipolar Memory	NA	34.9	-17.7
Bipolar Logic	NA	-21.5	-32.6
MOS Digital	NA	-3.3	17.7
MOS Memory	NA	-16.4	2.1
MOS Microcomponent	NA	18.0	31.6
MOS Logic	NA	1.1	24.8
Analog	NA	1.7	12.8
Total Discrete	NA	-10.0	12.5
Total Optoelectronic	NA	-13.6	13.5

NA = Not available
Source: Dataquest (October 1992)

Table 40
Revenue Growth from Worldwide Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Dedicated Systems	3.5	6.9	5.6	5.2	6.1	5.5
Total Semiconductor	1.8	13.8	13.7	7.1	7.6	8.7
Total IC	3.0	16.1	14.5	8.0	8.1	9.8
Bipolar Digital	-22.4	-41.0	-13.1	-9.6	-16.5	-21.4
Bipolar Memory	-23.3	-26.7	-37.6	-16.3	-5.0	-22.5
Bipolar Logic	-22.3	-42.1	-10.8	-9.1	-17.2	-21.3
MOS Digital	4.0	18.4	15.1	7.7	7.4	10.4
MOS Memory	22.7	27.6	17.1	1.1	7.1	14.7
MOS Microcomponent	13.6	16.2	15.7	15.9	7.9	13.8
MOS Logic	-20.3	7.8	11.1	9.3	7.1	2.2
Analog	-0.5	1.5	9.2	15.3	24.0	9.5
Total Discrete	-9.8	-2.9	6.6	-1.1	3.3	-0.9
Total Optoelectronic	4.2	5.7	11.5	3.9	4.4	5.9

Source: Dataquest (October 1992)

Table 41
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	8.9	8.6	9.3
Total IC	7.3	7.2	7.8
Bipolar Digital	0.4	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.3	0.2
MOS Digital	6.4	6.4	7.1
MOS Memory	2.9	2.5	2.4
MOS Microcomponent	1.4	1.6	2.0
MOS Logic	2.2	2.2	2.6
Analog	0.4	0.5	0.5
Total Discrete	0.9	0.9	0.9
Total Optoelectronic	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 42
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Dedicated Systems Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	9.2	9.8	10.5	10.7	10.8
Total IC	7.8	8.4	9.1	9.4	9.6
Bipolar Digital	0.2	0.1	0.1	0.1	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.1	0.1	0.1	0.1	0
MOS Digital	7.1	7.9	8.6	8.8	8.9
MOS Memory	2.9	3.4	3.8	3.6	3.7
MOS Microcomponent	2.2	2.4	2.7	2.9	3.0
MOS Logic	2.0	2.1	2.2	2.2	2.3
Analog	0.5	0.4	0.5	0.5	0.6
Total Discrete	0.8	0.7	0.7	0.7	0.7
Total Optoelectronic	0.6	0.6	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 43
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Communications	84,492	94,461	101,340
Total Semiconductor	6,841	7,468	8,131
Total IC	5,210	5,676	6,205
Bipolar Digital	505	508	438
Bipolar Memory	12	12	9
Bipolar Logic	493	496	429
MOS Digital	3,314	3,475	3,982
MOS Memory	1,337	1,125	1,165
MOS Microcomponent	813	1,030	1,256
MOS Logic	1,164	1,320	1,562
Analog	1,390	1,692	1,785
Total Discrete	1,175	1,323	1,359
Total Optoelectronic	456	469	568

Source: Dataquest (October 1992)

Table 44
Revenue from Worldwide Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Communications Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Communications	107,515	116,893	124,612	134,831	143,455
Total Semiconductor	8,544	9,765	10,972	11,840	12,854
Total IC	6,588	7,670	8,745	9,509	10,397
Bipolar Digital	363	324	286	252	216
Bipolar Memory	11	8	5	4	4
Bipolar Logic	352	316	281	248	212
MOS Digital	4,302	5,147	5,982	6,527	7,239
MOS Memory	1,302	1,606	1,901	1,855	2,026
MOS Microcomponent	1,404	1,641	1,940	2,299	2,547
MOS Logic	1,597	1,900	2,142	2,374	2,667
Analog	1,922	2,200	2,477	2,730	2,942
Total Discrete	1,374	1,460	1,533	1,589	1,671
Total Optoelectronic	583	635	694	741	785

Source: Dataquest (October 1992)

Table 45
Revenue Growth from Worldwide Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Communications	NA	11.8	7.3
Total Semiconductor	NA	9.2	8.9
Total IC	NA	8.9	9.3
Bipolar Digital	NA	0.6	-13.8
Bipolar Memory	NA	-0.6	-21.5
Bipolar Logic	NA	0.6	-13.6
MOS Digital	NA	4.9	14.6
MOS Memory	NA	-15.9	3.5
MOS Microcomponent	NA	26.7	21.8
MOS Logic	NA	13.4	18.3
Analog	NA	21.7	5.4
Total Discrete	NA	12.6	2.7
Total Optoelectronic	NA	2.9	21.0

NA = Not available
Source: Dataquest (October 1992)

Table 46
Revenue Growth from Worldwide Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Communications Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Communications	6.1	8.7	6.6	8.2	6.4	7.2
Total Semiconductor	5.1	14.3	12.4	7.9	8.6	9.6
Total IC	6.2	16.4	14.0	8.7	9.3	10.9
Bipolar Digital	-17.1	-10.8	-11.7	-11.8	-14.4	-13.2
Bipolar Memory	15.9	-29.7	-37.9	-20.8	-6.4	-17.8
Bipolar Logic	-17.9	-10.3	-11.1	-11.6	-14.5	-13.1
MOS Digital	8.0	19.6	16.2	9.1	10.9	12.7
MOS Memory	11.8	23.3	18.4	-2.4	9.2	11.7
MOS Microcomponent	11.8	16.9	18.2	18.5	10.8	15.2
MOS Logic	2.2	19.0	12.8	10.8	12.3	11.3
Analog	7.7	14.4	12.6	10.2	7.8	10.5
Total Discrete	1.1	6.3	5.0	3.7	5.1	4.2
Total Optoelectronic	2.7	8.8	9.4	6.8	5.9	6.7

Source: Dataquest (October 1992)

Table 47
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Communications Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	8.1	7.9	8.0
Total IC	6.2	6.0	6.1
Bipolar Digital	0.6	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.6	0.5	0.4
MOS Digital	3.9	3.7	3.9
MOS Memory	1.6	1.2	1.1
MOS Microcomponent	1.0	1.1	1.2
MOS Logic	1.4	1.4	1.5
Analog	1.6	1.8	1.8
Total Discrete	1.4	1.4	1.3
Total Optoelectronic	0.5	0.5	0.6

Source: Dataquest (October 1992)

Table 48
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Communications Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	7.9	8.4	8.8	8.8	9.0
Total IC	6.1	6.6	7.0	7.1	7.2
Bipolar Digital	0.3	0.3	0.2	0.2	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.3	0.2	0.2	0.1
MOS Digital	4.0	4.4	4.8	4.8	5.0
MOS Memory	1.2	1.4	1.5	1.4	1.4
MOS Microcomponent	1.3	1.4	1.6	1.7	1.8
MOS Logic	1.5	1.6	1.7	1.8	1.9
Analog	1.8	1.9	2.0	2.0	2.1
Total Discrete	1.3	1.2	1.2	1.2	1.2
Total Optoelectronic	0.5	0.5	0.6	0.5	0.5

Source: Dataquest (October 1992)

Table 49
Revenue from Worldwide Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Premise Telecom Equipment	35,156	38,066	40,701
Total Semiconductor	3,245	3,345	3,533
Total IC	2,575	2,658	2,833
Bipolar Digital	202	187	152
Bipolar Memory	3	3	3
Bipolar Logic	199	184	150
MOS Digital	1,746	1,722	1,910
MOS Memory	714	572	570
MOS Microcomponent	453	542	648
MOS Logic	580	608	692
Analog	626	749	771
Total Discrete	475	505	492
Total Optoelectronic	195	182	208

Source: Dataquest (October 1992)

Table 50
Revenue from Worldwide Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Premise Telecom Equipment	42,624	46,073	49,017	51,965	54,588
Total Semiconductor	3,761	4,339	4,884	5,234	5,732
Total IC	3,060	3,604	4,102	4,409	4,862
Bipolar Digital	121	107	92	77	62
Bipolar Memory	3	2	1	1	1
Bipolar Logic	118	105	90	76	61
MOS Digital	2,101	2,529	2,932	3,139	3,510
MOS Memory	629	776	926	864	977
MOS Microcomponent	742	885	1,048	1,226	1,380
MOS Logic	729	868	958	1,049	1,153
Analog	838	969	1,079	1,193	1,290
Total Discrete	479	494	524	548	579
Total Optoelectronic	222	240	258	276	291

Source: Dataquest (October 1992)

Table 51
Revenue Growth from Worldwide Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Premise Telecom Equipment	NA	8.3	6.9
Total Semiconductor	NA	3.1	5.6
Total IC	NA	3.2	6.6
Bipolar Digital	NA	-7.6	-18.5
Bipolar Memory	NA	-0.2	-11.1
Bipolar Logic	NA	-7.7	-18.6
MOS Digital	NA	-1.4	10.9
MOS Memory	NA	-19.9	-0.3
MOS Microcomponent	NA	19.8	19.5
MOS Logic	NA	4.9	13.8
Analog	NA	19.6	3.0
Total Discrete	NA	6.2	-2.6
Total Optoelectronic	NA	-6.8	14.4

NA = Not available
Source: Dataquest (October 1992)

Table 52
Revenue Growth from Worldwide Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Premise Telecom Equipment	4.7	8.1	6.4	6.0	5.0	6.0
Total Semiconductor	6.4	15.4	12.6	7.2	9.5	10.2
Total IC	8.0	17.8	13.8	7.5	10.3	11.4
Bipolar Digital	-20.4	-12.1	-14.1	-15.5	-20.0	-16.5
Bipolar Memory	16.8	-30.4	-38.1	-20.8	-11.7	-18.8
Bipolar Logic	-21.0	-11.6	-13.6	-15.5	-20.1	-16.4
MOS Digital	10.0	20.4	15.9	7.1	11.8	12.9
MOS Memory	10.4	23.4	19.3	-6.6	13.0	11.4
MOS Microcomponent	14.5	19.2	18.4	17.0	12.6	16.3
MOS Logic	5.4	19.0	10.4	9.5	9.9	10.8
Analog	8.6	15.7	11.4	10.6	8.1	10.8
Total Discrete	-2.7	3.2	6.1	4.6	5.6	3.3
Total Optoelectronic	7.0	8.0	7.4	7.1	5.3	6.9

Source: Dataquest (October 1992)

Table 53
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	9.2	8.8	8.7
Total IC	7.3	7.0	7.0
Bipolar Digital	0.6	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.6	0.5	0.4
MOS Digital	5.0	4.5	4.7
MOS Memory	2.0	1.5	1.4
MOS Microcomponent	1.3	1.4	1.6
MOS Logic	1.6	1.6	1.7
Analog	1.8	2.0	1.9
Total Discrete	1.4	1.3	1.2
Total Optoelectronic	0.6	0.5	0.5

Source: Dataquest (October 1992)

Table 54
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Premise Telecom Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	8.8	9.4	10.0	10.1	10.5
Total IC	7.2	7.8	8.4	8.5	8.9
Bipolar Digital	0.3	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.1	0.1
MOS Digital	4.9	5.5	6.0	6.0	6.4
MOS Memory	1.5	1.7	1.9	1.7	1.8
MOS Microcomponent	1.7	1.9	2.1	2.4	2.5
MOS Logic	1.7	1.9	2.0	2.0	2.1
Analog	2.0	2.1	2.2	2.3	2.4
Total Discrete	1.1	1.1	1.1	1.1	1.1
Total Optoelectronic	0.5	0.5	0.5	0.5	0.5

Source: Dataquest (October 1992)

Table 55
Revenue from Worldwide Public Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Public Telecom Equipment	24,446	28,450	30,763
Total Semiconductor	1,282	1,464	1,571
Total IC	917	1,027	1,110
Bipolar Digital	71	83	70
Bipolar Memory	3	3	3
Bipolar Logic	68	80	68
MOS Digital	611	649	740
MOS Memory	266	228	242
MOS Microcomponent	138	184	220
MOS Logic	207	237	278
Analog	235	295	300
Total Discrete	224	278	262
Total Optoelectronic	141	159	198

Source: Dataquest (October 1992)

Table 56
Revenue from Worldwide Public Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Public Telecom Equipment	32,842	35,874	37,925	40,065	43,052
Total Semiconductor	1,644	1,840	2,017	2,145	2,294
Total IC	1,187	1,363	1,523	1,635	1,753
Bipolar Digital	69	65	62	57	53
Bipolar Memory	3	2	1	1	1
Bipolar Logic	66	63	61	57	52
MOS Digital	790	936	1,072	1,160	1,266
MOS Memory	275	342	393	379	414
MOS Microcomponent	237	260	294	356	393
MOS Logic	278	335	385	425	459
Analog	328	362	390	418	433
Total Discrete	266	269	270	276	286
Total Optoelectronic	192	207	224	234	255

Source: Dataquest (October 1992)

Table 57
Revenue Growth from Worldwide Public Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Public Telecom Equipment	NA	16.4	8.1
Total Semiconductor	NA	14.2	7.3
Total IC	NA	12.0	8.1
Bipolar Digital	NA	16.9	-15.8
Bipolar Memory	NA	1.1	-13.1
Bipolar Logic	NA	17.6	-15.8
MOS Digital	NA	6.3	14.0
MOS Memory	NA	-14.1	6.1
MOS Microcomponent	NA	33.3	19.5
MOS Logic	NA	14.5	17.4
Analog	NA	25.4	1.7
Total Discrete	NA	24.1	-5.5
Total Optoelectronic	NA	13.0	24.5

NA = Not available
Source: Dataquest (October 1992)

Table 58
Revenue Growth from Worldwide Public Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Public Telecom Equipment	6.8	9.2	5.7	5.6	7.5	7.0
Total Semiconductor	4.7	11.9	9.7	6.3	7.0	7.9
Total IC	6.9	14.9	11.7	7.3	7.2	9.6
Bipolar Digital	-2.1	-5.1	-5.1	-7.1	-7.4	-5.4
Bipolar Memory	10.3	-31.9	-40.1	-22.3	-8.2	-20.3
Bipolar Logic	-2.6	-4.0	-4.1	-6.8	-7.4	-5.0
MOS Digital	6.7	18.5	14.5	8.2	9.2	11.3
MOS Memory	13.4	24.3	14.8	-3.5	9.4	11.3
MOS Microcomponent	8.0	9.5	13.4	20.9	10.3	12.3
MOS Logic	-0.1	20.3	15.0	10.4	8.1	10.5
Analog	9.4	10.4	7.6	7.2	3.8	7.6
Total Discrete	1.3	1.1	0.6	2.1	3.5	1.7
Total Optoelectronic	-3.2	8.3	7.9	4.5	9.0	5.2

Source: Dataquest (October 1992)

Table 59
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	5.2	5.1	5.1
Total IC	3.8	3.6	3.6
Bipolar Digital	0.3	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	2.5	2.3	2.4
MOS Memory	1.1	0.8	0.8
MOS Microcomponent	0.6	0.6	0.7
MOS Logic	0.8	0.8	0.9
Analog	1.0	1.0	1.0
Total Discrete	0.9	1.0	0.9
Total Optoelectronic	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 60
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Public Telecom Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	5.0	5.1	5.3	5.4	5.3
Total IC	3.6	3.8	4.0	4.1	4.1
Bipolar Digital	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.2	0.1	0.1
MOS Digital	2.4	2.6	2.8	2.9	2.9
MOS Memory	0.8	1.0	1.0	0.9	1.0
MOS Microcomponent	0.7	0.7	0.8	0.9	0.9
MOS Logic	0.8	0.9	1.0	1.1	1.1
Analog	1.0	1.0	1.0	1.0	1.0
Total Discrete	0.8	0.7	0.7	0.7	0.7
Total Optoelectronic	0.6	0.6	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 61
Revenue from Worldwide Mobile Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Mobile Communications Equipment	13,382	15,264	16,887
Total Semiconductor	1,450	1,695	1,983
Total IC	1,035	1,234	1,431
Bipolar Digital	152	162	152
Bipolar Memory	1	1	1
Bipolar Logic	150	160	151
MOS Digital	528	648	805
MOS Memory	166	166	185
MOS Microcomponent	134	179	231
MOS Logic	228	303	388
Analog	355	424	474
Total Discrete	336	373	443
Total Optoelectronic	79	88	109

Source: Dataquest (October 1992)

Table 62
Revenue from Worldwide Mobile Communications Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Mobile Communications Equipment	18,197	19,961	21,863	25,991	28,046
Total Semiconductor	1,968	2,220	2,535	2,784	3,178
Total IC	1,393	1,582	1,850	2,077	2,406
Bipolar Digital	115	103	89	80	66
Bipolar Memory	2	1	1	1	1
Bipolar Logic	113	101	88	79	65
MOS Digital	787	921	1,094	1,253	1,505
MOS Memory	199	231	272	298	328
MOS Microcomponent	234	276	332	386	442
MOS Logic	354	414	490	570	735
Analog	492	559	666	744	835
Total Discrete	452	503	531	538	592
Total Optoelectronic	122	135	154	169	179

Source: Dataquest (October 1992)

Table 63
Revenue Growth from Worldwide Mobile Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Mobile Communications Equipment	NA	14.1	10.6
Total Semiconductor	NA	16.9	17.0
Total IC	NA	19.2	16.0
Bipolar Digital	NA	6.6	-5.9
Bipolar Memory	NA	-7.1	0.5
Bipolar Logic	NA	6.7	-6.0
MOS Digital	NA	22.7	24.1
MOS Memory	NA	0	11.7
MOS Microcomponent	NA	33.5	29.0
MOS Logic	NA	32.8	28.1
Analog	NA	19.4	11.9
Total Discrete	NA	11.1	18.7
Total Optoelectronic	NA	11.1	24.6

NA = Not available

Source: Dataquest (October 1992)

Table 64
Revenue Growth from Worldwide Mobile Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Mobile Communications Equipment	7.8	9.7	9.5	18.9	7.9	10.7
Total Semiconductor	-0.8	12.8	14.2	9.8	14.1	9.9
Total IC	-2.6	13.5	17.0	12.3	15.8	11.0
Bipolar Digital	-24.5	-10.7	-13.0	-10.9	-16.6	-15.3
Bipolar Memory	34.4	-22.5	-32.3	-11.9	7.4	-7.8
Bipolar Logic	-25.0	-10.5	-12.8	-10.9	-16.9	-15.4
MOS Digital	-2.2	17.0	18.9	14.5	20.1	13.3
MOS Memory	7.6	15.8	18.0	9.3	10.3	12.1
MOS Microcomponent	1.1	17.9	20.5	16.2	14.4	13.8
MOS Logic	-8.9	17.1	18.3	16.3	29.1	13.6
Analog	3.7	13.6	19.3	11.7	12.2	12.0
Total Discrete	2.1	11.3	5.4	1.5	10.0	6.0
Total Optoelectronic	12.2	9.9	14.7	9.4	6.0	10.4

Source: Dataquest (October 1992)

Table 65
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	10.8	11.1	11.7
Total IC	7.7	8.1	8.5
Bipolar Digital	1.1	1.1	0.9
Bipolar Memory	0	0	0
Bipolar Logic	1.1	1.1	0.9
MOS Digital	3.9	4.2	4.8
MOS Memory	1.2	1.1	1.1
MOS Microcomponent	1.0	1.2	1.4
MOS Logic	1.7	2.0	2.3
Analog	2.7	2.8	2.8
Total Discrete	2.5	2.4	2.6
Total Optoelectronic	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 66
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Mobile Communications Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	10.8	11.1	11.6	10.7	11.3
Total IC	7.7	7.9	8.5	8.0	8.6
Bipolar Digital	0.6	0.5	0.4	0.3	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.6	0.5	0.4	0.3	0.2
MOS Digital	4.3	4.6	5.0	4.8	5.4
MOS Memory	1.1	1.2	1.2	1.1	1.2
MOS Microcomponent	1.3	1.4	1.5	1.5	1.6
MOS Logic	1.9	2.1	2.2	2.2	2.6
Analog	2.7	2.8	3.0	2.9	3.0
Total Discrete	2.5	2.5	2.4	2.1	2.1
Total Optoelectronic	0.7	0.7	0.7	0.7	0.6

Source: Dataquest (October 1992)

Table 67
Revenue from Worldwide Broadcast and Studio Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Broadcast and Studio	3,484	3,921	4,164
Total Semiconductor	210	234	249
Total IC	173	189	205
Bipolar Digital	23	23	21
Bipolar Memory	2	2	0
Bipolar Logic	21	22	21
MOS Digital	112	117	135
MOS Memory	50	41	43
MOS Microcomponent	24	33	41
MOS Logic	37	43	51
Analog	39	48	49
Total Discrete	29	36	34
Total Optoelectronic	9	9	10

Source: Dataquest (October 1992)

Table 68
Revenue from Worldwide Broadcast and Studio Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Broadcast and Studio	4,492	5,019	5,448	5,923	6,487
Total Semiconductor	265	313	361	408	415
Total IC	218	263	308	353	358
Bipolar Digital	18	17	17	15	14
Bipolar Memory	0	0	0	0	0
Bipolar Logic	18	17	17	15	14
MOS Digital	150	187	227	269	271
MOS Memory	49	67	85	89	88
MOS Microcomponent	47	55	71	102	101
MOS Logic	54	65	72	77	82
Analog	50	58	64	69	73
Total Discrete	36	38	39	40	40
Total Optoelectronic	11	12	14	15	16

Source: Dataquest (October 1992)

Table 69
Revenue Growth from Worldwide Broadcast and Studio Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Broadcast and Studio	NA	12.6	6.2
Total Semiconductor	NA	11.4	6.0
Total IC	NA	9.2	8.3
Bipolar Digital	NA	2.5	-11.0
Bipolar Memory	NA	2.7	-91.9
Bipolar Logic	NA	2.5	-5.2
MOS Digital	NA	5.3	14.7
MOS Memory	NA	-19.2	4.8
MOS Microcomponent	NA	37.5	23.0
MOS Logic	NA	17.5	17.6
Analog	NA	24.4	1.9
Total Discrete	NA	25.5	-6.0
Total Optoelectronic	NA	8.4	7.7

NA = Not available
Source: Dataquest (October 1992)

Table 70
Revenue Growth from Worldwide Broadcast and Studio Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Broadcast and Studio	7.9	11.7	8.5	8.7	9.5	9.3
Total Semiconductor	6.6	17.9	15.4	13.1	1.6	10.8
Total IC	6.5	20.6	17.2	14.5	1.6	11.9
Bipolar Digital	-13.6	-5.6	-1.3	-11.2	-4.2	-7.3
Bipolar Memory	-40.2	-54.6	-23.2	-14.6	-33.7	-34.8
Bipolar Logic	-13.4	-5.4	-1.3	-11.2	-4.2	-7.2
MOS Digital	11.2	25.1	21.3	18.2	0.8	15.0
MOS Memory	15.1	35.8	26.9	5.4	-1.4	15.6
MOS Microcomponent	14.4	17.6	27.7	44.5	-0.9	19.7
MOS Logic	5.5	21.8	10.1	7.5	5.7	9.9
Analog	2.1	16.4	9.6	8.1	6.0	8.4
Total Discrete	6.2	3.9	3.1	3.3	0.4	3.4
Total Optoelectronic	9.8	12.1	15.2	8.1	5.4	10.1

Source: Dataquest (October 1992)

Table 71
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	6.0	6.0	6.0
Total IC	5.0	4.8	4.9
Bipolar Digital	0.7	0.6	0.5
Bipolar Memory	0	0	0
Bipolar Logic	0.6	0.6	0.5
MOS Digital	3.2	3.0	3.2
MOS Memory	1.4	1.0	1.0
MOS Microcomponent	0.7	0.9	1.0
MOS Logic	1.1	1.1	1.2
Analog	1.1	1.2	1.2
Total Discrete	0.8	0.9	0.8
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (October 1992)

Table 72
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Broadcast and Studio Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	5.9	6.2	6.6	6.9	6.4
Total IC	4.9	5.2	5.7	6.0	5.5
Bipolar Digital	0.4	0.3	0.3	0.3	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.4	0.3	0.3	0.2	0.2
MOS Digital	3.3	3.7	4.2	4.5	4.2
MOS Memory	1.1	1.3	1.6	1.5	1.4
MOS Microcomponent	1.0	1.1	1.3	1.7	1.6
MOS Logic	1.2	1.3	1.3	1.3	1.3
Analog	1.1	1.2	1.2	1.2	1.1
Total Discrete	0.8	0.8	0.7	0.7	0.6
Total Optoelectronic	0.2	0.2	0.3	0.3	0.2

Source: Dataquest (October 1992)

Table 73
Revenue from Worldwide Other Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Other Telecom	8,025	8,759	8,826
Total Semiconductor	654	730	796
Total IC	510	567	626
Bipolar Digital	57	53	43
Bipolar Memory	3	3	3
Bipolar Logic	54	50	40
MOS Digital	317	338	393
MOS Memory	141	118	125
MOS Microcomponent	64	91	115
MOS Logic	112	128	153
Analog	135	176	190
Total Discrete	111	131	127
Total Optoelectronic	33	32	43

Source: Dataquest (October 1992)

Table 74
Revenue from Worldwide Other Telecom Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Other Telecom	9,360	9,967	10,359	10,886	11,282
Total Semiconductor	906	1,054	1,175	1,269	1,236
Total IC	730	858	962	1,035	1,018
Bipolar Digital	40	32	26	23	20
Bipolar Memory	3	2	1	1	1
Bipolar Logic	37	30	25	22	19
MOS Digital	475	574	657	706	687
MOS Memory	149	190	225	225	219
MOS Microcomponent	143	166	194	229	231
MOS Logic	182	218	238	253	238
Analog	215	252	279	306	311
Total Discrete	141	156	169	187	174
Total Optoelectronic	36	40	44	47	44

Source: Dataquest (October 1992)

Table 75
Revenue Growth from Worldwide Other Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Other Telecom	NA	9.1	0.8
Total Semiconductor	NA	11.8	9.0
Total IC	NA	11.2	10.2
Bipolar Digital	NA	-7.8	-19.1
Bipolar Memory	NA	-1.2	-13.2
Bipolar Logic	NA	-8.2	-19.5
MOS Digital	NA	6.6	16.1
MOS Memory	NA	-16.1	5.4
MOS Microcomponent	NA	42.8	26.2
MOS Logic	NA	14.3	18.8
Analog	NA	30.3	7.8
Total Discrete	NA	18.4	-2.9
Total Optoelectronic	NA	-2.7	34.8

NA = Not available
Source: Dataquest (October 1992)

Table 76
Revenue Growth from Worldwide Other Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Other Telecom	6.1	6.5	3.9	5.1	3.6	5.0
Total Semiconductor	13.9	16.3	11.5	8.0	-2.6	9.2
Total IC	16.7	17.5	12.2	7.6	-1.7	10.2
Bipolar Digital	-6.0	-19.7	-18.6	-13.0	-11.6	-13.9
Bipolar Memory	13.9	-30.8	-39.5	-25.9	-10.3	-20.5
Bipolar Logic	-7.3	-18.8	-17.1	-12.3	-11.7	-13.5
MOS Digital	20.9	20.8	14.6	7.5	-2.8	11.8
MOS Memory	19.7	27.3	18.4	-0.2	-2.7	11.9
MOS Microcomponent	24.3	15.6	17.3	17.6	0.9	14.9
MOS Logic	19.3	19.6	9.1	6.5	-6.1	9.2
Analog	13.1	17.2	10.7	9.8	1.6	10.4
Total Discrete	10.5	11.0	8.1	10.5	-6.8	6.4
Total Optoelectronic	-17.0	12.5	9.2	6.7	-5.8	0.5

Source: Dataquest (October 1992)

Table 77
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	8.1	8.3	9.0
Total IC	6.4	6.5	7.1
Bipolar Digital	0.7	0.6	0.5
Bipolar Memory	0	0	0
Bipolar Logic	0.7	0.6	0.5
MOS Digital	4.0	3.9	4.4
MOS Memory	1.8	1.4	1.4
MOS Microcomponent	0.8	1.0	1.3
MOS Logic	1.4	1.5	1.7
Analog	1.7	2.0	2.2
Total Discrete	1.4	1.5	1.4
Total Optoelectronic	0.4	0.4	0.5

Source: Dataquest (October 1992)

Table 78
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Telecom Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	9.7	10.6	11.3	11.7	11.0
Total IC	7.8	8.6	9.3	9.5	9.0
Bipolar Digital	0.4	0.3	0.3	0.2	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.4	0.3	0.2	0.2	0.2
MOS Digital	5.1	5.8	6.3	6.5	6.1
MOS Memory	1.6	1.9	2.2	2.1	1.9
MOS Microcomponent	1.5	1.7	1.9	2.1	2.0
MOS Logic	1.9	2.2	2.3	2.3	2.1
Analog	2.3	2.5	2.7	2.8	2.8
Total Discrete	1.5	1.6	1.6	1.7	1.5
Total Optoelectronic	0.4	0.4	0.4	0.4	0.4

Source: Dataquest (October 1992)

Table 79
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Industrial	90,940	99,139	102,514
Total Semiconductor	5,503	5,865	6,180
Total IC	3,705	3,935	4,225
Bipolar Digital	471	456	369
Bipolar Memory	24	23	18
Bipolar Logic	447	434	351
MOS Digital	2,158	2,216	2,527
MOS Memory	839	687	714
MOS Microcomponent	653	780	945
MOS Logic	666	749	868
Analog	1,076	1,263	1,328
Total Discrete	1,414	1,518	1,474
Total Optoelectronic	384	411	481

Source: Dataquest (October 1992)

Table 80
Revenue from Worldwide Industrial Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Industrial	104,901	113,118	121,185	128,694	137,486
Total Semiconductor	6,467	7,459	8,556	9,426	10,264
Total IC	4,464	5,294	6,212	6,912	7,605
Bipolar Digital	331	288	254	224	198
Bipolar Memory	22	16	10	8	8
Bipolar Logic	309	272	244	216	190
MOS Digital	2,720	3,360	4,078	4,568	5,098
MOS Memory	784	988	1,187	1,182	1,298
MOS Microcomponent	1,064	1,277	1,554	1,806	2,007
MOS Logic	872	1,096	1,338	1,579	1,792
Analog	1,413	1,646	1,880	2,120	2,309
Total Discrete	1,509	1,618	1,730	1,831	1,931
Total Optoelectronic	494	547	615	683	729

Source: Dataquest (October 1992)

Table 81
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Industrial	NA	9.0	3.4
Total Semiconductor	NA	6.6	5.4
Total IC	NA	6.2	7.4
Bipolar Digital	NA	-3.2	-19.1
Bipolar Memory	NA	-6.5	-19.7
Bipolar Logic	NA	-3.0	-19.1
MOS Digital	NA	2.7	14.0
MOS Memory	NA	-18.1	3.9
MOS Microcomponent	NA	19.4	21.2
MOS Logic	NA	12.4	15.9
Analog	NA	17.4	5.2
Total Discrete	NA	7.4	-2.9
Total Optoelectronic	NA	7.2	16.8

NA = Not available
Source: Dataquest (October 1992)

Table 82
Revenue Growth from Worldwide Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Industrial	2.3	7.8	7.1	6.2	6.8	6.0
Total Semiconductor	4.6	15.3	14.7	10.2	8.9	10.7
Total IC	5.7	18.6	17.3	11.3	10.0	12.5
Bipolar Digital	-10.4	-13.0	-11.6	-11.7	-11.8	-11.7
Bipolar Memory	18.7	-27.0	-36.5	-16.7	-4.4	-15.2
Bipolar Logic	-11.9	-12.1	-10.2	-11.5	-12.1	-11.6
MOS Digital	7.6	23.6	21.3	12.0	11.6	15.1
MOS Memory	9.9	25.9	20.1	-0.4	9.9	12.7
MOS Microcomponent	12.6	20.1	21.7	16.3	11.1	16.3
MOS Logic	0.4	25.7	22.1	18.1	13.5	15.6
Analog	6.4	16.5	14.2	12.8	8.9	11.7
Total Discrete	2.4	7.2	6.9	5.8	5.4	5.5
Total Optoelectronic	2.8	10.7	12.4	11.2	6.7	8.7

Source: Dataquest (October 1992)

Table 83
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	6.1	5.9	6.0
Total IC	4.1	4.0	4.1
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	2.4	2.2	2.5
MOS Memory	0.9	0.7	0.7
MOS Microcomponent	0.7	0.8	0.9
MOS Logic	0.7	0.8	0.8
Analog	1.2	1.3	1.3
Total Discrete	1.6	1.5	1.4
Total Optoelectronic	0.4	0.4	0.5

Source: Dataquest (October 1992)

Table 84
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Industrial Equipment Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	6.2	6.6	7.1	7.3	7.5
Total IC	4.3	4.7	5.1	5.4	5.5
Bipolar Digital	0.3	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1
MOS Digital	2.6	3.0	3.4	3.5	3.7
MOS Memory	0.7	0.9	1.0	0.9	0.9
MOS Microcomponent	1.0	1.1	1.3	1.4	1.5
MOS Logic	0.8	1.0	1.1	1.2	1.3
Analog	1.3	1.5	1.6	1.6	1.7
Total Discrete	1.4	1.4	1.4	1.4	1.4
Total Optoelectronic	0.5	0.5	0.5	0.5	0.5

Source: Dataquest (October 1992)

Table 85
Revenue from Worldwide Security/Energy Management Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Security/Energy Management	10,103	11,015	12,788
Total Semiconductor	518	574	654
Total IC	331	365	411
Bipolar Digital	36	32	27
Bipolar Memory	4	3	2
Bipolar Logic	33	30	25
MOS Digital	180	194	233
MOS Memory	58	48	54
MOS Microcomponent	51	64	80
MOS Logic	71	82	100
Analog	115	140	151
Total Discrete	143	159	179
Total Optoelectronic	44	50	64

Source: Dataquest (October 1992)

Table 86
Revenue from Worldwide Security/Energy Management Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Security/Energy Management	13,921	15,511	17,157	18,813	20,874
Total Semiconductor	761	884	1,025	1,150	1,285
Total IC	508	604	727	830	930
Bipolar Digital	27	23	20	17	14
Bipolar Memory	2	2	1	1	1
Bipolar Logic	24	21	18	16	13
MOS Digital	312	382	476	552	623
MOS Memory	83	99	120	122	130
MOS Microcomponent	103	131	165	201	230
MOS Logic	126	153	191	229	263
Analog	169	199	231	261	293
Total Discrete	181	197	206	217	232
Total Optoelectronic	72	82	93	104	123

Source: Dataquest (October 1992)

Table 87
Revenue Growth from Worldwide Security/Energy Management Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Security/Energy Management	NA	9.0	16.1
Total Semiconductor	NA	10.8	13.9
Total IC	NA	10.4	12.5
Bipolar Digital	NA	-11.5	-16.8
Bipolar Memory	NA	-24.3	-22.2
Bipolar Logic	NA	-10.1	-16.4
MOS Digital	NA	7.7	20.5
MOS Memory	NA	-16.5	11.2
MOS Microcomponent	NA	25.2	25.2
MOS Logic	NA	14.8	22.4
Analog	NA	21.7	8.1
Total Discrete	NA	11.1	12.6
Total Optoelectronic	NA	13.3	28.1

NA = Not available
Source: Dataquest (October 1992)

Table 88
Revenue Growth from Worldwide Security/Energy Management Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Security/Energy Management	8.9	11.4	10.6	9.6	11.0	10.3
Total Semiconductor	16.4	16.2	16.0	12.2	11.7	14.5
Total IC	23.6	19.0	20.3	14.1	12.1	17.8
Bipolar Digital	0.3	-16.2	-12.8	-13.8	-17.3	-12.2
Bipolar Memory	18.7	-27.1	-37.0	-16.3	-5.1	-15.4
Bipolar Logic	-1.2	-15.1	-10.7	-13.7	-18.0	-11.9
MOS Digital	33.6	22.7	24.6	15.9	13.0	21.7
MOS Memory	53.5	20.0	20.7	1.9	7.1	19.4
MOS Microcomponent	29.7	26.4	26.7	21.7	14.5	23.7
MOS Logic	25.9	21.5	25.3	19.5	14.8	21.3
Analog	12.3	17.7	15.9	13.0	12.2	14.2
Total Discrete	1.4	8.9	4.2	5.5	6.8	5.3
Total Optoelectronic	11.9	14.7	12.7	11.7	18.7	13.9

Source: Dataquest (October 1992)

Table 89
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	5.1	5.2	5.1
Total IC	3.3	3.3	3.2
Bipolar Digital	0.4	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	1.8	1.8	1.8
MOS Memory	0.6	0.4	0.4
MOS Microcomponent	0.5	0.6	0.6
MOS Logic	0.7	0.7	0.8
Analog	1.1	1.3	1.2
Total Discrete	1.4	1.4	1.4
Total Optoelectronic	0.4	0.5	0.5

Source: Dataquest (October 1992)

Table 90
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Security/Energy Management Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	5.5	5.7	6.0	6.1	6.2
Total IC	3.6	3.9	4.2	4.4	4.5
Bipolar Digital	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.1	0.1	0.1	0.1
MOS Digital	2.2	2.5	2.8	2.9	3.0
MOS Memory	0.6	0.6	0.7	0.6	0.6
MOS Microcomponent	0.7	0.8	1.0	1.1	1.1
MOS Logic	0.9	1.0	1.1	1.2	1.3
Analog	1.2	1.3	1.3	1.4	1.4
Total Discrete	1.3	1.3	1.2	1.2	1.1
Total Optoelectronic	0.5	0.5	0.5	0.6	0.6

Source: Dataquest (October 1992)

Table 91
Revenue from Worldwide Manufacturing Systems and Instruments Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Manufacturing Systems and Instrumentation	55,320	61,277	62,174
Total Semiconductor	3,715	3,910	4,120
Total IC	2,512	2,630	2,830
Bipolar Digital	328	322	260
Bipolar Memory	14	12	10
Bipolar Logic	314	310	250
MOS Digital	1,587	1,617	1,837
MOS Memory	660	544	563
MOS Microcomponent	502	593	717
MOS Logic	426	479	557
Analog	597	691	733
Total Discrete	940	997	962
Total Optoelectronic	262	283	328

Source: Dataquest (October 1992)

Table 92
Revenue from Worldwide Manufacturing Systems and Instruments Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Manufacturing Systems and Instrumentation	62,853	67,338	71,964	76,050	80,744
Total Semiconductor	4,141	4,759	5,443	5,958	6,512
Total IC	2,859	3,389	3,963	4,376	4,846
Bipolar Digital	222	193	171	150	134
Bipolar Memory	12	9	6	5	4
Bipolar Logic	210	184	165	145	129
MOS Digital	1,885	2,328	2,811	3,119	3,505
MOS Memory	584	735	877	863	968
MOS Microcomponent	785	934	1,121	1,282	1,416
MOS Logic	516	659	813	974	1,121
Analog	751	868	981	1,107	1,208
Total Discrete	958	1,016	1,079	1,133	1,196
Total Optoelectronic	325	354	401	450	470

Source: Dataquest (October 1992)

Table 93
Revenue Growth from Worldwide Manufacturing Systems and Instruments Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Manufacturing Systems and Instrumentation	NA	10.8	1.5
Total Semiconductor	NA	5.3	5.4
Total IC	NA	4.7	7.6
Bipolar Digital	NA	-1.6	-19.4
Bipolar Memory	NA	-9.5	-18.5
Bipolar Logic	NA	-1.3	-19.4
MOS Digital	NA	1.8	13.7
MOS Memory	NA	-17.5	3.5
MOS Microcomponent	NA	18.1	21.0
MOS Logic	NA	12.6	16.1
Analog	NA	15.7	6.1
Total Discrete	NA	6.0	-3.5
Total Optoelectronic	NA	8.0	15.7

NA = Not available
Source: Dataquest (October 1992)

Table 94
Revenue Growth from Worldwide Manufacturing Systems and Instruments Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Manufacturing Systems and Instrumentation	1.1	7.1	6.9	5.7	6.2	5.4
Total Semiconductor	0.5	14.9	14.4	9.5	9.3	9.6
Total IC	1.0	18.6	16.9	10.4	10.7	11.4
Bipolar Digital	-14.4	-13.2	-11.5	-12.3	-10.9	-12.4
Bipolar Memory	18.7	-27.2	-36.5	-16.7	-4.2	-15.2
Bipolar Logic	-15.7	-12.4	-10.3	-12.2	-11.1	-12.3
MOS Digital	2.6	23.5	20.7	11.0	12.4	13.8
MOS Memory	3.6	25.9	19.4	-1.6	12.1	11.4
MOS Microcomponent	9.5	18.9	20.0	14.4	10.5	14.6
MOS Logic	-7.3	27.8	23.2	19.8	15.1	15.0
Analog	2.4	15.5	13.1	12.8	9.1	10.5
Total Discrete	-0.4	6.0	6.3	4.9	5.6	4.5
Total Optoelectronic	-1.0	9.1	13.2	12.2	4.5	7.5

Source: Dataquest (October 1992)

Table 95
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	6.7	6.4	6.6
Total IC	4.5	4.3	4.6
Bipolar Digital	0.6	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.6	0.5	0.4
MOS Digital	2.9	2.6	3.0
MOS Memory	1.2	0.9	0.9
MOS Microcomponent	0.9	1.0	1.2
MOS Logic	0.8	0.8	0.9
Analog	1.1	1.1	1.2
Total Discrete	1.7	1.6	1.5
Total Optoelectronic	0.5	0.5	0.5

Source: Dataquest (October 1992)

Table 96
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	6.6	7.1	7.6	7.8	8.1
Total IC	4.5	5.0	5.5	5.8	6.0
Bipolar Digital	0.4	0.3	0.2	0.2	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.3	0.2	0.2	0.2
MOS Digital	3.0	3.5	3.9	4.1	4.3
MOS Memory	0.9	1.1	1.2	1.1	1.2
MOS Microcomponent	1.2	1.4	1.6	1.7	1.8
MOS Logic	0.8	1.0	1.1	1.3	1.4
Analog	1.2	1.3	1.4	1.5	1.5
Total Discrete	1.5	1.5	1.5	1.5	1.5
Total Optoelectronic	0.5	0.5	0.6	0.6	0.6

Source: Dataquest (October 1992)

Table 97
Revenue from Worldwide Medical Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Medical Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Medical Equipment	12,833	14,261	15,005
Total Semiconductor	673	719	734
Total IC	474	505	529
Bipolar Digital	70	66	54
Bipolar Memory	5	5	4
Bipolar Logic	65	61	50
MOS Digital	235	239	266
MOS Memory	81	64	65
MOS Microcomponent	58	69	84
MOS Logic	96	105	117
Analog	168	201	210
Total Discrete	167	179	166
Total Optoelectronic	32	34	39

Source: Dataquest (October 1992)

Table 98
Revenue from Worldwide Medical Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Medical Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Medical Equipment	15,599	16,887	18,110	19,328	20,616
Total Semiconductor	809	930	1,067	1,177	1,255
Total IC	590	693	811	905	976
Bipolar Digital	53	48	42	38	33
Bipolar Memory	5	3	2	2	2
Bipolar Logic	49	44	40	36	31
MOS Digital	304	377	463	526	581
MOS Memory	77	100	122	123	132
MOS Microcomponent	101	127	164	206	237
MOS Logic	126	150	177	197	211
Analog	232	269	306	341	363
Total Discrete	179	192	206	217	221
Total Optoelectronic	41	45	50	55	58

Source: Dataquest (October 1992)

Table 99
Revenue Growth from Worldwide Medical Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Medical Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Medical Equipment	NA	11.1	5.2
Total Semiconductor	NA	6.9	2.1
Total IC	NA	6.7	4.7
Bipolar Digital	NA	-5.2	-18.4
Bipolar Memory	NA	7.6	-19.9
Bipolar Logic	NA	-6.1	-18.2
MOS Digital	NA	1.3	11.3
MOS Memory	NA	-21.2	1.5
MOS Microcomponent	NA	18.9	21.1
MOS Logic	NA	9.7	10.8
Analog	NA	19.2	4.5
Total Discrete	NA	7.5	-7.6
Total Optoelectronic	NA	5.8	13.4

NA = Not available
Source: Dataquest (October 1992)

Table 100
Revenue Growth from Worldwide Medical Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Medical Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Medical Equipment	4.0	8.3	7.2	6.7	6.7	6.6
Total Semiconductor	10.3	15.0	14.7	10.2	6.7	11.3
Total IC	11.4	17.5	17.1	11.5	7.9	13.0
Bipolar Digital	-1.1	-10.6	-11.2	-10.0	-12.9	-9.3
Bipolar Memory	19.3	-26.8	-36.3	-16.8	-4.4	-15.1
Bipolar Logic	-2.8	-9.1	-9.2	-9.6	-13.3	-8.9
MOS Digital	14.5	23.8	22.9	13.7	10.4	16.9
MOS Memory	18.1	30.8	21.2	0.9	7.8	15.3
MOS Microcomponent	20.4	25.0	29.9	25.5	14.9	23.0
MOS Logic	8.3	18.6	18.0	11.5	7.2	12.6
Analog	10.7	15.8	14.0	11.3	6.3	11.6
Total Discrete	7.8	7.4	7.3	5.1	2.1	5.9
Total Optoelectronic	4.5	11.1	10.4	10.4	4.9	8.2

Source: Dataquest (October 1992)

Table 101
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Medical Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	5.2	5.0	4.9
Total IC	3.7	3.5	3.5
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.8	1.7	1.8
MOS Memory	0.6	0.4	0.4
MOS Microcomponent	0.5	0.5	0.6
MOS Logic	0.7	0.7	0.8
Analog	1.3	1.4	1.4
Total Discrete	1.3	1.3	1.1
Total Optoelectronic	0.3	0.2	0.3

Source: Dataquest (October 1992)

Table 102
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Medical Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	5.2	5.5	5.9	6.1	6.1
Total IC	3.8	4.1	4.5	4.7	4.7
Bipolar Digital	0.3	0.3	0.2	0.2	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.3	0.2	0.2	0.2
MOS Digital	2.0	2.2	2.6	2.7	2.8
MOS Memory	0.5	0.6	0.7	0.6	0.6
MOS Microcomponent	0.6	0.7	0.9	1.1	1.1
MOS Logic	0.8	0.9	1.0	1.0	1.0
Analog	1.5	1.6	1.7	1.8	1.8
Total Discrete	1.1	1.1	1.1	1.1	1.1
Total Optoelectronic	0.3	0.3	0.3	0.3	0.3

Source: Dataquest (October 1992)

Table 103
Revenue from Worldwide Other Industrial Systems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Other Industrial Systems	12,684	12,587	12,547
Total Semiconductor	597	662	673
Total IC	389	435	454
Bipolar Digital	38	36	29
Bipolar Memory	2	3	2
Bipolar Logic	35	33	27
MOS Digital	156	167	191
MOS Memory	40	31	32
MOS Microcomponent	42	54	64
MOS Logic	74	83	95
Analog	196	232	235
Total Discrete	164	183	168
Total Optoelectronic	45	44	50

Source: Dataquest (October 1992)

Table 104
Revenue from Worldwide Other Industrial Systems Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Other Industrial Systems	12,528	13,382	13,954	14,504	15,251
Total Semiconductor	756	886	1,020	1,141	1,212
Total IC	508	608	710	801	852
Bipolar Digital	28	24	21	19	17
Bipolar Memory	2	2	1	1	1
Bipolar Logic	26	23	20	19	16
MOS Digital	219	273	328	371	389
MOS Memory	41	53	68	74	68
MOS Microcomponent	74	86	103	117	124
MOS Logic	104	134	157	180	197
Analog	261	310	361	411	446
Total Discrete	191	213	239	264	281
Total Optoelectronic	57	65	71	75	79

Source: Dataquest (October 1992)

Table 105
Revenue Growth from Worldwide Other Industrial Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Other Industrial Systems	NA	-0.8	-0.3
Total Semiconductor	NA	10.9	1.6
Total IC	NA	11.9	4.5
Bipolar Digital	NA	-4.8	-19.6
Bipolar Memory	NA	9.4	-21.9
Bipolar Logic	NA	-5.8	-19.5
MOS Digital	NA	7.7	13.9
MOS Memory	NA	-23.1	3.8
MOS Microcomponent	NA	28.2	18.2
MOS Logic	NA	12.7	14.9
Analog	NA	18.4	1.4
Total Discrete	NA	11.9	-8.1
Total Optoelectronic	NA	-2.1	13.9

NA = Not available
Source: Dataquest (October 1992)

Table 106
Revenue Growth from Worldwide Other Industrial Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Other Industrial Systems	-0.2	6.8	4.3	3.9	5.2	4.0
Total Semiconductor	12.4	17.2	15.1	11.9	6.2	12.5
Total IC	11.7	19.7	16.9	12.8	6.3	13.4
Bipolar Digital	-1.9	-13.5	-12.7	-8.9	-12.3	-10.0
Bipolar Memory	17.6	-26.4	-36.1	-17.1	-4.8	-15.3
Bipolar Logic	-3.4	-12.3	-10.8	-8.4	-12.7	-9.6
MOS Digital	14.6	24.9	20.1	13.1	4.8	15.3
MOS Memory	29.5	29.1	27.5	8.6	-7.8	16.4
MOS Microcomponent	15.9	16.5	19.8	13.8	5.5	14.2
MOS Logic	8.8	29.2	17.2	14.6	9.6	15.7
Analog	11.0	18.9	16.5	13.8	8.6	13.7
Total Discrete	13.7	11.6	11.8	10.8	6.4	10.8
Total Optoelectronic	14.3	14.5	9.1	5.8	4.6	9.6

Source: Dataquest (October 1992)

Table 107
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	4.7	5.3	5.4
Total IC	3.1	3.5	3.6
Bipolar Digital	0.3	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	1.2	1.3	1.5
MOS Memory	0.3	0.2	0.3
MOS Microcomponent	0.3	0.4	0.5
MOS Logic	0.6	0.7	0.8
Analog	1.5	1.8	1.9
Total Discrete	1.3	1.5	1.3
Total Optoelectronic	0.4	0.3	0.4

Source: Dataquest (October 1992)

Table 108
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Industrial Systems Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	6.0	6.6	7.3	7.9	7.9
Total IC	4.1	4.5	5.1	5.5	5.6
Bipolar Digital	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.1	0.1	0.1
MOS Digital	1.7	2.0	2.4	2.6	2.5
MOS Memory	0.3	0.4	0.5	0.5	0.4
MOS Microcomponent	0.6	0.6	0.7	0.8	0.8
MOS Logic	0.8	1.0	1.1	1.2	1.3
Analog	2.1	2.3	2.6	2.8	2.9
Total Discrete	1.5	1.6	1.7	1.8	1.8
Total Optoelectronic	0.5	0.5	0.5	0.5	0.5

Source: Dataquest (October 1992)

Table 109
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Consumer	124,226	131,448	144,454
Total Semiconductor	10,890	11,309	12,779
Total IC	7,780	8,121	9,199
Bipolar Digital	102	91	74
Bipolar Memory	4	3	3
Bipolar Logic	98	88	71
MOS Digital	3,502	3,581	4,151
MOS Memory	966	805	860
MOS Microcomponent	1,096	1,344	1,613
MOS Logic	1,439	1,433	1,679
Analog	4,176	4,448	4,974
Total Discrete	2,205	2,282	2,524
Total Optoelectronic	906	906	1,056

Source: Dataquest (October 1992)

Table 110
Revenue from Worldwide Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Consumer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Consumer	149,218	163,803	175,705	187,554	201,976
Total Semiconductor	13,209	14,872	16,492	18,160	19,680
Total IC	9,632	10,917	12,197	13,460	14,703
Bipolar Digital	66	48	38	32	29
Bipolar Memory	3	2	1	1	1
Bipolar Logic	62	46	37	31	28
MOS Digital	4,367	5,144	5,958	6,681	7,363
MOS Memory	983	1,206	1,387	1,454	1,597
MOS Microcomponent	1,830	2,117	2,456	2,850	3,095
MOS Logic	1,554	1,821	2,115	2,377	2,670
Analog	5,199	5,725	6,201	6,746	7,312
Total Discrete	2,654	2,915	3,166	3,471	3,687
Total Optoelectronic	922	1,040	1,129	1,229	1,290

Source: Dataquest (October 1992)

Table 111
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Consumer	NA	5.8	9.9
Total Semiconductor	NA	3.8	13.0
Total IC	NA	4.4	13.3
Bipolar Digital	NA	-10.3	-18.8
Bipolar Memory	NA	-14.0	-12.6
Bipolar Logic	NA	-10.2	-19.0
MOS Digital	NA	2.3	15.9
MOS Memory	NA	-16.7	6.8
MOS Microcomponent	NA	22.6	20.1
MOS Logic	NA	-0.4	17.2
Analog	NA	6.5	11.8
Total Discrete	NA	3.5	10.6
Total Optoelectronic	NA	0	16.5

NA = Not available
Source: Dataquest (October 1992)

Table 112
Revenue Growth from Worldwide Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Consumer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Consumer	3.3	9.8	7.3	6.7	7.7	6.9
Total Semiconductor	3.4	12.6	10.9	10.1	8.4	9.0
Total IC	4.7	13.3	11.7	10.4	9.2	9.8
Bipolar Digital	-11.2	-26.9	-21.1	-14.9	-10.8	-17.2
Bipolar Memory	7.1	-30.0	-41.5	-22.0	-9.0	-20.8
Bipolar Logic	-12.0	-26.8	-20.1	-14.7	-10.9	-17.1
MOS Digital	5.2	17.8	15.8	12.1	10.2	12.1
MOS Memory	14.4	22.6	15.1	4.8	9.8	13.2
MOS Microcomponent	13.4	15.7	16.0	16.1	8.6	13.9
MOS Logic	-7.4	17.2	16.1	12.4	12.3	9.7
Analog	4.5	10.1	8.3	8.8	8.4	8.0
Total Discrete	5.2	9.8	8.6	9.6	6.2	7.9
Total Optoelectronic	-12.6	12.8	8.5	8.9	5.0	4.1

Source: Dataquest (October 1992)

Table 113
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Consumer Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	8.8	8.6	8.8
Total IC	6.3	6.2	6.4
Bipolar Digital	0.1	0.1	0.1
Bipolar Memory	0	0	0
Bipolar Logic	0.1	0.1	0
MOS Digital	2.8	2.7	2.9
MOS Memory	0.8	0.6	0.6
MOS Microcomponent	0.9	1.0	1.1
MOS Logic	1.2	1.1	1.2
Analog	3.4	3.4	3.4
Total Discrete	1.8	1.7	1.7
Total Optoelectronic	0.7	0.7	0.7

Source: Dataquest (October 1992)

Table 114
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Consumer Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	8.9	9.1	9.4	9.7	9.7
Total IC	6.5	6.7	6.9	7.2	7.3
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.9	3.1	3.4	3.6	3.6
MOS Memory	0.7	0.7	0.8	0.8	0.8
MOS Microcomponent	1.2	1.3	1.4	1.5	1.5
MOS Logic	1.0	1.1	1.2	1.3	1.3
Analog	3.5	3.5	3.5	3.6	3.6
Total Discrete	1.8	1.8	1.8	1.9	1.8
Total Optoelectronic	0.6	0.6	0.6	0.7	0.6

Source: Dataquest (October 1992)

Table 115
Revenue from Worldwide Audio Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Audio Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Audio	15,809	16,849	19,964
Total Semiconductor	2,082	2,177	2,535
Total IC	1,408	1,453	1,696
Bipolar Digital	18	12	11
Bipolar Memory	0	0	0
Bipolar Logic	18	12	11
MOS Digital	528	533	652
MOS Memory	99	85	87
MOS Microcomponent	177	209	261
MOS Logic	252	239	304
Analog	862	908	1,033
Total Discrete	410	460	524
Total Optoelectronic	264	264	315

Source: Dataquest (October 1992)

Table 116
Revenue from Worldwide Audio Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Audio Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Audio	21,098	23,483	25,764	28,176	31,124
Total Semiconductor	2,680	3,059	3,410	3,730	3,776
Total IC	1,831	2,131	2,415	2,657	2,696
Bipolar Digital	8	6	5	4	4
Bipolar Memory	0	0	0	0	0
Bipolar Logic	8	6	5	4	4
MOS Digital	716	868	995	1,114	1,177
MOS Memory	109	139	171	188	192
MOS Microcomponent	331	402	443	503	514
MOS Logic	275	327	380	423	472
Analog	1,107	1,257	1,415	1,538	1,515
Total Discrete	573	618	666	717	713
Total Optoelectronic	276	309	330	356	366

Source: Dataquest (October 1992)

Table 117
Revenue Growth from Worldwide Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Audio Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Audio	NA	6.6	18.5
Total Semiconductor	NA	4.6	16.4
Total IC	NA	3.2	16.7
Bipolar Digital	NA	-32.4	-14.5
Bipolar Memory	NM	NM	NM
Bipolar Logic	NA	-32.4	-14.5
MOS Digital	NA	0.9	22.4
MOS Memory	NA	-14.5	2.5
MOS Microcomponent	NA	18.0	24.9
MOS Logic	NA	-5.1	27.3
Analog	NA	5.3	13.8
Total Discrete	NA	12.3	13.8
Total Optoelectronic	NA	0	19.3

NA = Not available
NM = Not meaningful
Source: Dataquest (October 1992)

Table 118
Revenue Growth from Worldwide Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Audio Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Audio	5.7	11.3	9.7	9.4	10.5	9.3
Total Semiconductor	5.7	14.1	11.5	9.4	1.2	8.3
Total IC	8.0	16.4	13.3	10.0	1.5	9.7
Bipolar Digital	-22.9	-26.5	-11.1	-16.0	-12.5	-18.0
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	-22.9	-26.5	-11.1	-16.0	-12.5	-18.0
MOS Digital	9.7	21.3	14.6	12.0	5.6	12.5
MOS Memory	25.9	27.3	23.3	9.7	1.9	17.2
MOS Microcomponent	26.9	21.2	10.3	13.7	2.0	14.5
MOS Logic	-9.6	19.1	16.1	11.1	11.6	9.2
Analog	7.2	13.6	12.5	8.7	-1.5	8.0
Total Discrete	9.3	7.9	7.6	7.8	-0.6	6.4
Total Optoelectronic	-12.4	12.0	6.7	7.8	3.0	3.1

NM = Not meaningful
Source: Dataquest (October 1992)

Table 119
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Audio Applications, 1989-1991 (Percentage)

	1989	1990	1991
Total Semiconductor	13.2	12.9	12.7
Total IC	8.9	8.6	8.5
Bipolar Digital	0.1	0.1	0.1
Bipolar Memory	0	0	0
Bipolar Logic	0.1	0.1	0.1
MOS Digital	3.3	3.2	3.3
MOS Memory	0.6	0.5	0.4
MOS Microcomponent	1.1	1.2	1.3
MOS Logic	1.6	1.4	1.5
Analog	5.4	5.4	5.2
Total Discrete	2.6	2.7	2.6
Total Optoelectronic	1.7	1.6	1.6

Source: Dataquest (October 1992)

Table 120
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Audio Applications, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	12.7	13.0	13.2	13.2	12.1
Total IC	8.7	9.1	9.4	9.4	8.7
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	3.4	3.7	3.9	4.0	3.8
MOS Memory	0.5	0.6	0.7	0.7	0.6
MOS Microcomponent	1.6	1.7	1.7	1.8	1.7
MOS Logic	1.3	1.4	1.5	1.5	1.5
Analog	5.2	5.4	5.5	5.5	4.9
Total Discrete	2.7	2.6	2.6	2.5	2.3
Total Optoelectronic	1.3	1.3	1.3	1.3	1.2

Source: Dataquest (October 1992)

Table 121
Revenue from Worldwide Video Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Video Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Video	39,659	42,508	46,043
Total Semiconductor	5,446	5,555	6,257
Total IC	3,936	4,020	4,509
Bipolar Digital	32	30	25
Bipolar Memory	2	2	2
Bipolar Logic	30	28	23
MOS Digital	1,746	1,744	1,978
MOS Memory	310	251	268
MOS Microcomponent	548	641	744
MOS Logic	888	852	966
Analog	2,158	2,246	2,505
Total Discrete	1,104	1,127	1,274
Total Optoelectronic	406	408	475

Source: Dataquest (October 1992)

Table 122
Revenue from Worldwide Video Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Video Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Video	47,053	51,184	54,590	58,876	63,545
Total Semiconductor	6,052	6,589	7,105	7,838	8,751
Total IC	4,353	4,703	5,054	5,587	6,339
Bipolar Digital	27	19	15	14	13
Bipolar Memory	2	1	0	0	0
Bipolar Logic	25	18	15	14	13
MOS Digital	1,921	2,207	2,523	2,852	3,157
MOS Memory	302	375	417	453	473
MOS Microcomponent	769	857	990	1,142	1,236
MOS Logic	850	975	1,117	1,256	1,448
Analog	2,405	2,478	2,516	2,721	3,170
Total Discrete	1,311	1,435	1,554	1,714	1,851
Total Optoelectronic	388	451	496	537	561

Source: Dataquest (October 1992)

Table 123
Revenue Growth from Worldwide Video Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Video Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Video	NA	7.2	8.3
Total Semiconductor	NA	2.0	12.6
Total IC	NA	2.1	12.2
Bipolar Digital	NA	-5.9	-16.0
Bipolar Memory	NA	16.5	-15.0
Bipolar Logic	NA	-7.2	-16.0
MOS Digital	NA	-0.1	13.5
MOS Memory	NA	-19.0	6.8
MOS Microcomponent	NA	17.0	16.1
MOS Logic	NA	-4.1	13.4
Analog	NA	4.1	11.5
Total Discrete	NA	2.1	13.0
Total Optoelectronic	NA	0.3	16.4

NA = Not available

Source: Dataquest (October 1992)

Table 124
Revenue Growth from Worldwide Video Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Video Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Video	2.2	8.8	6.7	7.9	7.9	6.7
Total Semiconductor	-3.3	8.9	7.8	10.3	11.7	6.9
Total IC	-3.5	8.0	7.5	10.6	13.5	7.1
Bipolar Digital	6.0	-30.8	-20.2	-5.5	-9.4	-12.9
Bipolar Memory	9.4	-69.8	-58.0	-50.7	-64.1	-52.3
Bipolar Logic	5.8	-27.8	-19.0	-4.8	-9.0	-11.7
MOS Digital	-2.9	14.9	14.3	13.0	10.7	9.8
MOS Memory	12.9	24.1	11.1	8.8	4.4	12.1
MOS Microcomponent	3.3	11.4	15.5	15.4	8.2	10.7
MOS Logic	-12.0	14.7	14.6	12.5	15.2	8.4
Analog	-4.0	3.0	1.5	8.2	16.5	4.8
Total Discrete	2.9	9.5	8.3	10.3	8.0	7.8
Total Optoelectronic	-18.1	16.1	10.0	8.2	4.4	3.4

Source: Dataquest (October 1992)

Table 125
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Video Applications, 1989-1991 (Percentage)

	1989	1990	1991
Total Semiconductor	13.7	13.1	13.6
Total IC	9.9	9.5	9.8
Bipolar Digital	0.1	0.1	0.1
Bipolar Memory	0	0	0
Bipolar Logic	0.1	0.1	0.1
MOS Digital	4.4	4.1	4.3
MOS Memory	0.8	0.6	0.6
MOS Microcomponent	1.4	1.5	1.6
MOS Logic	2.2	2.0	2.1
Analog	5.4	5.3	5.4
Total Discrete	2.8	2.7	2.8
Total Optoelectronic	1.0	1.0	1.0

Source: Dataquest (October 1992)

Table 126
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Video Applications, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	12.9	12.9	13.0	13.3	13.8
Total IC	9.3	9.2	9.3	9.5	10.0
Bipolar Digital	0.1	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.1	0	0	0	0
MOS Digital	4.1	4.3	4.6	4.8	5.0
MOS Memory	0.6	0.7	0.8	0.8	0.7
MOS Microcomponent	1.6	1.7	1.8	1.9	1.9
MOS Logic	1.8	1.9	2.0	2.1	2.3
Analog	5.1	4.8	4.6	4.6	5.0
Total Discrete	2.8	2.8	2.8	2.9	2.9
Total Optoelectronic	0.8	0.9	0.9	0.9	0.9

Source: Dataquest (October 1992)

Table 127
Revenue from Worldwide Personal Electronics Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Personal Electronics	14,363	16,790	17,871
Total Semiconductor	1,253	1,386	1,562
Total IC	999	1,120	1,276
Bipolar Digital	29	31	25
Bipolar Memory	0	0	0
Bipolar Logic	29	31	25
MOS Digital	624	697	808
MOS Memory	309	269	295
MOS Microcomponent	151	224	268
MOS Logic	163	204	244
Analog	346	392	444
Total Discrete	130	137	142
Total Optoelectronic	125	129	144

Source: Dataquest (October 1992)

Table 128
Revenue from Worldwide Personal Electronics Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Personal Electronics	18,969	20,859	21,992	23,186	24,493
Total Semiconductor	1,685	1,908	2,226	2,480	2,661
Total IC	1,399	1,603	1,901	2,128	2,292
Bipolar Digital	20	15	12	9	9
Bipolar Memory	0	0	0	0	0
Bipolar Logic	20	15	12	9	9
MOS Digital	876	997	1,208	1,397	1,593
MOS Memory	311	348	395	412	490
MOS Microcomponent	309	349	445	563	645
MOS Logic	256	301	368	422	459
Analog	504	591	681	722	690
Total Discrete	156	164	170	177	176
Total Optoelectronic	130	141	155	174	193

Source: Dataquest (October 1992)

Table 129
Revenue Growth from Worldwide Personal Electronics Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Personal Electronics	NA	16.9	6.4
Total Semiconductor	NA	10.6	12.7
Total IC	NA	12.1	13.9
Bipolar Digital	NA	5.1	-19.6
Bipolar Memory	NM	NM	NM
Bipolar Logic	NA	5.1	-19.6
MOS Digital	NA	11.8	15.8
MOS Memory	NA	-12.9	9.7
MOS Microcomponent	NA	48.2	19.7
MOS Logic	NA	24.7	19.6
Analog	NA	13.4	13.1
Total Discrete	NA	5.9	3.6
Total Optoelectronic	NA	3.4	11.9

NA = Not available
NM = Not meaningful
Source: Dataquest (October 1992)

Table 130
Revenue Growth from Worldwide Personal Electronics Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Personal Electronics	6.1	10.0	5.4	5.4	5.6	6.5
Total Semiconductor	7.8	13.2	16.7	11.4	7.3	11.2
Total IC	9.7	14.6	18.6	12.0	7.7	12.4
Bipolar Digital	-20.6	-22.5	-23.8	-19.3	-6.1	-18.7
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	-20.6	-22.5	-23.8	-19.3	-6.1	-18.7
MOS Digital	8.4	13.9	21.2	15.6	14.1	14.6
MOS Memory	5.3	11.9	13.7	4.3	18.8	10.7
MOS Microcomponent	15.1	12.8	27.5	26.7	14.5	19.1
MOS Logic	4.9	17.6	22.4	14.5	8.8	13.5
Analog	13.7	17.2	15.3	6.0	-4.4	9.2
Total Discrete	9.5	5.3	3.9	4.1	-0.7	4.4
Total Optoelectronic	-10.1	8.4	10.5	12.0	10.8	6.0

NM = Not meaningful
Source: Dataquest (October 1992)

Table 131
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	8.7	8.3	8.7
Total IC	7.0	6.7	7.1
Bipolar Digital	0.2	0.2	0.1
Bipolar Memory	0	0	0
Bipolar Logic	0.2	0.2	0.1
MOS Digital	4.3	4.2	4.5
MOS Memory	2.2	1.6	1.7
MOS Microcomponent	1.1	1.3	1.5
MOS Logic	1.1	1.2	1.4
Analog	2.4	2.3	2.5
Total Discrete	0.9	0.8	0.8
Total Optoelectronic	0.9	0.8	0.8

Source: Dataquest (October 1992)

Table 132
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Personal Electronics Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	8.9	9.1	10.1	10.7	10.9
Total IC	7.4	7.7	8.6	9.2	9.4
Bipolar Digital	0.1	0.1	0.1	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.1	0.1	0.1	0	0
MOS Digital	4.6	4.8	5.5	6.0	6.5
MOS Memory	1.6	1.7	1.8	1.8	2.0
MOS Microcomponent	1.6	1.7	2.0	2.4	2.6
MOS Logic	1.3	1.4	1.7	1.8	1.9
Analog	2.7	2.8	3.1	3.1	2.8
Total Discrete	0.8	0.8	0.8	0.8	0.7
Total Optoelectronic	0.7	0.7	0.7	0.8	0.8

Source: Dataquest (October 1992)

Table 133
Revenue from Worldwide Appliances Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Appliances Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Appliances	45,074	45,768	50,394
Total Semiconductor	1,571	1,642	1,810
Total IC	1,114	1,191	1,333
Bipolar Digital	18	14	10
Bipolar Memory	0	0	0
Bipolar Logic	18	14	10
MOS Digital	463	468	545
MOS Memory	189	153	157
MOS Microcomponent	178	218	273
MOS Logic	96	97	114
Analog	634	708	778
Total Discrete	382	384	398
Total Optoelectronic	75	68	79

Source: Dataquest (October 1992)

Table 134
Revenue from Worldwide Appliances Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Appliances Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Appliances	52,247	57,162	61,515	65,079	69,871
Total Semiconductor	2,088	2,452	2,771	3,023	3,380
Total IC	1,578	1,891	2,160	2,354	2,627
Bipolar Digital	8	6	5	3	2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	8	6	5	3	2
MOS Digital	644	784	902	957	1,062
MOS Memory	191	252	296	282	314
MOS Microcomponent	335	387	437	487	545
MOS Logic	118	146	168	188	203
Analog	926	1,101	1,253	1,393	1,562
Total Discrete	429	474	521	571	650
Total Optoelectronic	81	87	90	99	103

Source: Dataquest (October 1992)

Table 135
Revenue Growth from Worldwide Appliances Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Appliances Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Appliances	NA	1.5	10.1
Total Semiconductor	NA	4.5	10.2
Total IC	NA	6.8	12.0
Bipolar Digital	NA	-18.5	-28.0
Bipolar Memory	NA	-51.3	-48.4
Bipolar Logic	NA	-18.5	-28.0
MOS Digital	NA	1.2	16.4
MOS Memory	NA	-19.2	2.9
MOS Microcomponent	NA	22.7	25.3
MOS Logic	NA	1.4	17.3
Analog	NA	11.7	9.9
Total Discrete	NA	0.3	3.8
Total Optoelectronic	NA	-8.7	15.1

NA = Not available
Source: Dataquest (October 1992)

Table 136
Revenue Growth from Worldwide Appliances Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Appliances Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Appliances	3.7	9.4	7.6	5.8	7.4	6.8
Total Semiconductor	15.3	17.4	13.0	9.1	11.8	13.3
Total IC	18.3	19.9	14.2	9.0	11.6	14.5
Bipolar Digital	-22.8	-27.6	-12.5	-31.2	-29.4	-25.0
Bipolar Memory	-18.1	-24.0	-33.6	-49.7	-56.0	-38.0
Bipolar Logic	-22.8	-27.6	-12.5	-31.2	-29.4	-25.0
MOS Digital	18.2	21.8	15.1	6.1	11.0	14.3
MOS Memory	21.3	32.2	17.7	-4.8	11.2	14.8
MOS Microcomponent	22.4	15.5	13.2	11.4	12.0	14.8
MOS Logic	3.7	22.8	15.7	11.4	8.1	12.2
Analog	19.0	18.9	13.8	11.2	12.1	15.0
Total Discrete	7.7	10.5	9.9	9.5	14.0	10.3
Total Optoelectronic	3.4	7.1	3.5	10.0	4.4	5.6

Source: Dataquest (October 1992)

Table 137
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Appliances Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	3.5	3.6	3.6
Total IC	2.5	2.6	2.6
Bipolar Digital	0	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0	0	0
MOS Digital	1.0	1.0	1.1
MOS Memory	0.4	0.3	0.3
MOS Microcomponent	0.4	0.5	0.5
MOS Logic	0.2	0.2	0.2
Analog	1.4	1.5	1.5
Total Discrete	0.8	0.8	0.8
Total Optoelectronic	0.2	0.1	0.2

Source: Dataquest (October 1992)

Table 138
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Appliances Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	4.0	4.3	4.5	4.6	4.8
Total IC	3.0	3.3	3.5	3.6	3.8
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	1.2	1.4	1.5	1.5	1.5
MOS Memory	0.4	0.4	0.5	0.4	0.4
MOS Microcomponent	0.6	0.7	0.7	0.7	0.8
MOS Logic	0.2	0.3	0.3	0.3	0.3
Analog	1.8	1.9	2.0	2.1	2.2
Total Discrete	0.8	0.8	0.8	0.9	0.9
Total Optoelectronic	0.2	0.2	0.1	0.2	0.1

Source: Dataquest (October 1992)

Table 139
Revenue from Worldwide Other Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Other Consumer	9,321	9,533	10,182
Total Semiconductor	537	548	615
Total IC	322	337	386
Bipolar Digital	4	4	3
Bipolar Memory	2	1	1
Bipolar Logic	2	2	2
MOS Digital	142	139	169
MOS Memory	60	48	53
MOS Microcomponent	42	51	66
MOS Logic	39	40	50
Analog	176	194	214
Total Discrete	179	174	186
Total Optoelectronic	36	37	43

Source: Dataquest (October 1992)

Table 140
Revenue from Worldwide Other Consumer Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Other Consumer	9,851	11,114	11,845	12,237	12,944
Total Semiconductor	704	865	980	1,089	1,112
Total IC	472	589	668	733	749
Bipolar Digital	3	2	1	1	1
Bipolar Memory	1	2	1	1	1
Bipolar Logic	2	1	0	0	0
MOS Digital	211	288	330	361	373
MOS Memory	71	92	108	118	129
MOS Microcomponent	86	124	141	154	156
MOS Logic	55	72	81	89	89
Analog	257	298	337	371	375
Total Discrete	186	224	255	292	296
Total Optoelectronic	47	52	57	64	67

Source: Dataquest (October 1992)

Table 141
Revenue Growth from Worldwide Other Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Other Consumer	NA	2.3	6.8
Total Semiconductor	NA	2.0	12.2
Total IC	NA	4.6	14.4
Bipolar Digital	NA	-19.6	-14.1
Bipolar Memory	NA	-36.5	-9.4
Bipolar Logic	NA	-1.0	-17.4
MOS Digital	NA	-1.6	21.1
MOS Memory	NA	-20.8	11.3
MOS Microcomponent	NA	21.4	28.6
MOS Logic	NA	2.9	23.2
Analog	NA	10.2	10.1
Total Discrete	NA	-2.8	6.8
Total Optoelectronic	NA	2.3	16.6

NA = Not available
Source: Dataquest (October 1992)

Table 142
Revenue Growth from Worldwide Other Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Other Consumer	-3.3	12.8	6.6	3.3	5.8	4.9
Total Semiconductor	14.6	22.7	13.3	11.1	2.1	12.6
Total IC	22.2	24.8	13.5	9.8	2.1	14.2
Bipolar Digital	2.8	-21.8	-55.5	-15.8	-2.1	-21.6
Bipolar Memory	4.2	23.1	-36.2	-15.8	-2.1	-7.5
Bipolar Logic	1.8	-57.5	NM	NM	NM	-100.0
MOS Digital	25.2	36.2	14.6	9.4	3.4	17.2
MOS Memory	33.6	30.0	17.0	9.8	8.6	19.4
MOS Microcomponent	29.8	44.0	14.2	8.9	1.2	18.7
MOS Logic	10.1	32.0	12.1	9.6	0.4	12.4
Analog	20.1	16.0	12.9	10.3	0.9	11.9
Total Discrete	0.2	20.4	13.8	14.5	1.3	9.8
Total Optoelectronic	8.1	11.4	9.2	11.8	5.2	9.1

NM = Not meaningful
Source: Dataquest (October 1992)

Table 143
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	5.8	5.8	6.0
Total IC	3.5	3.5	3.8
Bipolar Digital	0	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0	0	0
MOS Digital	1.5	1.5	1.7
MOS Memory	0.6	0.5	0.5
MOS Microcomponent	0.5	0.5	0.6
MOS Logic	0.4	0.4	0.5
Analog	1.9	2.0	2.1
Total Discrete	1.9	1.8	1.8
Total Optoelectronic	0.4	0.4	0.4

Source: Dataquest (October 1992)

Table 144
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Other Consumer Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	7.2	7.8	8.3	8.9	8.6
Total IC	4.8	5.3	5.6	6.0	5.8
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.1	2.6	2.8	3.0	2.9
MOS Memory	0.7	0.8	0.9	1.0	1.0
MOS Microcomponent	0.9	1.1	1.2	1.3	1.2
MOS Logic	0.6	0.6	0.7	0.7	0.7
Analog	2.6	2.7	2.8	3.0	2.9
Total Discrete	1.9	2.0	2.2	2.4	2.3
Total Optoelectronic	0.5	0.5	0.5	0.5	0.5

Source: Dataquest (October 1992)

Table 145
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Military/Civil Aerospace	86,731	86,730	81,918
Total Semiconductor	2,949	2,882	2,810
Total IC	2,287	2,243	2,186
Bipolar Digital	470	424	366
Bipolar Memory	85	58	43
Bipolar Logic	385	366	323
MOS Digital	1,237	1,207	1,233
MOS Memory	449	390	385
MOS Microcomponent	328	342	360
MOS Logic	460	475	487
Analog	581	613	587
Total Discrete	538	519	499
Total Optoelectronic	123	119	125

Source: Dataquest (October 1992)

Table 146
Revenue from Worldwide Military/Civil Aerospace Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Military/Civil Aerospace	82,366	85,564	88,416	91,056	93,515
Total Semiconductor	2,791	2,955	3,133	3,301	3,472
Total IC	2,176	2,313	2,460	2,601	2,743
Bipolar Digital	326	300	279	255	230
Bipolar Memory	34	26	24	21	18
Bipolar Logic	292	274	255	233	212
MOS Digital	1,279	1,402	1,535	1,654	1,792
MOS Memory	397	439	481	514	565
MOS Microcomponent	377	410	457	498	542
MOS Logic	505	552	597	642	684
Analog	572	611	647	692	722
Total Discrete	486	503	519	539	557
Total Optoelectronic	128	139	153	161	172

Source: Dataquest (October 1992)

Table 147
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, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Military/Civil Aerospace	NA	0.0	-5.5
Total Semiconductor	NA	-2.3	-2.5
Total IC	NA	-1.9	-2.6
Bipolar Digital	NA	-9.8	-13.5
Bipolar Memory	NA	-32.0	-24.8
Bipolar Logic	NA	-4.9	-11.8
MOS Digital	NA	-2.4	2.1
MOS Memory	NA	-13.2	-1.1
MOS Microcomponent	NA	4.5	5.2
MOS Logic	NA	3.3	2.5
Analog	NA	5.5	-4.2
Total Discrete	NA	-3.5	-3.9
Total Optoelectronic	NA	-3.6	5.0

NA = Not available
Source: Dataquest (October 1992)

Table 148
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, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Military/Civil Aerospace	0.5	3.9	3.3	3.0	2.7	2.7
Total Semiconductor	-0.7	5.9	6.0	5.4	5.2	4.3
Total IC	-0.4	6.3	6.4	5.7	5.5	4.6
Bipolar Digital	-11.0	-8.0	-7.1	-8.6	-9.7	-8.9
Bipolar Memory	-21.5	-23.6	-7.8	-11.0	-16.9	-16.4
Bipolar Logic	-9.5	-6.2	-7.0	-8.3	-9.0	-8.0
MOS Digital	3.7	9.6	9.5	7.8	8.3	7.8
MOS Memory	3.1	10.6	9.6	6.9	9.9	8.0
MOS Microcomponent	4.5	9.0	11.3	9.0	8.9	8.5
MOS Logic	3.7	9.3	8.1	7.6	6.6	7.0
Analog	-2.6	6.9	5.9	7.0	4.3	4.2
Total Discrete	-2.6	3.5	3.2	3.8	3.4	2.2
Total Optoelectronic	2.7	8.5	10.0	4.8	6.8	6.5

Source: Dataquest (October 1992)

Table 149
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	3.4	3.3	3.4
Total IC	2.6	2.6	2.7
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	0.4	0.4	0.4
MOS Digital	1.4	1.4	1.5
MOS Memory	0.5	0.4	0.5
MOS Microcomponent	0.4	0.4	0.4
MOS Logic	0.5	0.5	0.6
Analog	0.7	0.7	0.7
Total Discrete	0.6	0.6	0.6
Total Optoelectronic	0.1	0.1	0.2

Source: Dataquest (October 1992)

Table 150
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Military/Civil Aerospace Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	3.4	3.5	3.5	3.6	3.7
Total IC	2.6	2.7	2.8	2.9	2.9
Bipolar Digital	0.4	0.4	0.3	0.3	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.4	0.3	0.3	0.3	0.2
MOS Digital	1.6	1.6	1.7	1.8	1.9
MOS Memory	0.5	0.5	0.5	0.6	0.6
MOS Microcomponent	0.5	0.5	0.5	0.5	0.6
MOS Logic	0.6	0.6	0.7	0.7	0.7
Analog	0.7	0.7	0.7	0.8	0.8
Total Discrete	0.6	0.6	0.6	0.6	0.6
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (October 1992)

Table 151
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Transportation	19,590	20,992	22,000
Total Semiconductor	2,592	2,811	3,051
Total IC	1,963	2,140	2,323
Bipolar Digital	92	109	100
Bipolar Memory	2	2	0
Bipolar Logic	90	107	100
MOS Digital	1,379	1,499	1,668
MOS Memory	181	177	164
MOS Microcomponent	634	732	847
MOS Logic	564	590	657
Analog	492	531	556
Total Discrete	500	542	572
Total Optoelectronic	129	129	156

Source: Dataquest (October 1992)

Table 152
Revenue from Worldwide Transportation Equipment Production, and Revenue from All Semiconductors Shipped to the World for Use in Transportation Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Transportation	23,319	25,693	27,658	29,670	31,725
Total Semiconductor	3,230	3,727	4,214	4,601	5,054
Total IC	2,504	2,892	3,294	3,605	3,961
Bipolar Digital	89	90	83	84	77
Bipolar Memory	0	0	0	0	0
Bipolar Logic	89	90	83	84	77
MOS Digital	1,800	2,103	2,431	2,645	2,930
MOS Memory	170	210	245	243	268
MOS Microcomponent	925	1,047	1,219	1,325	1,465
MOS Logic	706	846	967	1,077	1,197
Analog	615	699	779	876	954
Total Discrete	588	669	730	779	848
Total Optoelectronic	138	166	190	216	245

Source: Dataquest (October 1992)

Table 153
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Transportation	NA	7.2	4.8
Total Semiconductor	NA	8.4	8.5
Total IC	NA	9.0	8.6
Bipolar Digital	NA	18.5	-8.8
Bipolar Memory	NA	3.3	-98.2
Bipolar Logic	NA	18.9	-7.1
MOS Digital	NA	8.7	11.3
MOS Memory	NA	-1.7	-7.6
MOS Microcomponent	NA	15.4	15.8
MOS Logic	NA	4.5	11.3
Analog	NA	8.0	4.7
Total Discrete	NA	8.4	5.5
Total Optoelectronic	NA	0.5	20.1

NA = Not available
Source: Dataquest (October 1992)

Table 154
Revenue Growth from Worldwide Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to the World for Use in Transportation Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Total Transportation	6.0	10.2	7.6	7.3	6.9	7.6
Total Semiconductor	5.9	15.4	13.1	9.2	9.8	10.6
Total IC	7.8	15.5	13.9	9.5	9.9	11.3
Bipolar Digital	-10.4	1.1	-7.6	1.1	-8.3	-5.0
Bipolar Memory	-31.5	-43.2	-42.4	-60.3	-5.4	-39.0
Bipolar Logic	-10.4	1.1	-7.6	1.1	-8.3	-5.0
MOS Digital	7.9	16.8	15.6	8.8	10.8	11.9
MOS Memory	3.6	23.5	16.8	-0.6	10.1	10.3
MOS Microcomponent	9.1	13.3	16.4	8.7	10.5	11.6
MOS Logic	7.5	19.9	14.3	11.3	11.2	12.8
Analog	10.6	13.7	11.5	12.4	8.9	11.4
Total Discrete	2.8	13.7	9.2	6.7	8.9	8.2
Total Optoelectronic	-11.2	20.6	14.1	13.9	13.0	9.5

Source: Dataquest (October 1992)

Table 155
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Transportation Applications, 1989-1991
(Percentage)

	1989	1990	1991
Total Semiconductor	13.2	13.4	13.9
Total IC	10.0	10.2	10.6
Bipolar Digital	0.5	0.5	0.5
Bipolar Memory	0	0	0
Bipolar Logic	0.5	0.5	0.5
MOS Digital	7.0	7.1	7.6
MOS Memory	0.9	0.8	0.7
MOS Microcomponent	3.2	3.5	3.9
MOS Logic	2.9	2.8	3.0
Analog	2.5	2.5	2.5
Total Discrete	2.6	2.6	2.6
Total Optoelectronic	0.7	0.6	0.7

Source: Dataquest (October 1992)

Table 156
Input/Output Ratios of All Semiconductors Shipped to the World for Use in Transportation Applications, 1992-1996
(Percentage)

	1992	1993	1994	1995	1996
Total Semiconductor	13.9	14.5	15.2	15.5	15.9
Total IC	10.7	11.3	11.9	12.2	12.5
Bipolar Digital	0.4	0.4	0.3	0.3	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.4	0.4	0.3	0.3	0.2
MOS Digital	7.7	8.2	8.8	8.9	9.2
MOS Memory	0.7	0.8	0.9	0.8	0.8
MOS Microcomponent	4.0	4.1	4.4	4.5	4.6
MOS Logic	3.0	3.3	3.5	3.6	3.8
Analog	2.6	2.7	2.8	3.0	3.0
Total Discrete	2.5	2.6	2.6	2.6	2.7
Total Optoelectronic	0.6	0.6	0.7	0.7	0.8

Source: Dataquest (October 1992)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Incorporated Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 49-89-930-9090
Facsimile: 49-89-930-3277

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo, 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

SAM-0945285 B: 1
Greg Sheppard
320-1240
Internal Distribution

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North American Semiconductor Consumption by Application Market

September 14, 1992

Source: Dataquest

Market Statistics

Semiconductor Application Markets

SAWW-SVC-MS-9202

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North American Semiconductor Consumption by Application Market

September 14, 1992

Source: Dataquest

Market Statistics

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Semiconductor Application Markets *Worldwide*
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File behind the *Market Statistics* tab inside the binder labeled **Semiconductor Application Markets** *Worldwide*

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North American Semiconductor Consumption by Application Market

Table of Contents

Note: All tables show estimated data.

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Table		Page

Note: All tables show estimated data.

Table		Page
61	Revenue from North American Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991 (Millions of U.S. Dollars)	70
62	Revenue from North American Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996 (Millions of U.S. Dollars)	71
63	Revenue Growth from North American Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991 (Percent Change)	72
64	Revenue Growth from North American Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996 (Percent Change)	73
65	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991 (Percent)	74
66	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996 (Percent)	75
67	Revenue from North American Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991 (Millions of U.S. Dollars)	76
68	Revenue from North American Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1992-1996 (Millions of U.S. Dollars)	77
69	Revenue Growth from North American Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991 (Percent Change)	78
70	Revenue Growth from North American Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1992-1996 (Percent Change)	79
71	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991 (Percent)	80
72	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Dedicated Applications, 1992-1996 (Percent)	81
73	Revenue from North American Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991 (Millions of U.S. Dollars)	82
74	Revenue from North American Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996 (Millions of U.S. Dollars)	83
75	Revenue Growth from North American Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991 (Percent Change)	84
76	Revenue Growth from North American Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996 (Percent Change)	85
77	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991 (Percent)	86
78	Input/Output Ratios of All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996 (Percent)	87

Note: All tables show estimated data.

Note: All tables show estimated data.

Table		Page

Note: All tables show estimated data.

Note: All tables show estimated data.

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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:

- 1989-1991 historical data
- 1992-1996 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 usage 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 type in the companion volume, Source: Dataquest, *Worldwide and North American Electronic Equipment Production Forecast.*

The aggregate semiconductor consumption forecast (that is, consumption across all electronic equipment segments) contained in this document may be found in its entirety in Source: Dataquest, *Semiconductor Consumption and Shipment Forecast.* Estimates in this document may differ slightly from estimates in the two aforementioned documents due to rounding.

The tables in this document are organized as follows:

- Tables 1- 42 cover the six broad application markets
- Tables 43-72 cover the individual equipment system groups of the data processing application market
- Tables 73-102 cover the individual equipment system groups of the communications application market
- Tables 103-126 cover the individual equipment system groups of the industrial application market
- Tables 127-156 cover the individual equipment system groups of the consumer application market

The following six tables are associated with each application market or equipment system group:

- Revenue from equipment production, and revenue from associated semiconductor shipments, 1989-1991
- Revenue from equipment production, and revenue from associated semiconductor shipments, 1992-1996
- Revenue growth from equipment production, and revenue growth from associated semiconductor shipments, 1989-1991
- Revenue growth from equipment production, and revenue growth from associated semiconductor shipments, 1992-1996
- Input/output ratios, 1989-1991
- Input/output ratios, 1992-1996

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 *Dataquest Research and Forecast Methodology* document located in the Source: Dataquest binder. For a complete listing of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary.*

Electronic Equipment Segmentation

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 purposes of semiconductor consumption analysis, Dataquest segments the electronics industry into six broad semiconductor application markets, disaggregated into narrower electronic system groups:

- Data Processing
  - Computers
  - Data Storage
  - Terminals
  - Input/Output Devices
  - Dedicated Systems
- 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 optoelectronic 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
      - Bipolar Memory
      - Bipolar Logic
    - MOS Digital
      - MOS Memory
      - MOS Microcomponents
      - MOS Logic
    - Analog
  - Total Discrete
  - Total Optoelectronic

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 Share Survey Guide.*

Electronic Equipment Definitions

Electronic systems groups comprise specific electronic equipment types:

Computer Systems. Include supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including personal computers).

Data Storage. Include rigid disk drives, flexible disk drives, optical disk drives, and tape drives.

Terminals. Include alphanumeric terminals and graphics terminals (for example, X terminals).

Input/Output Devices. Include printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, voice recognition/synthesizer equipment, mouse, keyboard, and digitizers.

Dedicated Systems. Include electronic copiers, electronic calculators, smart 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.

Premise Telecom Equipment. Includes image and text communication such as facsimile and video teleconferencing; data communications equipment such as modems, statistical multiplexers, T-1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area networks, internetworking, network management, and packet data switching/wide area networks; premise switching equipment such as PBX telephone equipment, and key telephone systems; call processing equipment such as voice messaging, interactive voice response systems, call accounting, and automatic call distributors; and desktop terminal equipment such as telephone sets/pay 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, mobile radios, and mobile radio base station equipment; portable radio receivers and transmitters; and radio checkout equipment.

Broadcast and Radio 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 theater equipment.

Other Telecom Equipment. Includes intercom equipment and electrical amplifiers, and communications equipment not elsewhere classified.

Security/Energy Management. Includes alarm systems such as intrusion detection and fire detection systems, and energy management systems.

Manufacturing Systems and Instrumentation. Includes semiconductor production equipment, controllers and actuators, sensor systems, management systems, and robotics; and semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and waveform analyzers, nuclear instruments, and other test and measurement equipment.

Medical Equipment. Includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analyzers, patient monitoring equipment, and other diagnostic and therapeutic equipment.

Other Industrial Equipment. Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

(Consumer) Audio Equipment. Includes compact disk players, radios, stereo components, musical instruments, and tape recorders.

(Consumer) Video Equipment. Includes VCRs and VTRs, video cameras and camcorders, videodisk players, and color and monochrome TVs.

Personal Electronics. Includes electronic games and toys, 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. Includes military electronics such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, computer systems, simulation systems, and military electronics not elsewhere classified; and civilian aerospace electronics such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

Transportation Electronics. Includes entertainment systems, vehicle controls, body controls, driver information systems, powertrain systems, and safety and convenience systems.

Semiconductor Device Definitions

Semiconductor device categories comprise specific types of semiconductor devices:

Total Semiconductor (IC + Discrete + Optoelectronic). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide) 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 Monolithic IC). An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. In a monolithic IC, discrete circuits are integrated onto a small number of dice.

Bipolar Digital (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.

Bipolar Memory. Defined as a bipolar digital semiconductor product in which binary data are stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), and first-in/first-out (FIFO) memory.

Bipolar Logic (Bipolar Application-Specific IC + Other Bipolar Logic IC + Bipolar Digital Microcomponent). Defined as a bipolar digital semiconductor product in which more than 50 percent of the die area performs logic functions. Includes bipolar digital microcomponent ICs.

MOS Digital (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 some MOS technology is employed.

MOS Memory (DRAM +SRAM + EPROM + Other Nonvolatile MOS Digital Memory + Other MOS Digital Memory). Defined as an MOS digital IC in which binary data are stored and electronically retrieved.

MOS Microcomponents (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral). Defined as an MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both CISC and RISC.

MOS Digital Logic (MOS Digital Application-Specific IC + Other MOS Logic IC). Defined as an MOS digital semiconductor product in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Analog IC. Defined as monolithic analog ICs plus hybrid ICs. (A monolithic analog IC is a semiconductor product 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 a semiconductor product that consists 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. Note that hybrid digital ICs are reported in this category, and not under the earlier category of monolithic digital ICs. 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 + Solar Cell). 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: United States and Canada (and, in future documents, Mexico)

United States: the 48 contiguous states, Washington, D.C., Alaska, Hawaii, and Puerto Rico

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 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 its products (that is, consuming chips) 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 Singapore 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 goods. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data exclude 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.

Revenue estimates for 1989 and 1990 have been restated from previous publication to reflect modifications in Dataquest's data.

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 estimates of manufacturers' shipments

- Trade association data
- 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 input/output (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 and Forecast Methodology Guide*.

The electronic equipment forecast contained in this document may be found in its entirety and in detail down to the level of specific equipment type in the companion Source: Dataquest volume, *Worldwide and North American Electronic Equipment Production Forecast.*

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 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 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 five-year revenue forecasts for the aggregate semiconductor market during the second and fourth quarters of each year. 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 and Forecast 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 four-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 uses a decomposition time series model to generate forecasts of regional total semiconductor sales. The model assumes that sales are affected by factors such as long-run trends, short-run aggregate economic and industry-specific conditions, and seasonality. The forecast is made by using statistical methods to analyze each of the components separately, then combining them into a single aggregate. The model is especially useful for assessing market fluctuations about the trend growth path.

Third, Dataquest's worldwide Semiconductor service and its Semiconductor Equipment, Materials, and Manufacturing service, in conjunction with various regional offices, collaborate to formulate expectations of semiconductor market short-range fluctuations around the long-range trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the short-range forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12- to 24-month time frame. Semiconductor fab facilities and long-term 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-term trend.

Input/Output Ratios and the Allocation of Aggregate Semiconductor Consumption

The input/output (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 with modeled semiconductor consumption. The semiconductor content analyses are typically performed on equipment that sell in high volume or otherwise impact the semiconductor market. These analyses include personal computers, disk drives, printers, and cellular mobile radios.

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 aggregate semiconductor 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 total semiconductor market is the net sum of nonperiodic fluctuations in the individual semiconductor device markets. Further, because of a variety of factors, some device markets are relatively more volatile than are 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 total 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 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 are therefore cautioned to focus on long-run trends in the I/O ratios rather than on the year-to-year movements in their values.

Forecast Assumptions

The following two sections discuss the assumptions that underlie the forecasts in this document. The first section gives the assumptions of the electronic equipment forecast. The second section gives the assumption of the semiconductor consumption forecast.

Electronic Equipment Forecast Assumptions

The Dun & Bradstreet Corporation forecasts the U.S. economy to recover from the recession in 1992. Real gross domestic product (GDP) is expected to expand 2.1 percent in 1992. (The U.S. economy contracted 0.7 percent in 1991.) Though modest in comparison to historical rates of expansion during recovery periods, the benefit is that inflationary pressures will likely be held in check, sustaining the expansion's duration. Expansion should accelerate to 2.5 percent in 1993.

Overall, North American electronic systems production is expected to expand 3.1 percent in 1992, after contracting 5.0 percent rate in 1991. Expansion is expected to accelerate further in 1993 to 4.4 percent as the economic climate improves. In 1992, however, the value of production growth will be constrained by two important influences, as follows:

- A moderate—in contrast to booming—rate of recovery from recession
- An abundance of productive capacity, combined with further proliferation of product and technology standards, both placing pressure on costs and prices

From a semiconductor application-market perspective, the forecast assumes the following:

- Data processing production will begin to make a moderate 2.9 percent recovery in 1992, after a depressing 9.3 percent decline in 1991. Recovery will continue into 1993 as economic conditions continue to improve and stabilize.

- Communications production growth—the most stable-growing of the application markets, owing to its heterogeneous composition of personal wireless communications, premise voice and data products, and large-scale, long-life investment in public telecommunications infrastructure—will accelerate slightly in 1992 to 6.9 percent from 6.3 percent in 1991. Investment in networking the existing stock of data processing equipment will help drive communications hardware growth through 1996.
- As is usually the case, production of industrial and consumer equipment has borne the brunt of the recent downturn in business conditions. Dataquest forecasts these equipment markets to rebound in 1993 with the expected relaxation of business' and households' budget constraints.
- North American military/civil aerospace electronics production was hit hard by Washington budget cuts in 1991, declining 8.8 percent. Few positive opportunities remain for all but the most specialized niche players participating in simulation systems, dedicated military computer systems, and civil-space projects. Civil aerospace electronics production will remain the bright spot in this application market, fueled by replacement of aging jet airliners and upgrades of the worldwide air traffic control system.
- Transportation electronics production growth is expected to rebound from a 5.7 percent decline in 1991 to 9.6 percent growth in 1992, and to 10.4 percent growth in 1993. Production was hurt by the recession, but growth prospects are relatively upbeat because of increased household spending, combined with increasing share of electronic systems' added value to new vehicles.

Semiconductor Forecast Assumptions

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 15.1 percent in 1992, up from a meager 2.7 percent in 1991. The market is clearly on target midway through the year: According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in June was 18.0 percent above year-earlier bookings, compared with 11.9 percent in May. Total semiconductor billings growth for the same period was 14.8 percent above year-earlier billings, compared with 13.3 percent in May.

Strength in the North American market owes itself largely to the recovery of the U.S. economy and the relaxation of household and business budget constraints for durable goods and capital equipment. In particular, however, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

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, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Electronic Equipment	219,273	226,535	215,230
Total Semiconductor	17,072	16,540	16,990
Total IC	15,104	14,616	15,269
Bipolar Digital	1,635	1,577	1,331
Bipolar Memory	180	160	131
Bipolar Logic	1,455	1,417	1,200
MOS Digital	10,990	10,390	11,296
MOS Memory	5,774	4,325	4,510
MOS Microcomponent	2,796	3,381	3,916
MOS Logic	2,420	2,684	2,870
Analog	2,479	2,649	2,642
Total Discrete	1,639	1,611	1,389
Total Optoelectronic	329	313	332

Source: Dataquest (September 1992)

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, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Electronic Equipment	221,881	231,568	243,481	254,763	267,406
Total Semiconductor	19,564	22,613	25,456	26,127	27,579
Total IC					
Bipolar Digital	1,332	1,170	1,042	935	828
Bipolar Memory	147	109	75	65	62
Bipolar Logic	1,185	1,061	967	870	766
MOS Digital	13,342	16,003	18,449	18,722	19,801
MOS Memory	5,477	7,133	8,360	7,507	7,820
MOS Microcomponent	4,698	5,149	5,847	6,464	6,754
MOS Logic	3,167	3,721	4,242	4,751	5,227
Analog	3,000	3,430	3,840	4,230	4,600
Total Discrete	1,530	1,630	1,725	1,820	1,915
Total Optoelectronic	360	380	400	420	435

Source: Dataquest (September 1992)

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, 1989-1991
(Percent Change)

	1989	1990	1991
Total Electronic Equipment	6.1	3.3	-5.0
Total Semiconductor	7.8	-3.1	2.7
Total IC			
Bipolar Digital	-18.7	-3.5	-15.6
Bipolar Memory	-23.4	-11.1	-18.1
Bipolar Logic	-18.1	-2.6	-15.3
MOS Digital	14.4	-5.5	8.7
MOS Memory	34.3	-25.1	4.3
MOS Microcomponent	3.3	20.9	15.8
MOS Logic	-7.0	10.9	6.9
Analog	12.8	6.9	-0.3
Total Discrete	-2.2	-1.7	-13.8
Total Optoelectronic	-6.8	-4.9	6.1

Source: Dataquest (September 1992)

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, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Electronic Equipment	3.1	4.4	5.1	4.6	5.0	4.4
Total Semiconductor	15.2	15.6	12.6	2.6	5.6	10.2
Total IC						
Bipolar Digital	0.1	-12.2	-10.9	-10.3	-11.4	-9.1
Bipolar Memory	12.2	-25.9	-31.2	-13.3	-4.6	-13.9
Bipolar Logic	-1.3	-10.5	-8.9	-10.0	-12.0	-8.6
MOS Digital	18.1	19.9	15.3	1.5	5.8	11.9
MOS Memory	21.4	30.2	17.2	-10.2	4.2	11.6
MOS Microcomponent	20.0	9.6	13.6	10.6	4.5	11.5
MOS Logic	10.3	17.5	14.0	12.0	10.0	12.7
Analog	13.6	14.3	12.0	10.2	8.7	11.7
Total Discrete	10.2	6.5	5.8	5.5	5.2	6.6
Total Optoelectronic	8.4	5.6	5.3	5.0	3.6	5.6

Source: Dataquest (September 1992)

Table 5
Input/Output Ratios of All Semiconductors Shipped to North America for Use in All Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	7.8	7.3	7.9
Total IC	6.9	6.5	7.1
Bipolar Digital	0.7	0.7	0.6
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	0.7	0.6	0.6
MOS Digital	5.0	4.6	5.2
MOS Memory	2.6	1.9	2.1
MOS Microcomponent	1.3	1.5	1.8
MOS Logic	1.1	1.2	1.3
Analog	1.1	1.2	1.2
Total Discrete	0.7	0.7	0.6
Total Optoelectronic	0.2	0.1	0.2

Source: Dataquest (September 1992)

Table 6
Input/Output Ratios of All Semiconductors Shipped to North America for Use in All Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	8.8	9.8	10.5	10.3	10.3
Total IC	8.0	8.9	9.6	9.4	9.4
Bipolar Digital	0.6	0.5	0.4	0.4	0.3
Bipolar Memory	0.1	0	0	0	0
Bipolar Logic	0.5	0.5	0.4	0.3	0.3
MOS Digital	6.0	6.9	7.6	7.3	7.4
MOS Memory	2.5	3.1	3.4	2.9	2.9
MOS Microcomponent	2.1	2.2	2.4	2.5	2.5
MOS Logic	1.4	1.6	1.7	1.9	2.0
Analog	1.4	1.5	1.6	1.7	1.7
Total Discrete	0.7	0.7	0.7	0.7	0.7
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 7
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Data Processing	77,500	81,234	73,691
Total Semiconductor	9,569	8,977	9,444
Total IC	9,288	8,708	9,195
Bipolar Digital	947	921	785
Bipolar Memory	78	82	72
Bipolar Logic	869	839	713
MOS Digital	7,850	7,291	7,940
MOS Memory	4,602	3,428	3,595
MOS Microcomponent	1,885	2,370	2,746
MOS Logic	1,363	1,493	1,599
Analog	491	495	470
Total Discrete	186	183	151
Total Optoelectronic	95	87	98

Source: Dataquest (September 1992)

Table 8
Revenue from North American Data Processing Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Processing Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Data Processing	75,861	78,257	82,432	85,554	90,264
Total Semiconductor	11,095	13,041	14,754	14,602	15,152
Total IC					
Bipolar Digital	824	724	644	579	515
Bipolar Memory	92	69	44	39	39
Bipolar Logic	732	655	599	540	476
MOS Digital	9,471	11,452	13,195	13,066	13,648
MOS Memory	4,415	5,803	6,823	6,067	6,296
MOS Microcomponent	3,292	3,574	4,020	4,387	4,511
MOS Logic	1,764	2,074	2,352	2,612	2,842
Analog	515	559	591	612	624
Total Discrete	172	182	191	200	209
Total Optoelectronic	113	124	132	145	156

Source: Dataquest (September 1992)

Table 9
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, 1989-1991 (Percent Change)

	1989	1990	1991
Total Data Processing	6.0	4.8	-9.3
Total Semiconductor	11.6	-6.2	5.2
Total IC			
Bipolar Digital	-16.3	-2.8	-14.8
Bipolar Memory	-30.3	4.0	-12.3
Bipolar Logic	-14.8	-3.4	-15.0
MOS Digital	17.3	-7.1	8.9
MOS Memory	34.5	-25.5	4.9
MOS Microcomponent	6.0	25.7	15.8
MOS Logic	-8.6	9.5	7.1
Analog	3.9	1.0	-5.1
Total Discrete	2.3	-2.1	-17.1
Total Optoelectronic	-0.4	-9.0	13.2

Source: Dataquest (September 1992)

Table 10

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, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Data Processing	2.9	3.2	5.3	3.8	5.5	4.1
Total Semiconductor	17.5	17.5	13.1	-1.0	3.8	9.9
Total IC						
Bipolar Digital	5.1	-12.1	-11.1	-10.1	-11.1	-8.1
Bipolar Memory	28.5	-24.8	-35.7	-12.7	0.6	-11.4
Bipolar Logic	2.7	-10.5	-8.5	-9.9	-12.0	-7.8
MOS Digital	19.3	20.9	15.2	-1.0	4.5	11.4
MOS Memory	22.8	31.4	17.6	-11.1	3.8	11.9
MOS Microcomponent	19.9	8.6	12.5	9.1	2.8	10.4
MOS Logic	10.3	17.6	13.4	11.0	8.8	12.2
Analog	9.5	8.5	5.7	3.5	2.1	5.8
Total Discrete	13.5	6.0	5.0	4.5	4.3	6.6
Total Optoelectronic	15.2	9.6	6.9	9.6	7.8	9.8

Source: Dataquest (September 1992)

Table 11
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Data Processing Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	12.3	11.1	12.8
Total IC	12.0	10.7	12.5
Bipolar Digital	1.2	1.1	1.1
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	1.1	1.0	1.0
MOS Digital	10.1	9.0	10.8
MOS Memory	5.9	4.2	4.9
MOS Microcomponent	2.4	2.9	3.7
MOS Logic	1.8	1.8	2.2
Analog	0.6	0.6	0.6
Total Discrete	0.2	0.2	0.2
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 12
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Data Processing Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	14.6	16.7	17.9	17.1	16.8
Total IC	14.3	16.3	17.5	16.7	16.4
Bipolar Digital	1.1	0.9	0.8	0.7	0.6
Bipolar Memory	0.1	0.1	0.1	0	0
Bipolar Logic	1.0	0.8	0.7	0.6	0.5
MOS Digital	12.5	14.6	16.0	15.3	15.1
MOS Memory	5.8	7.4	8.3	7.1	7.0
MOS Microcomponent	4.3	4.6	4.9	5.1	5.0
MOS Logic	2.3	2.7	2.9	3.1	3.1
Analog	0.7	0.7	0.7	0.7	0.7
Total Discrete	0.2	0.2	0.2	0.2	0.2
Total Optoelectronic	0.1	0.2	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 13
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Communications	28,360	29,935	31,832
Total Semiconductor	1,720	1,735	1,776
Total IC	1,437	1,444	1,525
Bipolar Digital	98	94	74
Bipolar Memory	7	7	6
Bipolar Logic	91	87	69
MOS Digital	859	806	897
MOS Memory	429	286	298
MOS Microcomponent	206	254	311
MOS Logic	224	265	288
Analog	480	544	553
Total Discrete	232	242	200
Total Optoelectronic	51	49	52

Source: Dataquest (September 1992)

Table 14
Revenue from North American Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Communications Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Communications	34,037	36,375	38,882	41,470	43,888
Total Semiconductor	2,082	2,419	2,742	2,911	3,124
Total IC					
Bipolar Digital	72	59	49	41	34
Bipolar Memory	7	5	3	2	2
Bipolar Logic	65	54	46	39	32
MOS Digital	1,080	1,311	1,534	1,608	1,728
MOS Memory	363	473	551	486	500
MOS Microcomponent	394	452	536	618	671
MOS Logic	323	387	446	503	557
Analog	650	755	856	949	1,038
Total Discrete	225	238	249	259	268
Total Optoelectronic	55	56	55	56	55

Source: Dataquest (September 1992)

Table 15
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Communications	11.6	5.6	6.3
Total Semiconductor	7.0	0.9	2.4
Total IC			
Bipolar Digital	-34.6	-3.9	-21.0
Bipolar Memory	-42.6	-2.4	-20.5
Bipolar Logic	-33.9	-4.1	-21.0
MOS Digital	12.2	-6.3	11.4
MOS Memory	55.5	-33.3	4.0
MOS Microcomponent	-0.9	23.5	22.3
MOS Logic	-20.6	18.2	8.9
Analog	21.5	13.4	1.7
Total Discrete	-3.1	4.3	-17.5
Total Optoelectronic	-11.9	-3.0	4.6

Source: Dataquest (September 1992)

Table 16
Revenue Growth from North American Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Communications Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Communications	6.9	6.9	6.9	6.7	5.8	6.6
Total Semiconductor	17.2	16.2	13.3	6.2	7.3	12.0
Total IC						
Bipolar Digital	-2.9	-18.3	-17.1	-16.5	-17.7	-14.7
Bipolar Memory	16.6	-31.8	-41.7	-20.8	-8.8	-19.7
Bipolar Logic	-4.6	-16.9	-15.0	-16.3	-18.2	-14.3
MOS Digital	20.4	21.4	17.0	4.8	7.5	14.0
MOS Memory	21.8	30.3	16.6	-11.8	2.9	10.9
MOS Microcomponent	26.6	14.7	18.8	15.2	8.6	16.6
MOS Logic	12.1	19.6	15.3	12.9	10.6	14.1
Analog	17.4	16.3	13.3	10.9	9.4	13.4
Total Discrete	12.9	5.5	4.5	4.0	3.8	6.1
Total Optoelectronic	6.4	1.3	-1.2	1.2	-0.4	1.4

Source: Dataquest (September 1992)

Table 17
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Communications Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	6.1	5.8	5.6
Total IC	5.1	4.8	4.8
Bipolar Digital	0.3	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	3.0	2.7	2.8
MOS Memory	1.5	1.0	0.9
MOS Microcomponent	0.7	0.8	1.0
MOS Logic	0.8	0.9	0.9
Analog	1.7	1.8	1.7
Total Discrete	0.8	0.8	0.6
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 18
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Communications Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	6.1	6.7	7.1	7.0	7.1
Total IC	5.3	5.8	6.3	6.3	6.4
Bipolar Digital	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.1	0.1	0.1	0.1
MOS Digital	3.2	3.6	3.9	3.9	3.9
MOS Memory	1.1	1.3	1.4	1.2	1.1
MOS Microcomponent	1.2	1.2	1.4	1.5	1.5
MOS Logic	1.0	1.1	1.1	1.2	1.3
Analog	1.9	2.1	2.2	2.3	2.4
Total Discrete	0.7	0.7	0.6	0.6	0.6
Total Optoelectronic	0.2	0.2	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 19
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Industrial	32,302	33,687	33,909
Total Semiconductor	1,664	1,722	1,737
Total IC	1,091	1,166	1,259
Bipolar Digital	171	162	129
Bipolar Memory	17	16	13
Bipolar Logic	154	145	115
MOS Digital	525	554	663
MOS Memory	171	120	135
MOS Microcomponent	180	210	266
MOS Logic	174	224	261
Analog	395	451	467
Total Discrete	499	485	404
Total Optoelectronic	74	71	75

Source: Dataquest (September 1992)

Table 20
Revenue from North American Industrial Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Industrial Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Industrial	35,482	37,958	40,547	43,395	46,479
Total Semiconductor	2,067	2,406	2,773	3,075	3,410
Total IC					
Bipolar Digital	126	103	85	71	59
Bipolar Memory	16	11	7	6	5
Bipolar Logic	110	92	78	66	54
MOS Digital	841	1,068	1,325	1,513	1,735
MOS Memory	178	252	318	304	338
MOS Microcomponent	350	417	513	614	692
MOS Logic	313	400	493	596	705
Analog	559	663	766	866	966
Total Discrete	460	489	515	541	566
Total Optoelectronic	80	82	82	84	85

Source: Dataquest (September 1992)

Table 21
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Industrial	6.3	4.3	0.7
Total Semiconductor	-1.1	3.5	0.9
Total IC			
Bipolar Digital	-34.8	-5.7	-20.5
Bipolar Memory	-42.0	-5.9	-17.7
Bipolar Logic	-33.8	-5.7	-20.9
MOS Digital	8.4	5.6	19.6
MOS Memory	65.8	-29.7	12.6
MOS Microcomponent	-2.3	16.7	27.0
MOS Logic	-11.7	28.6	16.5
Analog	26.6	14.1	3.7
Total Discrete	-7.1	-2.8	-16.8
Total Optoelectronic	-14.2	-3.7	5.7

Source: Dataquest (September 1992)

Table 22
Revenue Growth from North American Industrial Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Industrial Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Industrial	4.6	7.0	6.8	7.0	7.1	6.5
Total Semiconductor	19.0	16.4	15.2	10.9	10.9	14.4
Total IC						
Bipolar Digital	-1.7	-18.3	-17.5	-16.2	-17.0	-14.4
Bipolar Memory	20.6	-29.4	-39.7	-18.1	-5.6	-16.9
Bipolar Logic	-4.3	-16.7	-14.8	-16.0	-18.0	-14.1
MOS Digital	27.0	27.0	24.0	14.2	14.6	21.2
MOS Memory	31.9	41.1	26.3	-4.5	11.4	20.1
MOS Microcomponent	31.4	19.0	23.3	19.6	12.7	21.0
MOS Logic	19.9	27.9	23.3	20.7	18.3	22.0
Analog	19.7	18.6	15.5	13.0	11.6	15.6
Total Discrete	13.9	6.4	5.3	4.9	4.6	7.0
Total Optoelectronic	7.5	2.3	-0.2	2.3	0.6	2.5

Source: Dataquest (September 1992)

Table 23
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Industrial Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	5.2	5.1	5.1
Total IC	3.4	3.5	3.7
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0.1	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.6	1.6	2.0
MOS Memory	0.5	0.4	0.4
MOS Microcomponent	0.6	0.6	0.8
MOS Logic	0.5	0.7	0.8
Analog	1.2	1.3	1.4
Total Discrete	1.5	1.4	1.2
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 24
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Industrial Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	5.8	6.3	6.8	7.1	7.3
Total IC	4.3	4.8	5.4	5.6	5.9
Bipolar Digital	0.4	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1
MOS Digital	2.4	2.8	3.3	3.5	3.7
MOS Memory	0.5	0.7	0.8	0.7	0.7
MOS Microcomponent	1.0	1.1	1.3	1.4	1.5
MOS Logic	0.9	1.1	1.2	1.4	1.5
Analog	1.6	1.7	1.9	2.0	2.1
Total Discrete	1.3	1.3	1.3	1.2	1.2
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 25
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Consumer	17,082	16,995	16,660
Total Semiconductor	1,152	1,152	1,174
Total IC	891	899	957
Bipolar Digital	11	8	6
Bipolar Memory	2	2	2
Bipolar Logic	9	7	4
MOS Digital	345	326	365
MOS Memory	177	138	144
MOS Microcomponent	125	141	169
MOS Logic	42	47	53
Analog	535	564	586
Total Discrete	245	238	201
Total Optoelectronic	16	15	16

Source: Dataquest (September 1992)

Table 26
Revenue from North American Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Consumer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Consumer	17,312	18,216	19,161	20,155	21,127
Total Semiconductor	1,402	1,644	1,881	2,042	2,227
Total IC					
Bipolar Digital	5	4	3	2	2
Bipolar Memory	2	1	1	1	1
Bipolar Logic	4	3	2	1	1
MOS Digital	445	537	627	643	682
MOS Memory	176	230	269	238	246
MOS Microcomponent	209	234	272	307	326
MOS Logic	60	73	85	98	110
Analog	703	834	965	1,092	1,220
Total Discrete	233	251	269	286	304
Total Optoelectronic	17	18	18	19	19

Source: Dataquest (September 1992)

Table 27
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Consumer	10.5	-0.5	-2.0
Total Semiconductor	12.3	0	1.9
Total IC			
Bipolar Digital	-38.0	-24.4	-29.2
Bipolar Memory	24.4	-26.8	-15.8
Bipolar Logic	-45.8	-23.8	-32.8
MOS Digital	11.0	-5.5	11.9
MOS Memory	31.3	-22.4	4.4
MOS Microcomponent	2.0	12.3	19.7
MOS Logic	-20.1	12.0	10.7
Analog	23.5	5.6	3.9
Total Discrete	-0.4	-3.0	-15.5
Total Optoelectronic	-10.6	-7.0	6.7

Source: Dataquest (September 1992)

Table 28
Revenue Growth from North American Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Consumer Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Consumer	3.9	5.2	5.2	5.2	4.8	4.9
Total Semiconductor	19.5	17.3	14.4	8.6	9.1	13.7
Total IC						
Bipolar Digital	-8.0	-28.7	-31.4	-24.8	-21.0	-23.2
Bipolar Memory	23.5	-27.7	-38.3	-16.2	-3.4	-14.9
Bipolar Logic	-18.8	-29.3	-27.7	-28.8	-30.4	-27.1
MOS Digital	21.8	20.8	16.7	2.6	6.1	13.3
MOS Memory	22.3	30.9	17.1	-11.5	3.3	11.4
MOS Microcomponent	23.9	12.2	16.2	12.8	6.2	14.1
MOS Logic	14.0	21.5	17.2	14.8	12.5	15.9
Analog	19.9	18.7	15.6	13.2	11.7	15.8
Total Discrete	15.6	8.1	7.0	6.5	6.3	8.6
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

Source: Dataquest (September 1992)

Table 29
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Consumer Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	6.7	6.8	7.0
Total IC	5.2	5.3	5.7
Bipolar Digital	0.1	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0.1	0	0
MOS Digital	2.0	1.9	2.2
MOS Memory	1.0	0.8	0.9
MOS Microcomponent	0.7	0.8	1.0
MOS Logic	0.2	0.3	0.3
Analog	3.1	3.3	3.5
Total Discrete	1.4	1.4	1.2
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 30
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Consumer Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	8.1	9.0	9.8	10.1	10.5
Total IC	6.7	7.6	8.3	8.6	9.0
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.6	2.9	3.3	3.2	3.2
MOS Memory	1.0	1.3	1.4	1.2	1.2
MOS Microcomponent	1.2	1.3	1.4	1.5	1.5
MOS Logic	0.3	0.4	0.4	0.5	0.5
Analog	4.1	4.6	5.0	5.4	5.8
Total Discrete	1.3	1.4	1.4	1.4	1.4
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 31
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, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Military/Civil Aerospace	59,876	60,569	55,257
Total Semiconductor	2,059	2,038	1,925
Total IC	1,655	1,647	1,553
Bipolar Digital	391	361	310
Bipolar Memory	73	51	39
Bipolar Logic	318	310	271
MOS Digital	863	865	851
MOS Memory	334	298	287
MOS Microcomponent	192	204	205
MOS Logic	337	363	359
Analog	401	421	392
Total Discrete	332	321	304
Total Optoelectronic	72	70	68

Source: Dataquest (September 1992)

Table 32
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, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Military/Civil Aerospace	54,937	56,068	57,463	58,924	60,132
Total Semiconductor	1,873	1,940	2,028	2,130	2,225
Total IC					
Bipolar Digital	272	247	227	206	183
Bipolar Memory	30	22	20	18	15
Bipolar Logic	242	224	207	189	168
MOS Digital	863	920	983	1,061	1,142
MOS Memory	288	308	328	354	385
MOS Microcomponent	206	219	236	259	283
MOS Logic	368	393	420	448	475
Analog	379	398	420	448	469
Total Discrete	291	303	316	330	343
Total Optoelectronic	69	73	83	86	87

Source: Dataquest (September 1992)

Table 33
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, 1989-1991
(Percent Change)

	1989	1990	1991
Total Military/Civil Aerospace	2.9	1.2	-8.8
Total Semiconductor	3.0	-1.1	-5.5
Total IC			
Bipolar Digital	-9.5	-7.5	-14.3
Bipolar Memory	-2.8	-29.5	-24.3
Bipolar Logic	-10.9	-2.5	-12.7
MOS Digital	14.1	0.3	-1.7
MOS Memory	15.7	-10.5	-3.7
MOS Microcomponent	9.2	6.1	0.4
MOS Logic	15.5	7.7	-1.1
Analog	1.1	4.8	-6.8
Total Discrete	-2.3	-3.5	-5.2
Total Optoelectronic	-2.4	-3.7	-2.0

Source: Dataquest (September 1992)

Table 34
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, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Military/Civil Aerospace	-0.6	2.1	2.5	2.5	2.1	1.7
Total Semiconductor	-2.7	3.6	4.6	5.0	4.4	2.9
Total IC						
Bipolar Digital	-12.1	-9.3	-8.0	-9.1	-11.1	-9.9
Bipolar Memory	-22.0	-25.8	-10.3	-11.9	-15.3	-17.3
Bipolar Logic	-10.7	-7.2	-7.8	-8.8	-10.7	-9.1
MOS Digital	1.4	6.6	6.9	7.9	7.7	6.1
MOS Memory	0.4	6.9	6.2	7.9	8.9	6.0
MOS Microcomponent	0.7	6.2	7.7	10.1	9.0	6.7
MOS Logic	2.5	6.6	6.9	6.7	6.1	5.7
Analog	-3.4	5.0	5.4	6.7	4.7	3.6
Total Discrete	-4.2	4.0	4.4	4.4	3.9	2.4
Total Optoelectronic	0.7	6.1	14.3	2.9	2.0	5.1

Source: Dataquest (September 1992)

Table 35
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	3.4	3.4	3.5
Total IC	2.8	2.7	2.8
Bipolar Digital	0.7	0.6	0.6
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	0.5	0.5	0.5
MOS Digital	1.4	1.4	1.5
MOS Memory	0.6	0.5	0.5
MOS Microcomponent	0.3	0.3	0.4
MOS Logic	0.6	0.6	0.7
Analog	0.7	0.7	0.7
Total Discrete	0.6	0.5	0.5
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 36
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Military/Civil Aerospace Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	3.4	3.5	3.5	3.6	3.7
Total IC	2.8	2.8	2.8	2.9	3.0
Bipolar Digital	0.5	0.4	0.4	0.4	0.3
Bipolar Memory	0.1	0	0	0	0
Bipolar Logic	0.4	0.4	0.4	0.3	0.3
MOS Digital	1.6	1.6	1.7	1.8	1.9
MOS Memory	0.5	0.6	0.6	0.6	0.6
MOS Microcomponent	0.4	0.4	0.4	0.4	0.5
MOS Logic	0.7	0.7	0.7	0.8	0.8
Analog	0.7	0.7	0.7	0.8	0.8
Total Discrete	0.5	0.5	0.5	0.6	0.6
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 37
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Transportation	4,153	4,115	3,881
Total Semiconductor	907	917	933
Total IC	742	752	781
Bipolar Digital	16	31	28
Bipolar Memory	2	2	0
Bipolar Logic	15	29	28
MOS Digital	548	548	580
MOS Memory	61	54	51
MOS Microcomponent	208	202	220
MOS Logic	279	292	310
Analog	178	174	172
Total Discrete	144	143	129
Total Optoelectronic	21	22	23

Source: Dataquest (September 1992)

Table 38
Revenue from North American Transportation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Transportation Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Transportation	4,252	4,694	4,996	5,265	5,516
Total Semiconductor	1,043	1,162	1,278	1,365	1,441
Total IC					
Bipolar Digital	32	33	34	35	36
Bipolar Memory	0	0	0		
Bipolar Logic	32	33	34	35	36
MOS Digital	642	715	786	831	865
MOS Memory	56	67	71	58	55
MOS Microcomponent	247	253	269	278	271
MOS Logic	339	395	446	495	539
Analog	194	220	243	264	283
Total Discrete	149	167	185	204	225
Total Optoelectronic	26	27	29	31	32

Source: Dataquest (September 1992)

Table 39
Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Transportation Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Transportation	0.5	-0.9	-5.7
Total Semiconductor	-5.0	1.1	1.8
Total IC			
Bipolar Digital	-3.8	87.0	-8.3
Bipolar Memory	-40.6	5.5	-100.0
Bipolar Logic	4.1	96.9	-2.4
MOS Digital	-8.2	-0.1	6.0
MOS Memory	-16.6	-11.5	-5.2
MOS Microcomponent	-13.0	-2.8	8.7
MOS Logic	-2.0	4.4	6.2
Analog	-5.5	-2.0	-1.0
Total Discrete	9.9	-0.9	-9.5
Total Optoelectronic	-4.1	3.4	7.6

Source: Dataquest (September 1992)

Table 40

Revenue Growth from North American Transportation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Tranportation Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Transportation	9.6	10.4	6.4	5.4	4.8	7.3
Total Semiconductor	11.8	11.4	10.0	6.9	5.5	9.1
Total IC						
Bipolar Digital	13.7	3.0	4.7	3.2	0.8	5.0
Bipolar Memory	0	0	0	0	0	-100.0
Bipolar Logic	13.7	3.0	4.7	3.2	0.8	5.0
MOS Digital	10.7	11.3	10.0	5.6	4.1	8.3
MOS Memory	10.4	18.3	6.5	-18.5	-5.4	1.4
MOS Microcomponent	12.4	2.6	6.2	3.3	-2.5	4.3
MOS Logic	9.5	16.5	13.0	10.9	8.9	11.7
Analog	12.6	13.2	10.6	8.7	7.1	10.4
Total Discrete	15.5	11.7	10.9	10.6	10.2	11.8
Total Optoelectronic	9.9	6.9	6.4	6.1	4.5	6.7

Source: Dataquest (September 1992)

Table 41
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Transportation Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	21.8	22.3	24.0
Total IC	17.9	18.3	20.1
Bipolar Digital	0.4	0.7	0.7
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.7	0.7
MOS Digital	13.2	13.3	15.0
MOS Memory	1.5	1.3	1.3
MOS Microcomponent	5.0	4.9	5.7
MOS Logic	6.7	7.1	8.0
Analog	4.3	4.2	4.4
Total Discrete	3.5	3.5	3.3
Total Optoelectronic	0.5	0.5	0.6

Source: Dataquest (September 1992)

Table 42
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Transportation Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	24.5	24.7	25.6	25.9	26.1
Total IC	20.4	20.6	21.3	21.5	21.4
Bipolar Digital	0.7	0.7	0.7	0.7	0.6
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.7	0.7	0.7	0.7	0.6
MOS Digital	15.1	15.2	15.7	15.8	15.7
MOS Memory	1.3	1.4	1.4	1.1	1.0
MOS Microcomponent	5.8	5.4	5.4	5.3	4.9
MOS Logic	8.0	8.4	8.9	9.4	9.8
Analog	4.6	4.7	4.9	5.0	5.1
Total Discrete	3.5	3.6	3.7	3.9	4.1
Total Optoelectronic	0.6	0.6	0.6	0.6	0.6

Source: Dataquest (September 1992)

Table 43
Revenue from North American Computer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Computer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Computers	52,991	55,750	47,974
Total Semiconductor	7,120	6,571	6,851
Total IC	6,945	6,406	6,702
Bipolar Digital	845	822	703
Bipolar Memory	69	72	63
Bipolar Logic	775	751	641
MOS Digital	6,042	5,518	5,932
MOS Memory	3,766	2,774	2,857
MOS Microcomponent	1,327	1,715	1,974
MOS Logic	948	1,028	1,100
Analog	59	66	67
Total Discrete	119	117	96
Total Optoelectronic	56	48	53

Source: Dataquest (September 1992)

Table 44
Revenue from North American Computer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Computer Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Computers	50,676	52,668	56,756	59,591	64,148
Total Semiconductor	7,980	9,269	10,311	9,938	10,067
Total IC					
Bipolar Digital	741	654	583	526	468
Bipolar Memory	81	61	39	34	34
Bipolar Logic	660	593	544	492	434
MOS Digital	6,995	8,351	9,449	9,118	9,293
MOS Memory	3,441	4,427	5,082	4,403	4,439
MOS Microcomponent	2,344	2,512	2,780	2,975	2,989
MOS Logic	1,209	1,412	1,587	1,740	1,865
Analog	78	89	99	107	114
Total Discrete	109	115	120	124	129
Total Optoelectronic	58	60	61	63	63

Source: Dataquest (September 1992)

Table 45
Revenue Growth from North American Computer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Computer Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Computers	7.2	5.2	-13.9
Total Semiconductor	13.2	-7.7	4.3
Total IC			
Bipolar Digital	-16.6	-2.7	-14.4
Bipolar Memory	-28.3	3.4	-12.4
Bipolar Logic	-15.4	-3.2	-14.6
MOS Digital	19.5	-8.7	7.5
MOS Memory	35.0	-26.3	3.0
MOS Microcomponent	7.5	29.2	15.1
MOS Logic	-7.9	8.4	7.0
Analog	8.6	12.6	1.0
Total Discrete	5.2	-2.4	-17.3
Total Optoelectronic	0.8	-12.9	8.6

Source: Dataquest (September 1992)

Table 46
Revenue Growth from North American Computer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Computer Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Computers	5.6	3.9	7.8	5.0	7.6	6.0
Total Semiconductor	16.5	16.2	11.2	-3.6	1.3	8.0
Total IC						
Bipolar Digital	5.4	-11.8	-10.8	-9.8	-11.0	-7.8
Bipolar Memory	28.5	-24.8	-35.8	-12.8	0.5	-11.5
Bipolar Logic	3.1	-10.2	-8.2	-9.6	-11.8	-7.5
MOS Digital	17.9	19.4	13.1	-3.5	1.9	9.4
MOS Memory	20.4	28.6	14.8	-13.4	0.8	9.2
MOS Microcomponent	18.7	7.2	10.7	7.0	0.5	8.6
MOS Logic	9.9	16.8	12.3	9.7	7.2	11.1
Analog	16.2	14.7	11.2	8.4	6.6	11.4
Total Discrete	13.0	5.5	4.3	3.8	3.4	5.9
Total Optoelectronic	10.0	4.2	1.1	3.1	0.9	3.8

Source: Dataquest (September 1992)

Table 47
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Computer Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	13.4	11.8	14.3
Total IC	13.1	11.5	14.0
Bipolar Digital	1.6	1.5	1.5
Bipolar Memory	0.1	0.1	0.1
Bipolar Logic	1.5	1.3	1.3
MOS Digital	11.4	9.9	12.4
MOS Memory	7.1	5.0	6.0
MOS Microcomponent	2.5	3.1	4.1
MOS Logic	1.8	1.8	2.3
Analog	0.1	0.1	0.1
Total Discrete	0.2	0.2	0.2
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 48
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Computer Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	15.7	17.6	18.2	16.7	15.7
Total IC	15.4	17.3	17.8	16.4	15.4
Bipolar Digital	1.5	1.2	1.0	0.9	0.7
Bipolar Memory	0.2	0.1	0.1	0.1	0.1
Bipolar Logic	1.3	1.1	1.0	0.8	0.7
MOS Digital	13.8	15.9	16.6	15.3	14.5
MOS Memory	6.8	8.4	9.0	7.4	6.9
MOS Microcomponent	4.6	4.8	4.9	5.0	4.7
MOS Logic	2.4	2.7	2.8	2.9	2.9
Analog	0.2	0.2	0.2	0.2	0.2
Total Discrete	0.2	0.2	0.2	0.2	0.2
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 49
Revenue from North American Data Storage/Subsystems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Data Storage/Subsystems	5,458	5,400	5,091
Total Semiconductor	906	905	868
Total IC	878	879	847
Bipolar Digital	29	27	21
Bipolar Memory	3	3	2
Bipolar Logic	26	25	18
MOS Digital	513	522	525
MOS Memory	95	78	81
MOS Microcomponent	225	244	251
MOS Logic	193	200	193
Analog	336	330	301
Total Discrete	21	20	16
Total Optoelectronic	7	6	6

Source: Dataquest (September 1992)

Table 50
Revenue from North American Data Storage/Subsystems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Data Storage/Subsystems	4,081	3,255	2,265	1,743	1,240
Total Semiconductor	914	949	968	926	883
Total IC					
Bipolar Digital	19	15	12	9	7
Bipolar Memory	3	2	2	1	1
Bipolar Logic	16	13	10	8	6
MOS Digital	557	587	609	578	550
MOS Memory	100	131	153	135	138
MOS Microcomponent	267	256	254	243	219
MOS Logic	191	200	203	200	193
Analog	315	325	326	318	305
Total Discrete	16	16	16	15	15
Total Optoelectronic	6	6	6	5	5

Source: Dataquest (September 1992)

Table 51
Revenue Growth from North American Data Storage/Subsystems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Data Storage/Subsystems	-7.2	-1.1	-5.7
Total Semiconductor	-2.0	-0.1	-4.1
Total IC			
Bipolar Digital	-8.0	-4.4	-24.5
Bipolar Memory	-37.2	8.7	-11.1
Bipolar Logic	-3.7	-5.6	-26.0
MOS Digital	-4.9	1.7	0.7
MOS Memory	16.1	-18.4	4.9
MOS Microcomponent	-1.8	8.5	3.0
MOS Logic	-15.4	3.6	-3.7
Analog	3.4	-1.8	-9.0
Total Discrete	-2.5	-6.0	-22.7
Total Optoelectronic	-4.4	-15.3	2.5

Source: Dataquest (September 1992)

Table 52
Revenue Growth from North American Data Storage/Subsystems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Data Storage/Subsystems	-19.8	-20.2	-30.4	-23.0	-28.9	-24.6
Total Semiconductor	5.3	3.9	1.9	-4.3	-4.7	0.3
Total IC						
Bipolar Digital	-5.8	-22.4	-22.8	-20.3	-19.7	-18.4
Bipolar Memory	30.3	-23.7	-34.8	-11.5	1.9	-10.2
Bipolar Logic	-10.6	-22.2	-20.5	-21.7	-23.5	-19.8
MOS Digital	6.1	5.4	3.7	-5.1	-4.8	0.9
MOS Memory	22.6	31.0	16.9	-11.8	2.7	11.2
MOS Microcomponent	6.3	-4.1	-0.9	-4.2	-10.1	-2.7
MOS Logic	-1.1	5.1	1.1	-1.3	-3.5	0
Analog	4.6	3.3	0.2	-2.3	-4.0	0.3
Total Discrete	5.7	-1.4	-2.4	-2.9	-3.3	-0.9
Total Optoelectronic	3.8	-1.7	-4.6	-2.8	-4.8	-2.1

Source: Dataquest (September 1992)

Table 53
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	16.6	16.8	17.0
Total IC	16.1	16.3	16.6
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0	0.1	0
Bipolar Logic	0.5	0.5	0.4
MOS Digital	9.4	9.7	10.3
MOS Memory	1.7	1.4	1.6
MOS Microcomponent	4.1	4.5	4.9
MOS Logic	3.5	3.7	3.8
Analog	6.2	6.1	5.9
Total Discrete	0.4	0.4	0.3
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 54
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Data Storage/Subsystems Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	22.4	29.2	42.7	53.1	71.2
Total IC	21.8	28.5	41.8	51.9	69.6
Bipolar Digital	0.5	0.5	0.5	0.5	0.6
Bipolar Memory	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	0.4	0.4	0.4	0.5	0.5
MOS Digital	13.7	18.0	26.9	33.2	44.4
MOS Memory	2.4	4.0	6.7	7.7	11.2
MOS Microcomponent	6.5	7.9	11.2	13.9	17.6
MOS Logic	4.7	6.2	8.9	11.5	15.6
Analog	7.7	10.0	14.4	18.2	24.6
Total Discrete	0.4	0.5	0.7	0.9	1.2
Total Optoelectronic	0.1	0.2	0.2	0.3	0.4

Source: Dataquest (September 1992)

Table 55
Revenue from North American Terminal Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Terminal Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Terminals	2,179	2,081	1,952
Total Semiconductor	215	186	204
Total IC	203	176	195
Bipolar Digital	10	8	8
Bipolar Memory	1	1	1
Bipolar Logic	9	8	7
MOS Digital	147	122	139
MOS Memory	81	50	54
MOS Microcomponent	42	47	58
MOS Logic	24	25	28
Analog	47	46	48
Total Discrete	10	9	7
Total Optoelectronic	2	2	2

Source: Dataquest (September 1992)

Table 56
Revenue from North American Terminal Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Terminal Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Terminals	2,046	2,119	2,143	2,093	2,087
Total Semiconductor	249	301	351	371	401
Total IC					
Bipolar Digital	8	8	7	7	6
Bipolar Memory	1	1	1	1	1
Bipolar Logic	7	7	6	6	5
MOS Digital	172	212	251	260	278
MOS Memory	67	91	109	98	103
MOS Microcomponent	73	83	97	110	117
MOS Logic	32	38	45	52	58
Analog	58	70	81	92	102
Total Discrete	8	9	9	10	10
Total Optoelectronic	3	3	3	3	3

Source: Dataquest (September 1992)

Table 57
Revenue Growth from North American Terminal Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Terminal Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Terminals	-5.8	-4.5	-6.2
Total Semiconductor	0.9	-13.3	9.4
Total IC			
Bipolar Digital	-32.1	-11.0	-10.7
Bipolar Memory	-58.1	8.7	-3.6
Bipolar Logic	-27.7	-12.9	-11.6
MOS Digital	7.2	-17.0	14.0
MOS Memory	24.9	-38.5	7.5
MOS Microcomponent	-4.2	12.2	22.1
MOS Logic	-16.0	4.7	11.7
Analog	-2.3	-2.7	5.5
Total Discrete	-11.3	-11.4	-16.1
Total Optoelectronic	-36.2	-1.2	15.3

Source: Dataquest (September 1992)

Table 58
Revenue Growth from North American Terminal Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Terminal Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Terminals	4.8	3.6	1.1	-2.3	-0.3	1.3
Total Semiconductor	22.2	20.7	16.7	5.8	7.8	14.5
Total IC						
Bipolar Digital	10.8	-8.5	-8.2	-6.2	-6.6	-4.0
Bipolar Memory	41.3	-17.3	-29.3	-4.1	10.5	-2.6
Bipolar Logic	6.8	-7.0	-4.9	-6.4	-8.6	-4.2
MOS Digital	23.6	23.3	18.4	3.7	7.1	14.9
MOS Memory	25.8	34.3	19.9	-9.5	5.3	14.0
MOS Microcomponent	25.9	13.7	17.4	13.5	6.6	15.2
MOS Logic	14.6	21.9	17.2	14.5	11.8	16.0
Analog	21.2	19.7	16.1	13.2	11.2	16.2
Total Discrete	14.8	7.1	6.0	5.4	5.0	7.6
Total Optoelectronic	16.7	10.5	7.2	9.4	7.1	10.1

Source: Dataquest (September 1992)

Table 59
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Terminal Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	9.9	9.0	10.4
Total IC	9.3	8.5	10.0
Bipolar Digital	0.4	0.4	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.4	0.3
MOS Digital	6.7	5.9	7.1
MOS Memory	3.7	2.4	2.7
MOS Microcomponent	1.9	2.3	3.0
MOS Logic	1.1	1.2	1.4
Analog	2.2	2.2	2.5
Total Discrete	0.4	0.4	0.4
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 60
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Terminal Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	12.2	14.2	16.4	17.7	19.2
Total IC	11.7	13.6	15.8	17.1	18.5
Bipolar Digital	0.4	0.4	0.3	0.3	0.3
Bipolar Memory	0.1	0	0	0	0
Bipolar Logic	0.3	0.3	0.3	0.3	0.3
MOS Digital	8.4	10.0	11.7	12.4	13.3
MOS Memory	3.3	4.3	5.1	4.7	5.0
MOS Microcomponent	3.6	3.9	4.5	5.3	5.6
MOS Logic	1.5	1.8	2.1	2.5	2.8
Analog	2.9	3.3	3.8	4.4	4.9
Total Discrete	0.4	0.4	0.4	0.5	0.5
Total Optoelectronic	0.1	0.1	0.1	0.2	0.2

Source: Dataquest (September 1992)

Table 61
Revenue from North American Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Input/Output Devices	11,847	13,209	14,079
Total Semiconductor	994	1,008	1,191
Total IC	942	954	1,134
Bipolar Digital	49	50	42
Bipolar Memory	4	5	4
Bipolar Logic	45	45	38
MOS Digital	855	862	1,047
MOS Memory	507	408	477
MOS Microcomponent	198	264	344
MOS Logic	150	190	225
Analog	38	43	44
Total Discrete	25	27	24
Total Optoelectronic	26	27	34

Source: Dataquest (September 1992)

Table 62
Revenue from North American Input/Output Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Input/Output Devices	14,299	15,186	15,985	16,635	17,095
Total Semiconductor	1,559	2,055	2,591	2,836	3,252
Total IC					
Bipolar Digital	44	39	35	31	27
Bipolar Memory	5	4	2	2	2
Bipolar Logic	39	35	32	29	25
MOS Digital	1,391	1,871	2,391	2,617	3,015
MOS Memory	653	953	1,241	1,220	1,396
MOS Microcomponent	464	565	709	861	982
MOS Logic	274	354	441	536	636
Analog	53	63	72	80	88
Total Discrete	28	32	35	39	43
Total Optoelectronic	42	51	59	69	80

Source: Dataquest (September 1992)

Table 63
Revenue Growth from North American Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Input/Output Devices	14.0	11.5	6.6
Total Semiconductor	22.8	1.4	18.1
Total IC			
Bipolar Digital	-6.6	0.8	-14.9
Bipolar Memory	-40.2	8.7	-12.9
Bipolar Logic	-1.6	0.1	-15.1
MOS Digital	26.8	0.8	21.5
MOS Memory	43.1	-19.4	16.9
MOS Microcomponent	14.8	32.9	30.6
MOS Logic	1.8	26.7	18.6
Analog	12.1	12.1	4.0
Total Discrete	5.7	6.0	-12.1
Total Optoelectronic	7.1	2.3	24.5

Source: Dataquest (September 1992)

Table 64
Revenue Growth from North American Input/Output Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Input/Output Devices	1.6	6.2	5.3	4.1	2.8	4.0
Total Semiconductor	30.9	31.9	26.1	9.5	14.7	22.3
Total IC						
Bipolar Digital	4.8	-12.4	-11.4	-10.4	-11.5	-8.4
Bipolar Memory	27.6	-25.3	-36.2	-13.4	-0.2	-12.1
Bipolar Logic	2.5	-10.7	-8.8	-10.1	-12.3	-8.0
MOS Digital	32.8	34.6	27.8	9.5	15.2	23.6
MOS Memory	36.7	46.0	30.3	-1.7	14.4	23.9
MOS Microcomponent	34.8	21.6	25.6	21.5	14.0	23.3
MOS Logic	21.7	29.4	24.4	21.5	18.7	23.1
Analog	19.5	18.0	14.4	11.6	9.7	14.6
Total Discrete	20.1	12.1	10.9	10.3	9.9	12.6
Total Optoelectronic	26.1	19.4	15.9	18.2	15.6	19.0

Source: Dataquest (September 1992)

Table 65
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Input/Output Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	8.4	7.6	8.5
Total IC	8.0	7.2	8.1
Bipolar Digital	0.4	0.4	0.3
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.3	0.3
MOS Digital	7.2	6.5	7.4
MOS Memory	4.3	3.1	3.4
MOS Microcomponent	1.7	2.0	2.4
MOS Logic	1.3	1.4	1.6
Analog	0.3	0.3	0.3
Total Discrete	0.2	0.2	0.2
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 66
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Input/Output Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	10.9	13.5	16.2	17.0	19.0
Total IC	10.4	13.0	15.6	16.4	18.3
Bipolar Digital	0.3	0.3	0.2	0.2	0.2
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1
MOS Digital	9.7	12.3	15.0	15.7	17.6
MOS Memory	4.6	6.3	7.8	7.3	8.2
MOS Microcomponent	3.2	3.7	4.4	5.2	5.7
MOS Logic	1.9	2.3	2.8	3.2	3.7
Analog	0.4	0.4	0.4	0.5	0.5
Total Discrete	0.2	0.2	0.2	0.2	0.2
Total Optoelectronic	0.3	0.3	0.4	0.4	0.5

Source: Dataquest (September 1992)

Table 67
Revenue from North American Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Dedicated Systems	5,025	4,794	4,595
Total Semiconductor	335	307	331
Total IC	320	293	318
Bipolar Digital	15	13	11
Bipolar Memory	2	2	2
Bipolar Logic	13	11	9
MOS Digital	294	269	297
MOS Memory	153	118	125
MOS Microcomponent	93	100	118
MOS Logic	48	50	54
Analog	11	11	10
Total Discrete	11	11	9
Total Optoelectronic	5	4	4

Source: Dataquest (September 1992)

Table 68

Revenue from North American Dedicated Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Dedicated Systems	4,759	5,029	5,283	5,492	5,694
Total Semiconductor	394	467	532	530	549
Total IC					
Bipolar Digital	11	9	8	7	6
Bipolar Memory	2	1	1	1	1
Bipolar Logic	9	8	7	6	5
MOS Digital	357	430	495	493	512
MOS Memory	154	203	238	211	218
MOS Microcomponent	144	159	180	198	204
MOS Logic	59	68	77	84	90
Analog	12	13	14	15	15
Total Discrete	10	11	11	12	12
Total Optoelectronic	4	4	4	4	4

Source: Dataquest (September 1992)

Table 69
Revenue Growth from North American Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Dedicated Systems	-1.6	-4.6	-4.2
Total Semiconductor	-0.2	-8.4	7.8
Total IC			
Bipolar Digital	-27.8	-13.3	-18.1
Bipolar Memory	-44.1	8.7	-16.0
Bipolar Logic	-25.1	-16.0	-18.5
MOS Digital	2.7	-8.5	10.4
MOS Memory	16.8	-22.7	5.5
MOS Microcomponent	-4.4	8.1	18.1
MOS Logic	-17.3	4.6	6.7
Analog	-2.3	-0.6	-2.5
Total Discrete	-10.6	-1.6	-16.6
Total Optoelectronic	-20.3	-21.0	6.3

Source: Dataquest (September 1992)

Table 70
Revenue Growth from North American Dedicated Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Dedicated Systems	3.6	5.7	5.1	4.0	3.7	4.4
Total Semiconductor	19.1	18.6	14.0	-0.3	3.5	10.7
Total IC						
Bipolar Digital	2.0	-16.6	-16.2	-14.0	-14.5	-12.1
Bipolar Memory	23.1	-28.0	-38.5	-16.5	-3.8	-15.2
Bipolar Logic	-1.5	-14.2	-12.3	-13.7	-15.7	-11.6
MOS Digital	20.3	20.4	15.2	-0.4	3.8	11.5
MOS Memory	23.3	31.7	17.6	-11.3	3.2	11.8
MOS Microcomponent	21.9	10.0	13.6	9.9	3.1	11.5
MOS Logic	9.6	16.5	12.0	9.4	6.9	10.8
Analog	12.1	10.7	7.4	4.7	2.9	7.5
Total Discrete	14.0	6.4	5.2	4.7	4.3	6.9
Total Optoelectronic	7.6	1.9	-1.1	0.9	-1.3	1.5

Source: Dataquest (September 1992)

Table 71
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Dedicated Systems Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	6.7	6.4	7.2
Total IC	6.4	6.1	6.9
Bipolar Digital	0.3	0.3	0.2
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.2	0.2
MOS Digital	5.8	5.6	6.5
MOS Memory	3.0	2.5	2.7
MOS Microcomponent	1.8	2.1	2.6
MOS Logic	1.0	1.0	1.2
Analog	0.2	0.2	0.2
Total Discrete	0.2	0.2	0.2
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 72
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Dedicated Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	8.3	9.3	10.1	9.7	9.6
Total IC	8.0	9.0	9.8	9.4	9.4
Bipolar Digital	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.1	0.1	0.1
MOS Digital	7.5	8.5	9.4	9.0	9.0
MOS Memory	3.2	4.0	4.5	3.8	3.8
MOS Microcomponent	3.0	3.2	3.4	3.6	3.6
MOS Logic	1.2	1.4	1.5	1.5	1.6
Analog	0.2	0.3	0.3	0.3	0.3
Total Discrete	0.2	0.2	0.2	0.2	0.2
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 73
Revenue from North American Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Premise Telecom Equipment	12,656	13,916	15,003
Total Semiconductor	971	1,008	1,042
Total IC	825	852	909
Bipolar Digital	51	51	41
Bipolar Memory	2	2	2
Bipolar Logic	49	50	39
MOS Digital	508	491	555
MOS Memory	258	178	185
MOS Microcomponent	132	166	208
MOS Logic	118	147	161
Analog	265	309	314
Total Discrete	125	134	110
Total Optoelectronic	21	22	23

Source: Dataquest (September 1992)

Table 74
Revenue from North American Premise Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Premise Telecom Equipment	15,929	16,895	17,914	18,986	20,131
Total Semiconductor	1,232	1,443	1,649	1,761	1,899
Total IC					
Bipolar Digital	39	32	26	22	18
Bipolar Memory	2	1	1	1	0
Bipolar Logic	37	30	26	21	17
MOS Digital	677	829	979	1,039	1,128
MOS Memory	226	295	344	304	313
MOS Microcomponent	269	314	380	446	492
MOS Logic	182	220	255	290	323
Analog	367	426	481	531	579
Total Discrete	124	131	137	142	147
Total Optoelectronic	25	26	26	27	27

Source: Dataquest (September 1992)

Table 75
Revenue Growth from North American Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Premise Telecom Equipment	17.9	10.0	7.8
Total Semiconductor	11.9	3.8	3.5
Total IC			
Bipolar Digital	-32.0	0.9	-21.2
Bipolar Memory	-37.8	-2.4	-11.0
Bipolar Logic	-31.8	1.0	-21.6
MOS Digital	17.6	-3.3	12.9
MOS Memory	60.9	-31.0	4.1
MOS Microcomponent	2.7	26.0	25.0
MOS Logic	-17.5	24.6	9.7
Analog	25.2	16.4	1.5
Total Discrete	0	6.9	-17.6
Total Optoelectronic	-9.5	5.8	6.3

Source: Dataquest (September 1992)

Table 76
Revenue Growth from North American Premise Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Premise Telecom Equipment	6.2	6.1	6.0	6.0	6.0	6.1
Total Semiconductor	18.2	17.1	14.3	6.8	7.8	12.7
Total IC						
Bipolar Digital	-4.5	-18.3	-16.7	-17.1	-18.7	-15.2
Bipolar Memory	13.8	-33.5	-43.4	-23.4	-12.0	-22.0
Bipolar Logic	-5.3	-17.5	-15.6	-16.9	-18.9	-15.0
MOS Digital	22.1	22.4	18.2	6.1	8.5	15.2
MOS Memory	22.0	30.5	16.7	-11.7	3.0	11.1
MOS Microcomponent	29.2	16.9	21.0	17.3	10.4	18.8
MOS Logic	12.9	20.4	16.1	13.7	11.4	14.9
Analog	17.1	16.0	12.9	10.5	9.0	13.1
Total Discrete	12.8	5.4	4.3	3.8	3.6	5.9
Total Optoelectronic	8.1	2.9	0.2	2.7	1.0	2.9

Source: Dataquest (September 1992)

Table 77
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	7.7	7.2	6.9
Total IC	6.5	6.1	6.1
Bipolar Digital	0.4	0.4	0.3
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.4	0.3
MOS Digital	4.0	3.5	3.7
MOS Memory	2.0	1.3	1.2
MOS Microcomponent	1.0	1.2	1.4
MOS Logic	0.9	1.1	1.1
Analog	2.1	2.2	2.1
Total Discrete	1.0	1.0	0.7
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 78
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Premise Telecom Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	7.7	8.5	9.2	9.3	9.4
Total IC	6.8	7.6	8.3	8.4	8.6
Bipolar Digital	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.1	0.1	0.1
MOS Digital	4.3	4.9	5.5	5.5	5.6
MOS Memory	1.4	1.7	1.9	1.6	1.6
MOS Microcomponent	1.7	1.9	2.1	2.3	2.4
MOS Logic	1.1	1.3	1.4	1.5	1.6
Analog	2.3	2.5	2.7	2.8	2.9
Total Discrete	0.8	0.8	0.8	0.7	0.7
Total Optoelectronic	0.2	0.2	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 79
Revenue from North American Public Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Public Telecom Equipment	7,020	7,217	7,578
Total Semiconductor	340	325	327
Total IC	273	259	270
Bipolar Digital	13	12	10
Bipolar Memory	2	2	2
Bipolar Logic	12	10	8
MOS Digital	174	155	168
MOS Memory	83	52	54
MOS Microcomponent	37	43	51
MOS Logic	53	60	64
Analog	85	91	91
Total Discrete	51	51	41
Total Optoelectronic	16	16	16

Source: Dataquest (September 1992)

Table 80
Revenue from North American Public Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Public Telecom Equipment	8,247	8,949	9,660	10,397	11,061
Total Semiconductor	374	426	472	490	514
Total IC					
Bipolar Digital	10	8	6	5	4
Bipolar Memory	2	1	1	1	0
Bipolar Logic	8	6	5	5	4
MOS Digital	197	234	266	272	286
MOS Memory	65	83	96	84	86
MOS Microcomponent	61	66	75	82	84
MOS Logic	71	84	95	106	116
Analog	105	120	134	146	157
Total Discrete	46	48	50	52	53
Total Optoelectronic	17	16	16	16	15

Source: Dataquest (September 1992)

Table 81
Revenue Growth from North American Public Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Public Telecom Equipment	4.2	2.8	5.0
Total Semiconductor	1.3	-4.5	0.6
Total IC			
Bipolar Digital	-39.0	-8.2	-20.0
Bipolar Memory	-37.8	-2.4	-11.0
Bipolar Logic	-39.1	-9.2	-21.6
MOS Digital	4.9	-10.9	8.5
MOS Memory	49.2	-37.6	3.1
MOS Microcomponent	-6.8	16.1	16.4
MOS Logic	-23.7	11.9	7.5
Analog	15.1	7.2	0
Total Discrete	-6.6	-1.5	-18.3
Total Optoelectronic	-15.3	-3.0	2.3

Source: Dataquest (September 1992)

Table 82
Revenue Growth from North American Public Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Public Telecom Equipment	8.8	8.5	7.9	7.6	6.4	7.9
Total Semiconductor	14.6	13.9	10.8	3.7	5.0	9.5
Total IC						
Bipolar Digital	-2.1	-20.5	-20.0	-17.6	-18.1	-15.9
Bipolar Memory	13.8	-33.5	-43.4	-23.4	-12.0	-22.0
Bipolar Logic	-5.2	-17.5	-15.6	-16.9	-18.9	-14.9
MOS Digital	16.8	18.8	14.1	2.1	5.0	11.1
MOS Memory	20.7	29.2	15.5	-12.6	1.9	9.9
MOS Microcomponent	20.3	8.9	12.7	9.2	2.8	10.6
MOS Logic	10.6	18.0	13.7	11.4	9.1	12.5
Analog	15.3	14.3	11.2	8.9	7.4	11.4
Total Discrete	11.8	4.5	3.4	3.0	2.7	5.0
Total Optoelectronic	4.0	-1.1	-3.6	-1.2	-2.9	-1.0

Source: Dataquest (September 1992)

Table 83
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	4.8	4.5	4.3
Total IC	3.9	3.6	3.6
Bipolar Digital	0.2	0.2	0.1
Bipolar Memory	0	0	0
Bipolar Logic	0.2	0.1	0.1
MOS Digital	2.5	2.2	2.2
MOS Memory	1.2	0.7	0.7
MOS Microcomponent	0.5	0.6	0.7
MOS Logic	0.8	0.8	0.8
Analog	1.2	1.3	1.2
Total Discrete	0.7	0.7	0.5
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 84
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Public Telecom Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	4.5	4.8	4.9	4.7	4.7
Total IC	3.8	4.0	4.2	4.1	4.0
Bipolar Digital	0.1	0.1	0.1	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.1	0.1	0.1	0	0
MOS Digital	2.4	2.6	2.8	2.6	2.6
MOS Memory	0.8	0.9	1.0	0.8	0.8
MOS Microcomponent	0.7	0.7	0.8	0.8	0.8
MOS Logic	0.9	0.9	1.0	1.0	1.0
Analog	1.3	1.3	1.4	1.4	1.4
Total Discrete	0.6	0.5	0.5	0.5	0.5
Total Optoelectronic	0.2	0.2	0.2	0.1	0.1

Source: Dataquest (September 1992)

Table 85
Revenue from North American Mobile Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Mobile Communications Equipment	2,970	2,973	3,138
Total Semiconductor	126	125	127
Total IC	104	102	107
Bipolar Digital	11	9	8
Bipolar Memory	1	1	1
Bipolar Logic	10	9	7
MOS Digital	35	27	30
MOS Memory	18	10	11
MOS Microcomponent	8	9	10
MOS Logic	8	9	9
Analog	59	65	68
Total Discrete	17	18	15
Total Optoelectronic	5	5	5

Source: Dataquest (September 1992)

Table 86
Revenue from North American Mobile Communications Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Mobile Communications Equipment	3,442	3,820	4,289	4,724	5,162
Total Semiconductor	151	176	201	220	242
Total IC					
Bipolar Digital	8	7	6	5	4
Bipolar Memory	1	1	1	1	1
Bipolar Logic	7	6	5	5	4
MOS Digital	37	45	53	55	59
MOS Memory	13	18	21	19	20
MOS Microcomponent	13	14	17	19	20
MOS Logic	11	13	15	17	19
Analog	83	100	116	133	150
Total Discrete	18	19	20	22	23
Total Optoelectronic	5	5	5	6	6

Source: Dataquest (September 1992)

Table 87
Revenue Growth from North American Mobile Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Mobile Communications Equipment	28.9	0.1	5.5
Total Semiconductor	6.9	-1.2	1.9
Total IC			
Bipolar Digital	-33.9	-10.1	-16.4
Bipolar Memory	-53.4	-2.4	2.2
Bipolar Logic	-31.2	-10.8	-18.4
MOS Digital	11.7	-21.3	11.8
MOS Memory	48.6	-42.6	6.1
MOS Microcomponent	4.9	1.0	20.3
MOS Logic	-23.3	1.3	10.2
Analog	22.4	10.8	5.1
Total Discrete	-3.1	4.0	-15.6
Total Optoelectronic	-5.4	-3.0	6.3

Source: Dataquest (September 1992)

Table 88
Revenue Growth from North American Mobile Communications Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Mobile Communications Equipment	9.7	11.0	12.3	10.1	9.3	10.5
Total Semiconductor	18.8	16.7	14.2	9.7	10.0	13.8
Total IC						
Bipolar Digital	2.4	-15.5	-15.2	-13.3	-13.8	-11.3
Bipolar Memory	30.8	-23.7	-35.0	-12.0	1.0	-10.4
Bipolar Logic	-1.3	-14.1	-12.1	-13.5	-15.5	-11.5
MOS Digital	20.9	22.4	17.5	4.0	7.5	14.2
MOS Memory	24.2	32.9	18.9	-10.1	4.9	13.1
MOS Microcomponent	24.4	12.5	16.5	12.9	6.3	14.4
MOS Logic	13.4	20.9	16.6	14.1	11.8	15.3
Analog	21.2	20.1	16.9	14.4	12.9	17.0
Total Discrete	15.5	7.9	6.8	6.3	6.0	8.5
Total Optoelectronic	8.1	2.9	0.2	2.7	1.0	2.9

Source: Dataquest (September 1992)

Table 89
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	4.2	4.2	4.0
Total IC	3.5	3.4	3.4
Bipolar Digital	0.4	0.3	0.3
Bipolar Memory	0	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	1.2	0.9	1.0
MOS Memory	0.6	0.3	0.3
MOS Microcomponent	0.3	0.3	0.3
MOS Logic	0.3	0.3	0.3
Analog	2.0	2.2	2.2
Total Discrete	0.6	0.6	0.5
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 90
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Mobile Communications Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	4.4	4.6	4.7	4.7	4.7
Total IC	3.7	4.0	4.1	4.1	4.1
Bipolar Digital	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.1	0.1	0.1
MOS Digital	1.1	1.2	1.2	1.2	1.1
MOS Memory	0.4	0.5	0.5	0.4	0.4
MOS Microcomponent	0.4	0.4	0.4	0.4	0.4
MOS Logic	0.3	0.3	0.4	0.4	0.4
Analog	2.4	2.6	2.7	2.8	2.9
Total Discrete	0.5	0.5	0.5	0.5	0.4
Total Optoelectronic	0.2	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 91
Revenue from North American Broadcast & Radio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Broadcast & Radio	1,786	1,815	1,923
Total Semiconductor	74	72	70
Total IC	62	59	59
Bipolar Digital	7	6	4
Bipolar Memory	1	1	0
Bipolar Logic	6	5	4
MOS Digital	37	34	36
MOS Memory	19	12	12
MOS Microcomponent	7	9	11
MOS Logic	11	12	13
Analog	18	19	19
Total Discrete	10	11	8
Total Optoelectronic	3	3	3

Source: Dataquest (September 1992)

Table 92
Revenue from North American Broadcast & Radio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Broadcast & Radio	2,038	2,149	2,284	2,418	2,560
Total Semiconductor	78	86	94	95	97
Total IC					
Bipolar Digital	3	3	2	2	2
Bipolar Memory	0	0	0		
Bipolar Logic	3	3	2	2	2
MOS Digital	41	47	53	52	54
MOS Memory	14	18	20	17	17
MOS Microcomponent	13	13	15	16	16
MOS Logic	14	16	18	19	21
Analog	22	25	27	29	31
Total Discrete	9	9	9	9	9
Total Optoelectronic	3	3	2	2	2

Source: Dataquest (September 1992)

Table 93
Revenue Growth from North American Broadcast & Radio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Broadcast & Radio	4.5	1.6	6.0
Total Semiconductor	-3.5	-2.8	-3.5
Total IC			
Bipolar Digital	-39.0	-15.3	-34.9
Bipolar Memory	-53.4	-2.4	-100.0
Bipolar Logic	-35.8	-17.4	-22.5
MOS Digital	4.0	-9.6	5.8
MOS Memory	44.4	-35.6	0.6
MOS Microcomponent	-6.8	26.2	13.6
MOS Logic	-25.1	9.7	4.8
Analog	10.2	10.2	-1.4
Total Discrete	-11.9	8.4	-21.0
Total Optoelectronic	-5.4	-3.0	-1.9

Source: Dataquest (September 1992)

Table 94
Revenue Growth from North American Broadcast & Radio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Broadcast & Radio	6.0	5.4	6.3	5.9	5.9	5.9
Total Semiconductor	11.7	11.2	8.2	1.0	2.5	6.8
Total IC						
Bipolar Digital	-6.3	-18.4	-16.6	-17.9	-19.8	-15.9
Bipolar Memory	-100.0	-100.0	-100.0	NM	NM	-100.0
Bipolar Logic	-6.3	-18.4	-16.6	-17.9	-19.8	-15.9
MOS Digital	14.1	16.2	11.4	-0.9	2.3	8.4
MOS Memory	17.9	26.1	12.8	-14.7	-0.4	7.3
MOS Microcomponent	17.4	6.2	9.9	6.6	0.3	8.0
MOS Logic	7.9	15.0	10.9	8.6	6.4	9.7
Analog	13.8	12.7	9.7	7.4	6.0	9.9
Total Discrete	8.1	1.0	0	-0.4	-0.7	1.6
Total Optoelectronic	-0.3	-5.2	-7.6	-5.3	-6.9	-5.1

NM = Not meaningful
Source: Dataquest (September 1992)

Table 95
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	4.2	4.0	3.6
Total IC	3.5	3.2	3.1
Bipolar Digital	0.4	0.3	0.2
Bipolar Memory	0.1	0	0
Bipolar Logic	0.3	0.3	0.2
MOS Digital	2.1	1.9	1.9
MOS Memory	1.0	0.7	0.6
MOS Microcomponent	0.4	0.5	0.6
MOS Logic	0.6	0.7	0.7
Analog	1.0	1.1	1.0
Total Discrete	0.5	0.6	0.4
Total Optoelectronic	0.2	0.2	0.1

Source: Dataquest (September 1992)

Table 96
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Broadcast & Radio Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	3.8	4.0	4.1	3.9	3.8
Total IC	3.2	3.5	3.6	3.4	3.4
Bipolar Digital	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.1	0.1	0.1	0.1
MOS Digital	2.0	2.2	2.3	2.2	2.1
MOS Memory	0.7	0.8	0.9	0.7	0.7
MOS Microcomponent	0.6	0.6	0.6	0.6	0.6
MOS Logic	0.7	0.7	0.8	0.8	0.8
Analog	1.1	1.1	1.2	1.2	1.2
Total Discrete	0.4	0.4	0.4	0.4	0.4
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 97
Revenue from North American Other Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Total Other Telecom	3,928	4,014	4,190
Total Semiconductor	209	205	211
Total IC	174	172	181
Bipolar Digital	16	15	12
Bipolar Memory	2	2	2
Bipolar Logic	14	13	11
MOS Digital	105	98	108
MOS Memory	51	34	36
MOS Microcomponent	21	26	32
MOS Logic	33	37	40
Analog	53	59	61
Total Discrete	28	29	24
Total Optoelectronic	7	5	5

Source: Dataquest (September 1992)

Table 98
Revenue from North American Other Telecom Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Other Telecom	4,381	4,562	4,735	4,945	4,974
Total Semiconductor	247	287	326	345	371
Total IC					
Bipolar Digital	12	10	8	7	6
Bipolar Memory	2	1	1	1	0
Bipolar Logic	10	9	8	6	5
MOS Digital	129	156	182	189	202
MOS Memory	44	59	69	62	64
MOS Microcomponent	39	44	50	56	60
MOS Logic	45	54	63	71	78
Analog	72	85	98	110	121
Total Discrete	28	30	32	34	36
Total Optoelectronic	5	5	5	6	6

Source: Dataquest (September 1992)

Table 99
Revenue Growth from North American Other Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Other Telecom	0.3	2.2	4.4
Total Semiconductor	-0.6	-1.6	2.5
Total IC			
Bipolar Digital	-37.2	-6.9	-18.7
Bipolar Memory	-37.8	-2.4	-11.0
Bipolar Logic	-37.2	-7.5	-19.7
MOS Digital	3.8	-6.7	10.5
MOS Memory	47.5	-33.3	5.2
MOS Microcomponent	-10.8	28.5	19.4
MOS Logic	-23.7	12.8	9.1
Analog	17.5	12.0	3.0
Total Discrete	-6.3	1.9	-15.5
Total Optoelectronic	-17.2	-30.7	6.3

Source: Dataquest (September 1992)

Table 100
Revenue Growth from North American Other Telecom Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Other Telecom	4.6	4.1	3.8	4.4	0.6	3.5
Total Semiconductor	17.2	16.5	13.4	6.0	7.5	12.0
Total IC						
Bipolar Digital	-0.8	-18.2	-17.3	-15.6	-16.6	-13.9
Bipolar Memory	13.8	-33.5	-43.4	-23.4	-12.0	-22.0
Bipolar Logic	-3.0	-15.5	-13.6	-14.9	-17.0	-12.9
MOS Digital	19.2	21.5	16.4	3.7	7.0	13.3
MOS Memory	23.2	31.8	17.9	-10.8	4.1	12.2
MOS Microcomponent	23.5	11.7	15.6	12.1	5.5	13.5
MOS Logic	12.3	19.7	15.4	13.0	10.7	14.2
Analog	18.8	17.7	14.6	12.1	10.6	14.7
Total Discrete	15.6	8.0	6.9	6.4	6.1	8.5
Total Optoelectronic	8.1	2.9	0.2	2.7	1.0	2.9

Source: Dataquest (September 1992)

Table 101
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	5.3	5.1	5.0
Total IC	4.4	4.3	4.3
Bipolar Digital	0.4	0.4	0.3
Bipolar Memory	0	0	0
Bipolar Logic	0.4	0.3	0.3
MOS Digital	2.7	2.4	2.6
MOS Memory	1.3	0.9	0.9
MOS Microcomponent	0.5	0.7	0.8
MOS Logic	0.8	0.9	1.0
Analog	1.3	1.5	1.5
Total Discrete	0.7	0.7	0.6
Total Optoelectronic	0.2	0.1	0.1

Source: Dataquest (September 1992)

Table 102
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Telecom Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	5.6	6.3	6.9	7.0	7.5
Total IC	4.9	5.5	6.1	6.2	6.6
Bipolar Digital	0.3	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.2	0.1	0.1
MOS Digital	2.9	3.4	3.8	3.8	4.1
MOS Memory	1.0	1.3	1.5	1.2	1.3
MOS Microcomponent	0.9	1.0	1.1	1.1	1.2
MOS Logic	1.0	1.2	1.3	1.4	1.6
Analog	1.7	1.9	2.1	2.2	2.4
Total Discrete	0.6	0.7	0.7	0.7	0.7
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 103
Revenue from North American Security/Energy Management Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Security/Energy Management	3,490	3,691	3,781
Total Semiconductor	131	139	140
Total IC	98	109	116
Bipolar Digital	20	18	14
Bipolar Memory	2	2	1
Bipolar Logic	17	16	13
MOS Digital	38	44	54
MOS Memory	9	6	7
MOS Microcomponent	8	11	15
MOS Logic	20	27	32
Analog	41	47	48
Total Discrete	29	27	20
Total Optoelectronic	4	4	4

Source: Dataquest (September 1992)

Table 104

Revenue from North American Security/Energy Management Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1992-1996

(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Security/Energy Management	3,929	4,144	4,377	4,607	4,849
Total Semiconductor	164	191	220	249	281
Total IC					
Bipolar Digital	14	11	9	8	7
Bipolar Memory	2	1	1	1	1
Bipolar Logic	12	10	9	7	6
MOS Digital	69	89	113	136	161
MOS Memory	8	11	13	11	12
MOS Microcomponent	22	28	36	46	55
MOS Logic	39	51	64	78	94
Analog	56	66	75	84	92
Total Discrete	21	21	20	19	18
Total Optoelectronic	4	4	3	3	3

Source: Dataquest (September 1992)

Table 105
Revenue Growth from North American Security/Energy Management Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Security/Energy Management	4.7	5.8	2.4
Total Semiconductor	-4.3	6.2	0.4
Total IC			
Bipolar Digital	-34.3	-9.4	-20.6
Bipolar Memory	-37.8	-26.8	-17.7
Bipolar Logic	-33.7	-6.9	-20.9
MOS Digital	4.5	18.0	21.5
MOS Memory	57.0	-30.7	5.0
MOS Microcomponent	5.9	33.3	36.1
MOS Logic	-10.2	34.4	19.3
Analog	24.4	13.5	2.3
Total Discrete	-14.8	-7.8	-23.8
Total Optoelectronic	-6.6	-1.2	-0.2

Source: Dataquest (September 1992)

Table 106

Revenue Growth from North American Security/Energy Management Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1992-1996

(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Security/Energy Management	3.9	5.5	5.6	5.3	5.3	5.1
Total Semiconductor	17.3	16.2	15.6	13.2	12.6	15.0
Total IC						
Bipolar Digital	-1.8	-18.4	-17.6	-16.3	-17.1	-14.4
Bipolar Memory	20.6	-29.4	-39.7	-18.1	-5.6	-16.9
Bipolar Logic	-4.4	-16.7	-14.8	-16.1	-18.1	-14.2
MOS Digital	27.8	29.5	26.4	20.4	18.7	24.5
MOS Memory	22.7	31.1	17.1	-11.6	3.0	11.4
MOS Microcomponent	40.7	27.2	31.5	27.4	19.8	29.1
MOS Logic	22.6	30.5	25.7	22.9	20.3	24.4
Analog	18.0	16.9	13.9	11.4	10.0	14.0
Total Discrete	4.1	-2.8	-3.9	-4.4	-4.7	-2.4
Total Optoelectronic	1.5	-3.4	-5.8	-3.5	-5.1	-3.3

Source: Dataquest (September 1992)

Table 107
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	3.8	3.8	3.7
Total IC	2.8	2.9	3.1
Bipolar Digital	0.6	0.5	0.4
Bipolar Memory	0.1	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.1	1.2	1.4
MOS Memory	0.3	0.2	0.2
MOS Microcomponent	0.2	0.3	0.4
MOS Logic	0.6	0.7	0.8
Analog	1.2	1.3	1.3
Total Discrete	0.8	0.7	0.5
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 108
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Security/Energy Management Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	4.2	4.6	5.0	5.4	5.8
Total IC	3.5	4.0	4.5	4.9	5.4
Bipolar Digital	0.4	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1
MOS Digital	1.8	2.2	2.6	2.9	3.3
MOS Memory	0.2	0.3	0.3	0.2	0.2
MOS Microcomponent	0.6	0.7	0.8	1.0	1.1
MOS Logic	1.0	1.2	1.5	1.7	1.9
Analog	1.4	1.6	1.7	1.8	1.9
Total Discrete	0.5	0.5	0.5	0.4	0.4
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 109
Revenue from North American Manufacturing Systems and Instrumentation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Manufacturing Systems and Instrumentation	18,832	19,567	19,244
Total Semiconductor	999	1,021	1,037
Total IC	621	657	725
Bipolar Digital	99	93	74
Bipolar Memory	10	9	7
Bipolar Logic	89	84	67
MOS Digital	345	361	439
MOS Memory	114	82	95
MOS Microcomponent	151	171	215
MOS Logic	81	107	129
Analog	177	203	212
Total Discrete	324	313	258
Total Optoelectronic	53	51	54

Source: Dataquest (September 1992)

Table 110
Revenue from North American Manufacturing Systems and Instrumentation Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Manufacturing Systems and Instrumentation	19,936	21,326	22,898	24,514	26,264
Total Semiconductor	1,244	1,452	1,683	1,862	2,064
Total IC					
Bipolar Digital	73	59	49	41	34
Bipolar Memory	9	6	4	3	3
Bipolar Logic	64	53	45	38	31
MOS Digital	567	723	903	1,030	1,180
MOS Memory	129	187	241	235	267
MOS Microcomponent	279	328	398	467	516
MOS Logic	159	209	264	327	397
Analog	254	303	352	399	448
Total Discrete	291	306	319	331	341
Total Optoelectronic	59	60	60	61	61

Source: Dataquest (September 1992)

Table 111
Revenue Growth from North American Manufacturing Systems and Instrumentation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Manufacturing Systems and Instrumentation	6.5	3.9	-1.7
Total Semiconductor	-1.7	2.2	1.6
Total IC			
Bipolar Digital	-34.9	-5.9	-20.5
Bipolar Memory	-41.5	-8.5	-17.7
Bipolar Logic	-34.0	-5.6	-20.8
MOS Digital	11.3	4.4	21.7
MOS Memory	71.6	-27.8	15.8
MOS Microcomponent	-2.8	13.7	25.6
MOS Logic	-9.1	32.5	20.1
Analog	26.4	14.7	4.2
Total Discrete	-7.9	-3.6	-17.5
Total Optoelectronic	-14.1	-3.0	5.7

Source: Dataquest (September 1992)

Table 112
Revenue Growth from North American Manufacturing Systems and Instrumentation Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Manufacturing Systems and Instrumentation	3.6	7.0	7.4	7.1	7.1	6.4
Total Semiconductor	19.9	16.7	15.9	10.6	10.9	14.8
Total IC						
Bipolar Digital	-1.8	-18.2	-17.4	-16.1	-17.0	-14.3
Bipolar Memory	20.6	-29.4	-39.7	-18.1	-5.6	-16.9
Bipolar Logic	-4.3	-16.6	-14.7	-16.0	-18.0	-14.0
MOS Digital	29.1	27.5	24.9	14.0	14.6	21.9
MOS Memory	35.4	44.6	29.1	-2.5	13.6	22.9
MOS Microcomponent	29.8	17.3	21.3	17.5	10.5	19.1
MOS Logic	23.4	31.4	26.6	23.8	21.1	25.2
Analog	20.3	19.1	16.0	13.6	12.1	16.2
Total Discrete	12.8	5.3	4.2	3.6	3.2	5.8
Total Optoelectronic	7.5	2.3	-0.2	2.2	0.6	2.5

Source: Dataquest (September 1992)

Table 113
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	5.3	5.2	5.4
Total IC	3.3	3.4	3.8
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0.1	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.8	1.8	2.3
MOS Memory	0.6	0.4	0.5
MOS Microcomponent	0.8	0.9	1.1
MOS Logic	0.4	0.5	0.7
Analog	0.9	1.0	1.1
Total Discrete	1.7	1.6	1.3
Total Optoelectronic	0.3	0.3	0.3

Source: Dataquest (September 1992)

Table 114
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Manufacturing Systems and Instrumentation Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	6.2	6.8	7.3	7.6	7.9
Total IC	4.5	5.1	5.7	6.0	6.3
Bipolar Digital	0.4	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1
MOS Digital	2.8	3.4	3.9	4.2	4.5
MOS Memory	0.6	0.9	1.1	1.0	1.0
MOS Microcomponent	1.4	1.5	1.7	1.9	2.0
MOS Logic	0.8	1.0	1.2	1.3	1.5
Analog	1.3	1.4	1.5	1.6	1.7
Total Discrete	1.5	1.4	1.4	1.3	1.3
Total Optoelectronic	0.3	0.3	0.3	0.2	0.2

Source: Dataquest (September 1992)

Table 115
Revenue from North American Medical Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Medical Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Medical Equipment	6,355	6,680	7,182
Total Semiconductor	277	287	284
Total IC	201	213	220
Bipolar Digital	34	33	26
Bipolar Memory	3	4	3
Bipolar Logic	31	29	23
MOS Digital	84	86	98
MOS Memory	32	21	23
MOS Microcomponent	10	13	19
MOS Logic	42	51	56
Analog	83	94	96
Total Discrete	69	67	56
Total Optoelectronic	7	7	8

Source: Dataquest (September 1992)

Table 116
Revenue from North American Medical Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Medical Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Medical Equipment	7,653	8,220	8,791	9,444	10,160
Total Semiconductor	331	382	434	476	524
Total IC					
Bipolar Digital	26	21	17	14	12
Bipolar Memory	4	3	2	1	1
Bipolar Logic	22	18	16	13	11
MOS Digital	120	151	185	208	238
MOS Memory	29	39	47	43	45
MOS Microcomponent	28	37	51	68	86
MOS Logic	63	75	87	98	108
Analog	114	133	151	169	186
Total Discrete	64	68	72	76	79
Total Optoelectronic	8	9	9	9	9

Source: Dataquest (September 1992)

Table 117
Revenue Growth from North American Medical Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Medical Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Medical Equipment	6.2	5.1	7.5
Total Semiconductor	-0.5	3.4	-1.0
Total IC			
Bipolar Digital	-34.7	-3.1	-20.6
Bipolar Memory	-44.7	9.8	-17.7
Bipolar Logic	-33.4	-4.5	-21.0
MOS Digital	5.8	1.5	14.1
MOS Memory	60.2	-33.0	7.9
MOS Microcomponent	15.1	27.3	42.7
MOS Logic	-17.0	21.0	9.3
Analog	27.8	13.4	2.3
Total Discrete	-6.1	-2.6	-16.3
Total Optoelectronic	-16.9	-1.2	5.7

Source: Dataquest (September 1992)

Table 118
Revenue Growth from North American Medical Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Medical Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Medical Equipment	6.6	7.4	6.9	7.4	7.6	7.2
Total Semiconductor	16.7	15.3	13.6	9.7	10.1	13.0
Total IC						
Bipolar Digital	-1.6	-18.5	-17.9	-16.3	-17.0	-14.5
Bipolar Memory	20.6	-29.4	-39.7	-18.1	-5.6	-16.9
Bipolar Logic	-4.5	-16.8	-14.9	-16.2	-18.1	-14.2
MOS Digital	22.3	26.5	22.1	12.9	14.4	19.5
MOS Memory	26.2	34.7	20.3	-9.1	5.9	14.5
MOS Microcomponent	47.5	33.3	37.9	33.6	25.6	35.4
MOS Logic	12.3	19.6	15.2	12.6	10.2	14.0
Analog	18.0	16.9	13.9	11.5	10.0	14.0
Total Discrete	14.4	6.8	5.6	5.1	4.7	7.2
Total Optoelectronic	7.5	2.3	-0.2	2.2	0.6	2.5

Source: Dataquest (September 1992)

Table 119
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Medical Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	4.4	4.3	4.0
Total IC	3.2	3.2	3.1
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.3	1.3	1.4
MOS Memory	0.5	0.3	0.3
MOS Microcomponent	0.2	0.2	0.3
MOS Logic	0.7	0.8	0.8
Analog	1.3	1.4	1.3
Total Discrete	1.1	1.0	0.8
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 120
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Medical Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	4.3	4.6	4.9	5.0	5.2
Total IC	3.4	3.7	4.0	4.1	4.3
Bipolar Digital	0.3	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.1	0.1
MOS Digital	1.6	1.8	2.1	2.2	2.3
MOS Memory	0.4	0.5	0.5	0.5	0.4
MOS Microcomponent	0.4	0.4	0.6	0.7	0.8
MOS Logic	0.8	0.9	1.0	1.0	1.1
Analog	1.5	1.6	1.7	1.8	1.8
Total Discrete	0.8	0.8	0.8	0.8	0.8
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 121
Revenue from North American Other Industrial Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
Other Industrial Systems	3,625	3,749	3,702
Total Semiconductor	257	275	276
Total IC	170	188	198
Bipolar Digital	19	18	14
Bipolar Memory	2	2	1
Bipolar Logic	17	16	13
MOS Digital	57	63	72
MOS Memory	16	10	10
MOS Microcomponent	10	14	17
MOS Logic	31	39	44
Analog	94	107	112
Total Discrete	77	79	70
Total Optoelectronic	9	8	9

Source: Dataquest (September 1992)

Table 122
Revenue from North American Other Industrial Systems Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Other Industrial Systems	3,964	4,269	4,481	4,830	5,206
Total Semiconductor	328	382	437	488	541
Total IC					
Bipolar Digital	14	11	9	8	7
Bipolar Memory	2	1	1	1	1
Bipolar Logic	12	10	9	7	6
MOS Digital	86	105	124	140	156
MOS Memory	12	15	17	15	15
MOS Microcomponent	21	24	29	32	35
MOS Logic	52	65	78	92	106
Analog	135	161	188	214	241
Total Discrete	84	94	104	115	127
Total Optoelectronic	10	10	10	11	11

Source: Dataquest (September 1992)

Table 123
Revenue Growth from North American Other Industrial Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Other Industrial Systems	7.1	3.4	-1.3
Total Semiconductor	2.7	7.3	0.4
Total IC			
Bipolar Digital	-34.8	-5.4	-20.6
Bipolar Memory	-44.7	9.8	-17.7
Bipolar Logic	-33.7	-6.9	-20.9
MOS Digital	-1.1	10.3	13.7
MOS Memory	45.6	-35.9	1.2
MOS Microcomponent	-13.7	36.3	21.4
MOS Logic	-11.3	25.3	14.2
Analog	26.8	13.8	4.6
Total Discrete	-1.0	2.5	-12.0
Total Optoelectronic	-15.0	-11.1	8.0

Source: Dataquest (September 1992)

Table 124
Revenue Growth from North American Other Industrial Systems Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Other Industrial Systems	7.1	7.7	5.0	7.8	7.8	7.1
Total Semiconductor	18.8	16.4	14.3	11.8	11.0	14.4
Total IC						
Bipolar Digital	-1.8	-18.4	-17.6	-16.3	-17.1	-14.4
Bipolar Memory	20.6	-29.4	-39.7	-18.1	-5.6	-16.9
Bipolar Logic	-4.4	-16.7	-14.8	-16.1	-18.1	-14.2
MOS Digital	19.4	22.3	18.5	12.2	11.5	16.7
MOS Memory	18.3	26.4	12.8	-14.8	-0.7	7.4
MOS Microcomponent	25.4	13.4	17.3	13.6	6.8	15.1
MOS Logic	17.4	25.0	20.3	17.7	15.2	19.1
Analog	20.7	19.6	16.5	14.0	12.5	16.6
Total Discrete	20.3	12.3	11.1	10.5	10.1	12.8
Total Optoelectronic	9.8	4.5	1.9	4.4	2.7	4.6

Source: Dataquest (September 1992)

Table 125
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	7.1	7.3	7.5
Total IC	4.7	5.0	5.3
Bipolar Digital	0.5	0.5	0.4
Bipolar Memory	0	0	0
Bipolar Logic	0.5	0.4	0.3
MOS Digital	1.6	1.7	1.9
MOS Memory	0.4	0.3	0.3
MOS Microcomponent	0.3	0.4	0.5
MOS Logic	0.9	1.0	1.2
Analog	2.6	2.8	3.0
Total Discrete	2.1	2.1	1.9
Total Optoelectronic	0.3	0.2	0.2

Source: Dataquest (September 1992)

Table 126
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Industrial Systems Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	8.3	8.9	9.7	10.1	10.4
Total IC	5.9	6.5	7.2	7.5	7.7
Bipolar Digital	0.4	0.3	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.1	0.1
MOS Digital	2.2	2.5	2.8	2.9	3.0
MOS Memory	0.3	0.4	0.4	0.3	0.3
MOS Microcomponent	0.5	0.6	0.6	0.7	0.7
MOS Logic	1.3	1.5	1.8	1.9	2.0
Analog	3.4	3.8	4.2	4.4	4.6
Total Discrete	2.1	2.2	2.3	2.4	2.4
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 127
Revenue from North American Audio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Audio	698	707	671
Total Semiconductor	42	44	44
Total IC	31	33	35
Bipolar Digital	0	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0	0	0
MOS Digital	9	9	11
MOS Memory	3	3	3
MOS Microcomponent	6	6	7
MOS Logic	1	1	1
Analog	22	23	24
Total Discrete	11	11	9
Total Optoelectronic	1	1	1

Source: Dataquest (September 1992)

Table 128

Revenue from North American Audio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Audio	690	725	756	786	818
Total Semiconductor	52	60	67	73	78
Total IC					
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	13	15	17	18	19
MOS Memory	3	4	4	3	3
MOS Microcomponent	8	10	11	13	13
MOS Logic	1	2	2	2	2
Analog	28	33	38	42	46
Total Discrete	10	11	11	12	12
Total Optoelectronic	1	1	1	1	1

Source: Dataquest (September 1992)

Table 129
Revenue Growth from North American Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Audio	-0.7	1.3	-5.1
Total Semiconductor	-1.0	4.2	0.1
Total IC			
Bipolar Digital	NM	NM	NM
Bipolar Memory	NM	NM	NM
Bipolar Logic	NM	NM	NM
MOS Digital	-5.7	0.4	12.7
MOS Memory	40.7	-2.2	-1.9
MOS Microcomponent	-6.3	1.6	19.9
MOS Logic	-51.0	0.6	12.5
Analog	13.6	8.6	2.3
Total Discrete	-11.5	-1.0	-16.8
Total Optoelectronic	-5.6	-1.5	6.7

NM = Not meaningful
Source: Dataquest (September 1992)

Table 130
Revenue Growth from North American Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Audio	2.8	5.1	4.3	4.0	4.1	4.0
Total Semiconductor	17.7	14.4	12.4	8.8	7.8	12.1
Total IC						
Bipolar Digital	NM	NM	NM	NM	NM	NM
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	NM	NM	NM	NM	NM	NM
MOS Digital	20.9	16.0	15.0	6.0	5.4	12.5
MOS Memory	15.0	22.9	9.9	-17.0	-3.1	4.5
MOS Microcomponent	24.1	12.3	16.4	12.9	6.3	14.2
MOS Logic	15.7	23.3	18.9	16.4	14.0	17.6
Analog	18.0	16.9	13.8	11.4	9.9	13.9
Total Discrete	13.9	6.4	5.3	4.9	4.6	7.0
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

NM = Not meaningful
Source: Dataquest (September 1992)

Table 131
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	6.1	6.3	6.6
Total IC	4.4	4.6	5.2
Bipolar Digital	0	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0	0	0
MOS Digital	1.3	1.3	1.6
MOS Memory	0.4	0.4	0.4
MOS Microcomponent	0.8	0.8	1.0
MOS Logic	0.1	0.1	0.2
Analog	3.1	3.3	3.6
Total Discrete	1.5	1.5	1.3
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 132
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	7.5	8.2	8.8	9.3	9.6
Total IC	6.0	6.6	7.2	7.6	8.0
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	1.9	2.1	2.3	2.3	2.3
MOS Memory	0.4	0.5	0.6	0.4	0.4
MOS Microcomponent	1.2	1.3	1.5	1.6	1.6
MOS Logic	0.2	0.2	0.2	0.3	0.3
Analog	4.1	4.5	5.0	5.3	5.6
Total Discrete	1.4	1.5	1.5	1.5	1.5
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 133
Revenue from North American Audio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Video	3,406	3,376	3,382
Total Semiconductor	257	259	258
Total IC	188	192	201
Bipolar Digital	3	2	1
Bipolar Memory	1	1	1
Bipolar Logic	2	1	1
MOS Digital	69	68	75
MOS Memory	33	28	28
MOS Microcomponent	26	30	35
MOS Logic	10	11	12
Analog	117	123	125
Total Discrete	65	62	52
Total Optoelectronic	4	4	5

Source: Dataquest (September 1992)

Table 134
Revenue from North American Audio Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Video	3,465	3,627	3,796	3,973	4,158
Total Semiconductor	303	347	389	415	445
Total IC					
Bipolar Digital	2	1	0	0	
Bipolar Memory	1	0	0		
Bipolar Logic	1	1	0	0	
MOS Digital	90	107	123	125	131
MOS Memory	34	45	52	45	46
MOS Microcomponent	42	47	54	60	62
MOS Logic	13	16	18	20	23
Analog	147	171	194	215	236
Total Discrete	59	63	66	69	73
Total Optoelectronic	5	5	5	5	6

Source: Dataquest (September 1992)

Table 135
Revenue Growth from North American Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Video	18.9	-0.9	0.2
Total Semiconductor	19.3	0.8	-0.4
Total IC			
Bipolar Digital	-35.9	-27.7	-19.8
Bipolar Memory	-17.1	9.8	-15.8
Bipolar Logic	-42.2	-45.5	-23.7
MOS Digital	16.8	-1.4	10.6
MOS Memory	36.8	-16.1	3.3
MOS Microcomponent	9.3	12.5	17.9
MOS Logic	-10.9	10.7	9.2
Analog	34.2	5.4	1.9
Total Discrete	6.0	-4.0	-16.7
Total Optoelectronic	-5.6	-1.5	6.7

Source: Dataquest (September 1992)

Table 136
Revenue Growth from North American Audio Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Video	2.5	4.7	4.7	4.7	4.7	4.2
Total Semiconductor	17.4	14.7	12.1	6.8	7.1	11.5
Total IC						
Bipolar Digital	8.0	-59.1	NM	NM	NM	-100.0
Bipolar Memory	23.5	NM	NM	NM	NM	-100.0
Bipolar Logic	-8.5	-0.5	NM	NM	NM	-100.0
MOS Digital	20.2	19.1	15.1	1.4	4.7	11.8
MOS Memory	21.1	29.5	15.8	-12.5	2.2	10.2
MOS Microcomponent	22.0	10.5	14.4	11.0	4.6	12.3
MOS Logic	12.4	19.8	15.5	13.0	10.7	14.2
Analog	17.5	16.4	13.4	11.0	9.5	13.5
Total Discrete	13.9	6.4	5.4	4.9	4.6	7.0
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

NM = Not meaningful
Source: Dataquest (September 1992)

Table 137
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Audio Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	7.5	7.7	7.6
Total IC	5.5	5.7	6.0
Bipolar Digital	0.1	0.1	0
Bipolar Memory	0	0	0
Bipolar Logic	0.1	0	0
MOS Digital	2.0	2.0	2.2
MOS Memory	1.0	0.8	0.8
MOS Microcomponent	0.8	0.9	1.0
MOS Logic	0.3	0.3	0.3
Analog	3.4	3.6	3.7
Total Discrete	1.9	1.8	1.5
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 138
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Audio Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	8.7	9.6	10.2	10.5	10.7
Total IC	6.9	7.7	8.4	8.6	8.8
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.6	3.0	3.3	3.2	3.2
MOS Memory	1.0	1.2	1.4	1.1	1.1
MOS Microcomponent	1.2	1.3	1.4	1.5	1.5
MOS Logic	0.4	0.4	0.5	0.5	0.5
Analog	4.2	4.7	5.1	5.4	5.7
Total Discrete	1.7	1.7	1.7	1.7	1.7
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 139
Revenue from North American Personal Electronics Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Personal Electronics	479	481	489
Total Semiconductor	26	27	27
Total IC	20.	21	23
Bipolar Digital	1	0	0
Bipolar Memory	0	0	0
Bipolar Logic	1	0	0
MOS Digital	7	8	9
MOS Memory	2	2	2
MOS Microcomponent	4	5	6
MOS Logic	1	1	1
Analog	13	14	14
Total Discrete	5	5	4
Total Optoelectronic	1	1	1

Source: Dataquest (September 1992)

Table 140
Revenue from North American Personal Electronics Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Personal Electronics	494	503	511	520	530
Total Semiconductor	32	37	42	46	50
Total IC					
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	10	12	14	15	16
MOS Memory	2	3	3	3	3
MOS Microcomponent	7	7	9	9	10
MOS Logic	1	2	3	3	4
Analog	17	20	23	25	28
Total Discrete	4	4	4	5	5
Total Optoelectronic	1	1	1	1	1

Source: Dataquest (September 1992)

Table 141

Revenue Growth from North American Personal Electronics Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1989-1991

(Percent Change)

	1989	1990	1991
Total Personal Electronics	18.3	0.4	1.7
Total Semiconductor	8.4	3.7	2.2
Total IC			
Bipolar Digital	-13.3	NM	NM
Bipolar Memory	NM	NM	NM
Bipolar Logic	-13.3	NM	NM
MOS Digital	-17.3	14.9	13.8
MOS Memory	-6.2	-2.2	0.4
MOS Microcomponent	-6.3	27.1	17.4
MOS Logic	-51.0	0.6	22.0
Analog	27.6	7.2	3.1
Total Discrete	20.6	-1.0	-19.5
Total Optoelectronic	-5.6	-1.5	6.7

NM = Not meaningful

Source: Dataquest (September 1992)

Table 142
Revenue Growth from North American Personal Electronics Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Personal Electronics	1.0	1.8	1.6	1.8	1.9	1.6
Total Semiconductor	17.5	15.0	13.3	10.1	8.5	12.8
Total IC						
Bipolar Digital	NM	NM	NM	NM	NM	NM
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	NM	NM	NM	NM	NM	NM
MOS Digital	19.3	16.5	16.1	9.7	7.4	13.7
MOS Memory	8.5	25.8	12.5	-7.8	-0.8	7.0
MOS Microcomponent	21.5	10.0	13.9	10.5	4.1	11.9
MOS Logic	25.5	33.8	28.9	26.2	23.6	27.5
Analog	19.0	17.9	14.8	12.3	10.8	14.9
Total Discrete	10.1	2.9	1.9	1.4	1.2	3.4
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

NM = Not meaningful
Source: Dataquest (September 1992)

Table 143
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	5.4	5.6	5.6
Total IC	4.2	4.4	4.6
Bipolar Digital	0.2	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0.2	0	0
MOS Digital	1.4	1.6	1.8
MOS Memory	0.4	0.4	0.4
MOS Microcomponent	0.8	1.0	1.1
MOS Logic	0.2	0.2	0.2
Analog	2.7	2.8	2.9
Total Discrete	1.0	1.0	0.8
Total Optoelectronic	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 144
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Personal Electronics Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	6.5	7.4	8.2	8.9	9.5
Total IC	5.5	6.3	7.2	7.8	8.4
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.1	2.4	2.7	2.9	3.1
MOS Memory	0.4	0.5	0.6	0.5	0.5
MOS Microcomponent	1.4	1.5	1.7	1.8	1.8
MOS Logic	0.3	0.4	0.5	0.6	0.8
Analog	3.4	3.9	4.4	4.9	5.3
Total Discrete	0.9	0.9	0.9	0.9	0.9
Total Optoelectronic	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (September 1992)

Table 145
Revenue from North American Appliances Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Appliances Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Appliances	11,431	11,358	11,033
Total Semiconductor	732	730	751
Total IC	581	585	626
Bipolar Digital	5	5	3
Bipolar Memory	0	0	0
Bipolar Logic	5	5	3
MOS Digital	229	215	241
MOS Memory	121	94	98
MOS Microcomponent	81	90	109
MOS Logic	28	31	34
Analog	347	366	382
Total Discrete	143	139	118
Total Optoelectronic	8	6	7

Source: Dataquest (September 1992)

Table 146
Revenue from North American Appliances Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Appliances Applications, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Appliances	11,529	12,163	12,832	13,539	14,214
Total Semiconductor	902	1,067	1,229	1,340	1,469
Total IC					
Bipolar Digital	2	2	2	1	1
Bipolar Memory	0	0	0	0	0
Bipolar Logic	2	2	2	1	1
MOS Digital	294	356	416	426	451
MOS Memory	120	157	184	163	168
MOS Microcomponent	135	152	177	201	214
MOS Logic	39	47	55	62	70
Analog	461	552	642	731	822
Total Discrete	138	150	162	174	186
Total Optoelectronic	7	7	7	8	8

Source: Dataquest (September 1992)

Table 147
Revenue Growth from North American Appliances Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Appliances Applications, 1989-1991
(Percent Change)

	1989	1990	1991
Total Appliances	9.1	-0.6	-2.9
Total Semiconductor	11.4	-0.3	2.8
Total IC			
Bipolar Digital	-48.0	-9.2	-36.5
Bipolar Memory	NM	NM	NM
Bipolar Logic	-48.0	-9.2	-36.5
MOS Digital	10.1	-6.3	11.9
MOS Memory	28.7	-22.6	4.5
MOS Microcomponent	0.7	12.3	20.1
MOS Logic	-18.8	11.0	10.3
Analog	21.9	5.5	4.6
Total Discrete	-2.2	-3.1	-14.8
Total Optoelectronic	-5.6	-23.4	6.7

NM = Not meaningful

Source: Dataquest (September 1992)

Table 148
Revenue Growth from North American Appliances Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Appliances Applications, 1992-1996
(Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Appliances	4.5	5.5	5.5	5.5	5.0	5.2
Total Semiconductor	20.2	18.2	15.2	9.0	9.6	14.4
Total IC						
Bipolar Digital	-23.8	-17.2	-2.6	-28.8	-30.4	-21.2
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	-23.8	-17.2	-2.6	-28.8	-30.4	-21.2
MOS Digital	22.0	21.2	16.8	2.4	6.1	13.4
MOS Memory	22.5	30.9	17.1	-11.5	3.3	11.4
MOS Microcomponent	24.3	12.6	16.6	13.1	6.6	14.5
MOS Logic	13.5	20.9	16.6	14.1	11.7	15.3
Analog	20.7	19.5	16.4	13.9	12.4	16.5
Total Discrete	16.6	9.0	7.9	7.4	7.1	9.5
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

NM = Not meaningful
Source: Dataquest (September 1992)

Table 149
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Appliances Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	6.4	6.4	6.8
Total IC	5.1	5.2	5.7
Bipolar Digital	0	0	0
Bipolar Memory	0	0	0
Bipolar Logic	0	0	0
MOS Digital	2.0	1.9	2.2
MOS Memory	1.1	0.8	0.9
MOS Microcomponent	0.7	0.8	1.0
MOS Logic	0.2	0.3	0.3
Analog	3.0	3.2	3.5
Total Discrete	1.3	1.2	1.1
Total Optoelectronic	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 150
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Appliances Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	7.8	8.8	9.6	9.9	10.3
Total IC	6.6	7.5	8.3	8.6	9.0
Bipolar Digital	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
MOS Digital	2.5	2.9	3.2	3.1	3.2
MOS Memory	1.0	1.3	1.4	1.2	1.2
MOS Microcomponent	1.2	1.2	1.4	1.5	1.5
MOS Logic	0.3	0.4	0.4	0.5	0.5
Analog	4.0	4.5	5.0	5.4	5.8
Total Discrete	1.2	1.2	1.3	1.3	1.3
Total Optoelectronic	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (September 1992)

Table 151
Revenue from North American Other Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Consumer Applications, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Total Other Consumer	1,068	1,073	1,085
Total Semiconductor	95	92	94
Total IC	71	67	72
Bipolar Digital	3	2	1
Bipolar Memory	2	1	1
Bipolar Logic	1	1	1
MOS Digital	31	26	30
MOS Memory	19	12	13
MOS Microcomponent	9	10	13
MOS Logic	3	4	4
Analog	37	39	41
Total Discrete	22	22	19
Total Optoelectronic	2	3	3

Source: Dataquest (September 1992)

Table 152
Revenue from North American Other Consumer Equipment Production, and Revenue from All Semiconductors Shipped to North America for Use in Other Consumer, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Total Other Consumer	1,134	1,198	1,266	1,337	1,407
Total Semiconductor	113	134	154	168	185
Total IC					
Bipolar Digital	2	1	1	1	1
Bipolar Memory	1	1	1	1	1
Bipolar Logic	1	0	0	0	0
MOS Digital	38	47	57	59	64
MOS Memory	16	22	27	24	26
MOS Microcomponent	16	18	22	25	27
MOS Logic	5	7	8	10	11
Analog	49	59	69	78	88
Total Discrete	22	24	25	27	29
Total Optoelectronic	3	3	3	3	3

Source: Dataquest (September 1992)

Table 153
Revenue Growth from North American Other Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Consumer Applications, 1989-1991 (Percent Change)

	1989	1990	1991
Total Other Consumer	6.7	0.5	1.1
Total Semiconductor	9.3	-3.2	2.3
Total IC			
Bipolar Digital	26.2	-26.5	-19.8
Bipolar Memory	65.8	-45.1	-15.8
Bipolar Logic	-13.3	8.9	-23.7
MOS Digital	19.6	-15.3	14.6
MOS Memory	44.3	-36.4	7.9
MOS Microcomponent	4.1	11.8	22.0
MOS Logic	-26.5	34.1	15.1
Analog	13.0	4.8	4.6
Total Discrete	-3.5	-1.0	-15.1
Total Optoelectronic	-37.1	47.7	6.7

Source: Dataquest (September 1992)

Table 154
Revenue Growth from North American Other Consumer Equipment Production, and Revenue Growth from All Semiconductors Shipped to North America for Use in Other Consumer Applications, 1992-1996 (Percent Change)

	1992	1993	1994	1995	1996	CAGR 1991-1996
Total Other Consumer	4.5	5.6	5.7	5.6	5.2	5.3
Total Semiconductor	20.7	18.3	15.2	8.9	10.0	14.5
Total IC						
Bipolar Digital	8.0	-14.9	-38.3	-16.2	-3.4	-14.4
Bipolar Memory	23.5	44.6	-38.3	-16.2	-3.4	-2.2
Bipolar Logic	-8.5	NM	NM	NM	NM	-100.0
MOS Digital	25.2	25.0	20.1	4.4	9.0	16.4
MOS Memory	26.5	35.2	20.9	-8.6	6.7	15.1
MOS Microcomponent	26.2	14.3	18.4	14.9	8.2	16.3
MOS Logic	18.5	26.3	21.7	19.1	16.7	20.4
Analog	20.7	19.6	16.4	14.0	12.5	16.6
Total Discrete	16.2	8.5	7.4	7.0	6.7	9.1
Total Optoelectronic	8.5	3.3	0.7	3.3	1.6	3.5

NM = Not meaningful
Source: Dataquest (September 1992)

Table 155
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Consumer Applications, 1989-1991
(Percent)

	1989	1990	1991
Total Semiconductor	8.9	8.5	8.7
Total IC	6.6	6.3	6.7
Bipolar Digital	0.2	0.2	0.1
Bipolar Memory	0.2	0.1	0.1
Bipolar Logic	0.1	0.1	0.1
MOS Digital	2.9	2.4	2.8
MOS Memory	1.8	1.1	1.2
MOS Microcomponent	0.9	1.0	1.2
MOS Logic	0.3	0.4	0.4
Analog	3.5	3.6	3.8
Total Discrete	2.1	2.0	1.7
Total Optoelectronic	0.2	0.2	0.3

Source: Dataquest (September 1992)

Table 156
Input/Output Ratios of All Semiconductors Shipped to North America for Use in Other Consumer Applications, 1992-1996
(Percent)

	1992	1993	1994	1995	1996
Total Semiconductor	10.0	11.2	12.2	12.6	13.2
Total IC	7.8	9.0	10.0	10.3	10.9
Bipolar Digital	0.1	0.1	0.1	0.1	0
Bipolar Memory	0.1	0.1	0.1	0.1	0
Bipolar Logic	0.1	0	0	0	0
MOS Digital	3.3	3.9	4.5	4.4	4.6
MOS Memory	1.4	1.8	2.1	1.8	1.8
MOS Microcomponent	1.4	1.5	1.7	1.9	1.9
MOS Logic	0.5	0.6	0.6	0.7	0.8
Analog	4.3	4.9	5.4	5.8	6.2
Total Discrete	1.9	2.0	2.0	2.0	2.0
Total Optoelectronic	0.3	0.3	0.3	0.2	0.2

Source: Dataquest (September 1992)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Incorporated Invitational
Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 49-89-930-9090
Facsimile: 49-89-930-3277

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo, 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

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Worldwide and North American Electronic Equipment Production Forecast

August 17, 1992

Source: Dataquest

Market Statistics

Dataquest

Semiconductor Application Markets *Worldwide*

SAWW-SVC-MS-9201

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Market Statistics

File behind the ***Market Statistics*** tab inside the binder labeled **Semiconductor Application Markets** ***Worldwide***

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Worldwide and North American Electronic Equipment Production Forecast

Table of Contents

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:

- 1989-1991 historical data
- 1992-1996 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 systems 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 3 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 semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for market comparisons. In the forecast period, Dataquest assumes that the most recent actual month's exchange rate will apply throughout all months of the forecast. For example, the current semiconductor forecast uses actual exchange rates through June 1992, and assumes that the June rate applies throughout all future months. Then the quarterly and annual exchange rates are estimated as described in the previous paragraph.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* 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 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 *Dataquest Research and Forecast Methodology* document located in the Source: Dataquest binder. For a complete listing of all market segments tracked by Dataquest, please refer to the *Dataquest High-Technology Guide: Segmentation and Glossary*.

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
  - Terminals
  - Input/Output Devices
  - Dedicated Systems
- Communications
  - Premise Telecom
  - Public Telecom
  - Mobile Communication
  - Broadcast and Studio Equipment
  - Other Communication
- 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. 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.*

Electronic systems groups are comprised of the following specific electronic equipment types.

Computer Systems: Includes supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers), workstations, and personal computers (including portable computers).

Data Storage: Includes rigid disk drives, flexible disk drives, optical disk drives, and tape drives.

Terminals: Includes alphanumeric terminals and graphics terminals (for example, X terminals)

Input/Output Devices: Includes printers, media-to-media data conversion, magnetic ink character recognition, optical scanning equipment, plotters, voice recognition/synthesizer equipment, mouse, keyboard, and digitizers.

Dedicated Systems: Includes electronic copiers, electronic calculators, smart 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.

Premise Telecom Equipment: Includes image and text communication, such as facsimile and video teleconferencing; data communications equipment such as modems, statistical multiplexers, T-1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area networks, internetworking, network management, and packet data switching/wide area networks; premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging, interactive voice response systems, call accounting, and automatic call distributors; and desktop terminal equipment, such as telephone sets/pay 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, mobile radios, and mobile radio base station equipment; portable radio receivers and transmitters, and radio checkout equipment.

Broadcast and Radio 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 theater equipment.

Other Telecom Equipment: Includes intercom equipment and electrical amplifiers, and communications equipment not elsewhere classified.

Security/Energy Management: Includes alarm systems, such as intrusion detection and fire detection systems, and energy management systems.

Manufacturing Systems and Instrumentation: Includes semiconductor production equipment, controllers and actuators, sensor systems, management systems, and robotics; and semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and waveform analyzers, nuclear instruments, and other test and measurement equipment.

Medical Equipment: Includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analyzers, patient monitoring equipment, and other diagnostic and therapeutic equipment.

Other Industrial Equipment: Includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

(Consumer) Audio Equipment: Includes compact disk players, radios, stereo components, musical instruments, and tape recorders.

(Consumer) Video Equipment: Includes VCRs and VTRs, video cameras and camcorders, videodisk players, and color and monochrome TVs.

Personal Electronics: Includes electronic games and toys, 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: Includes military electronics, such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, computer systems, simulation systems, and military electronics not elsewhere classified; and civilian aerospace electronics, such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

Transportation Electronics: Includes entertainment systems, vehicle controls, body controls, driver information systems, powertrain systems, and safety and convenience systems.

Regional Definitions

North America: Includes United States and Canada (and, in future documents, Mexico)

United States: Includes 48 contiguous states, Washington, D.C., Alaska, Hawaii, and Puerto Rico

Canada: Canada

Europe: Western Europe includes Benelux (Belgium, Netherlands, and Luxembourg), France, Italy, Scandinavia (Denmark, Finland, Norway, Sweden, and Iceland), United Kingdom and Eire (England, Wales, Scotland, Northern Ireland, and Ireland), Germany (including former East Germany), and Rest of Europe (Austria, Gibraltar, Greece, Liechtenstein, Malta, Monaco, Portugal, San Marino, Spain, Switzerland, Turkey, Andorra, and Vatican City)

Japan: Japan

Asia/Pacific: Includes East Asia (People's Republic of China, Hong Kong, Macau, North and South Korea, and Republic of China), South Asia (Bangladesh, Myanmar, India, Nepal, Maldives, Pakistan, Sri Lanka, and Bhutan), Southeast Asia (Brunei, Timor, Indonesia, Kampuchea, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Borneo, Sumatra, Sulawesi, and Java)

Rest of World: All other countries

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 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 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 association data
- 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 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 and Forecast Methodology Guide.*

Dataquest follows a three-step process to forecast electronic equipment production. First, current and expected future worldwide macroeconomic conditions are assessed and forecast. 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 are in general comprised of 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 judgments, expert opinions, and subjective probabilities) or technological models (that is, curve fitting and the use of analogous data).

Forecast Assumptions

The worldwide economy is expected to show mixed results in 1992. The Dun & Bradstreet Corporation forecast the following outlook for the Group of Seven (G7) Countries:

- The U.S., Canadian, and U.K. economies are expected to recover from the recession in 1992. Real gross domestic product (GDP) is expected to expand 2.1, 1.6, and 0.5 percent, respectively, in 1992. (These economies contracted at rates of 0.7, 1.5, and 2.4 percent, respectively, in 1991.) Though modest in comparison to historical rates of expansion during recovery periods, the benefit is that inflationary pressures will likely be held in check, sustaining the expansion's duration. Expansion should accelerate to 2.5, 4.0, and 2.2 percent, respectively, in 1993.
- Real GDP growth is expected to accelerate in France and Italy during 1991, from 0.9 percent in 1991 to 2.1 percent and from 1.4 percent in 1991 to 1.5 percent, respectively. The pace of growth should pick up in 1993 to 2.7 and 2.2 percent, respectively.
- Real GDP growth is expected to decelerate in Germany and Japan during 1992, from 3.2 percent in 1991 to 1.1 percent and from 4.4 percent in 1991 to 2.0 percent, respectively. Moderating these countries' short-term growth prospects are the cost burden of Germany's reunification and the rise in Japan's cost of capital and recent bout of asset deflation. The respective economies are expected to reaccelerate to 2.8 percent and 3.3 percent growth in 1993.

Overall, worldwide electronic systems production is expected to expand 3.1 percent in 1992, slightly faster than the 2.4 percent rate of growth in 1991. Expansion is expected to accelerate further in 1993 to 7.6 percent as the worldwide economic climate improves. In 1992, however, the value of worldwide production will be constrained by two important influences:

- A moderate—in contrast to booming—rate of recovery from recession
- An abundance of productive capacity, combined with further proliferation of product and technology standards, both placing pressure on costs and prices

From a semiconductor application-market perspective, the forecast carries assumptions detailed in the following paragraphs.

Data processing production will begin to make a moderate 2.6 percent recovery in 1992, after a depressing 2.2 percent decline in 1991. In North America, recovery will continue into 1993 as economic conditions continue to improve and stabilize. Japanese production will remain hemmed in for the remainder of 1992, as business and households adjust downward their spending plans in response to the lackluster business climate. The year 1993 and beyond should, however, find Japan back on the path of normal growth. Local content regulations are spurring the placement of production facilities in Europe, helping explain the boost of growth in 1993. Once facilities are in place, though, growth is expected to assume a more sustainable pace. Asia/Pacific-ROW production prospects remain upbeat as it increasingly becomes the region of choice for mass manufacturing of established technologies.

Communications production growth—the most stable-growing of the application markets, owing to its heterogeneous composition of personal wireless communications, premise voice, and data products, and large-scale, long-life investment in public telecommunications infrastructure—will decelerate slightly in 1992 to 6.1 percent from 7.3 percent in 1991. Investment in networking the existing stock of data processing equipment will help drive communications hardware growth through 1996.

As is usually the case, production of industrial and consumer equipment have borne the brunt of the recent downturn in business conditions, especially in North America and Japan. Europe and A/P-ROW have been somewhat insulated from the recent cycle, owing to foreign investment spurred by local production factors and cost of production advantages, respectively. In North America and Japan, though, these application markets are forecast to rebound in 1993, with the expected relaxation of business and household budget constraints.

Military/civil aerospace electronics production was hit hard by Washington, D.C. budget cuts in 1991, declining 5.5 percent worldwide. Few positive opportunities remain for all but the most specialized niche players participating in simulation systems, dedicated military computer systems, and civil-space projects. Civil aerospace electronics production will remain the bright spot in this application market, fueled by replacement of aging jet airliners and upgrades of the worldwide air traffic control system.

Transportation electronics production growth is expected to accelerate from 4.8 percent growth in 1991 to 6.0 percent in 1992, and to 10.2 percent in 1993. Production was hurt by the recession, but growth prospects are relatively upbeat because of increased household spending, combined with increasing share of electronic systems' added value to new vehicles.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. The following outlines these rates for 1991:

Japan (Yen/U.S.$)	136.00
Europe (ECU/U.S.$)	0.81
France (Franc/U.S.$)	5.64
Germany (Deutsche Mark/U.S.$)	1.66
United Kingdom (U.S.$/Pound Sterling)	1.77

Table 1
Worldwide Revenue from Production of Each Electronic Equipment Group, 1989-1991
(Millions of U.S. Dollars)

	1989	1990	1991
Computers	103,435	108,120	103,255
Data Storage	20,511	20,476	21,125
Terminals	15,319	16,105	16,664
Input/Output	22,929	25,209	27,252
Dedicated Systems	19,444	19,026	20,113
Data Processing	181,638	188,936	188,409
Premises Telecom	35,156	38,066	40,701
Public Telecom	24,446	28,450	30,763
Mobile Communication	13,382	15,264	16,887
Broadcast & Studio	3,484	3,921	4,164
Other Communication	8,025	8,759	8,826
Communication	84,492	94,461	101,340
Security & Energy Management	10,103	11,015	12,788
Manufacturing Systems/Instruments	55,320	61,276	62,174
Medical Equipment	12,833	14,261	15,005
Other Industrial	12,684	12,587	12,547
Industrial	90,940	99,139	102,514
Audio	15,809	16,849	19,964
Video	39,659	42,508	46,043
Personal Electronics	14,363	16,790	17,871
Appliances	45,074	45,768	50,394
Other Consumer	9,321	9,533	10,182
Consumer	124,226	131,448	144,454
Military/Civil Aerospace	86,731	86,730	81,918
Transportation	19,590	20,992	22,000
Total Equipment	587,617	621,707	640,635
Exchange Rates:			
Yen/U.S.$	138	144	136
ECU/U.S.$	0.908	0.788	0.811

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 2
Worldwide Revenue from Production of Each Electronic Equipment Group, 1992-1996
(Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
Computers	108,940	114,089	121,892	129,438	139,600
Data Storage	21,703	23,457	23,756	24,433	25,237
Terminals	17,293	18,377	19,630	20,803	22,238
Input/Output	28,009	30,091	32,283	34,028	35,816
Dedicated Systems	20,810	22,248	23,500	24,723	26,241
Data Processing	196,755	208,263	221,062	233,425	249,132
Premises Telecom	42,624	46,073	49,017	51,965	54,588
Public Telecom	32,842	35,874	37,925	40,065	43,052
Mobile Communication	18,197	19,961	21,863	25,991	28,046
Broadcast & Studio	4,492	5,019	5,448	5,923	6,487
Other Communication	9,360	9,967	10,359	10,886	11,282
Communication	107,515	116,893	124,612	134,831	143,455
Security & Energy Management	13,922	15,512	17,158	18,813	20,874
Manufacturing Systems/Instruments	62,854	67,338	71,965	76,050	80,745
Medical Equipment	15,599	16,887	18,111	19,328	20,616
Other Industrial	12,528	13,382	13,954	14,504	15,251
Industrial	104,902	113,119	121,187	128,695	137,486
Audio	21,098	23,483	25,764	28,176	31,124
Video	47,053	51,184	54,590	58,876	63,545
Personal Electronics	18,969	20,859	21,992	23,186	24,493
Appliances	52,247	57,162	61,515	65,079	69,871
Other Consumer	9,851	11,114	11,845	12,237	12,944
Consumer	149,218	163,803	175,705	187,554	201,976
Military/Civil Aerospace	82,366	85,564	88,416	91,056	93,515
Transportation	23,319	25,693	27,658	29,670	31,725
Total Equipment	664,075	713,334	758,639	805,231	857,289
Exchange Rates:					
Yen/U.S.$	136	136	136	136	136
ECU/U.S.$	0.791	0.791	0.791	0.791	0.791

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 3
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1989-1991 (Percentage Change)

	1989	1990	1991
Computers	12.3	4.5	-4.5
Data Storage	3.3	-0.2	3.2
Terminals	1.7	5.1	3.5
Input/Output	7.2	9.9	8.1
Dedicated Systems	3.2	-2.1	5.7
Data Processing	8.6	4.0	-0.3
Premises Telecom	13.7	8.3	6.9
Public Telecom	-1.9	16.4	8.1
Mobile Communication	8.1	14.1	10.6
Broadcast & Studio	3.2	12.6	6.2
Other Communication	3.9	9.1	0.8
Communication	6.5	11.8	7.3
Security & Energy Management	3.2	9.0	16.1
Manufacturing Systems/Instruments	5.5	10.8	1.5
Medical Equipment	1	11.1	5.2
Other Industrial	5.8	-0.8	-0.3
Industrial	4.6	9.0	3.4
Audio	-1.6	6.6	18.5
Video	-0.2	7.2	8.3
Personal Electronics	8.8	16.9	6.4
Appliances	6.2	1.5	10.1
Other Consumer	-0.6	2.3	6.8
Consumer	2.8	5.8	9.9
Military/Civil Aerospace	2.1	0	-5.5
Transportation	7.3	7.2	4.8
Total Equipment	5.4	5.8	3.0
U.S.$ Appreciation versus			
Yen (%)	6.2	4.3	-5.6
ECU (%)	7.3	-13.2	2.9

Source: Dataquest (August 1992)

Table 4
Worldwide Revenue Growth from Production of Each Electronic Equipment Group, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996
Computers	5.5	4.7	6.8	6.2	7.9
Data Storage	2.7	8.1	1.3	2.8	3.3
Terminals	3.8	6.3	6.8	6.0	6.9
Input/Output	2.8	7.4	7.3	5.4	5.3
Dedicated Systems	3.5	6.9	5.6	5.2	6.1
Data Processing	4.4	5.8	6.1	5.6	6.7
Premises Telecom	4.7	8.1	6.4	6.0	5.0
Public Telecom	6.8	9.2	5.7	5.6	7.5
Mobile Communication	7.8	9.7	9.5	18.9	7.9
Broadcast & Studio	7.9	11.7	8.5	8.7	9.5
Other Communication	6.1	6.5	3.9	5.1	3.6
Communication	6.1	8.7	6.6	8.2	6.4
Security & Energy Management	8.9	11.4	10.6	9.6	11.0
Manufacturing Systems/Instruments	1.1	7.1	6.9	5.7	6.2
Medical Equipment	4.0	8.3	7.2	6.7	6.7
Other Industrial	-0.2	6.8	4.3	3.9	5.2
Industrial	2.3	7.8	7.1	6.2	6.8
Audio	5.7	11.3	9.7	9.4	10.5
Video	2.2	8.8	6.7	7.9	7.9
Personal Electronics	6.1	10.0	5.4	5.4	5.6
Appliances	3.7	9.4	7.6	5.8	7.4
Other Consumer	-3.3	12.8	6.6	3.3	5.8
Consumer	3.3	9.8	7.3	6.7	7.7
Military/Civil Aerospace	0.5	3.9	3.3	3.0	2.7
Transportation	6.0	10.2	7.6	7.3	6.9
Total Equipment	3.7	7.4	6.4	6.1	6.5
U.S.$ Appreciation versus					
Yen (%)	0	0	0	0	0
ECU (%)	-2.4	0	0	0	0

Source: Dataquest (August 1992)

Table 5
Worldwide Revenue from Production of Each Equipment Group as a Share of Each Application Market, 1989-1991 (Percentage)

	1989	1990	1991
Computers	56.9	57.2	54.8
Data Storage	11.3	10.8	11.2
Terminals	8.4	8.5	8.8
Input/Output	12.6	13.3	14.5
Dedicated Systems	10.7	10.1	10.7
Data Processing	100.0	100.0	100.0
Premises Telecom	41.6	40.3	40.2
Public Telecom	28.9	30.1	30.4
Mobile Communication	15.8	16.2	16.7
Broadcast & Studio	4.1	4.2	4.1
Other Communication	9.5	9.3	8.7
Communication	100.0	100.0	100.0
Security & Energy Management	11.1	11.1	12.5
Manufacturing Systems/Instruments	60.8	61.8	60.6
Medical Equipment	14.1	14.4	14.6
Other Industrial	13.9	12.7	12.2
Industrial	100.0	100.0	100.0
Audio	12.7	12.8	13.8
Video	31.9	32.3	31.9
Personal Electronics	11.6	12.8	12.4
Appliances	36.3	34.8	34.9
Other Consumer	7.5	7.3	7.0
Consumer	100.0	100.0	100.0
Military/Civil Aerospace	100.0	100.0	100.0
Transportation	100.0	100.0	100.0
Total Equipment	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 6
Worldwide Revenue from Production of Each Equipment Group as a Share of Each Application Market, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
Computers	55.4	54.8	55.1	55.5	56.0
Data Storage	11.0	11.3	10.7	10.5	10.1
Terminals	8.8	8.8	8.9	8.9	8.9
Input/Output	14.2	14.4	14.6	14.6	14.4
Dedicated Systems	10.6	10.7	10.6	10.6	10.5
Data Processing	100.0	100.0	100.0	100.0	100.0
Premises Telecom	39.6	39.4	39.3	38.5	38.1
Public Telecom	30.5	30.7	30.4	29.7	30.0
Mobile Communication	16.9	17.1	17.5	19.3	19.6
Broadcast & Studio	4.2	4.3	4.4	4.4	4.5
Other Communication	8.7	8.5	8.3	8.1	7.9
Communication	100.0	100.0	100.0	100.0	100.0
Security & Energy Management	13.3	13.7	14.2	14.6	15.2
Manufacturing Systems/Instruments	59.9	59.5	59.4	59.1	58.7
Medical Equipment	14.9	14.9	14.9	15.0	15.0
Other Industrial	11.9	11.8	11.5	11.3	11.1
Industrial	100.0	100.0	100.0	100.0	100.0
Audio	14.1	14.3	14.7	15	15.4
Video	31.5	31.2	31.1	31.4	31.5
Personal Electronics	12.7	12.7	12.5	12.4	12.1
Appliances	35.0	34.9	35.0	34.7	34.6
Other Consumer	6.6	6.8	6.7	6.5	6.4
Consumer	100.0	100.0	100.0	100.0	100.0
Military/Civil Aerospace	100.0	100.0	100.0	100.0	100.0
Transportation	100.0	100.0	100.0	100.0	100.0
Total Equipment	100.0	100.0	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 7

Worldwide Revenue from Production of Each Equipment Group as a Share of Total Equipment, 1989-1991 (Percentage)

	1989	1990	1991
Computers	17.6	17.4	16.1
Data Storage	3.5	3.3	3.3
Terminals	2.6	2.6	2.6
Input/Output	3.9	4.1	4.3
Dedicated Systems	3.3	3.1	3.1
Data Processing	30.9	30.4	29.4
Premises Telecom	6.0	6.1	6.4
Public Telecom	4.2	4.6	4.8
Mobile Communication	2.3	2.5	2.6
Broadcast & Studio	0.6	0.6	0.7
Other Communication	1.4	1.4	1.4
Communication	14.4	15.2	15.8
Security & Energy Management	1.7	1.8	2.0
Manufacturing Systems/Instruments	9.4	9.9	9.7
Medical Equipment	2.2	2.3	2.3
Other Industrial	2.2	2.0	2.0
Industrial	15.5	15.9	16.0
Audio	2.7	2.7	3.1
Video	6.7	6.8	7.2
Personal Electronics	2.4	2.7	2.8
Appliances	7.7	7.4	7.9
Other Consumer	1.6	1.5	1.6
Consumer	21.1	21.1	22.5
Military/Civil Aerospace	14.8	14.0	12.8
Transportation	3.3	3.4	3.4
Total Equipment	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 8
Worldwide Revenue from Production of Each Equipment Group as a Share of Total Equipment, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
Computers	16.4	16.0	16.1	16.1	16.3
Data Storage	3.3	3.3	3.1	3.0	2.9
Terminals	2.6	2.6	2.6	2.6	2.6
Input/Output	4.2	4.2	4.3	4.2	4.2
Dedicated Systems	3.1	3.1	3.1	3.1	3
Data Processing	29.6	29.2	29.1	29.0	29.1
Premises Telecom	6.4	6.5	6.5	6.5	6.4
Public Telecom	4.9	5.0	5.0	5.0	5.0
Mobile Communication	2.7	2.8	2.9	3.2	3.3
Broadcast & Studio	0.7	0.7	0.7	0.7	0.8
Other Communication	1.4	1.4	1.4	1.4	1.3
Communication	16.2	16.4	16.4	16.7	16.7
Security & Energy Management	2.1	2.2	2.3	2.3	2.4
Manufacturing Systems/Instruments	9.5	9.4	9.5	9.4	9.4
Medical Equipment	2.3	2.4	2.4	2.4	2.4
Other Industrial	1.9	1.9	1.8	1.8	1.8
Industrial	15.8	15.9	16.0	16.0	16.0
Audio	3.2	3.3	3.4	3.5	3.6
Video	7.1	7.2	7.2	7.3	7.4
Personal Electronics	2.9	2.9	2.9	2.9	2.9
Appliances	7.9	8.0	8.1	8.1	8.2
Other Consumer	1.5	1.6	1.6	1.5	1.5
Consumer	22.5	23.0	23.2	23.3	23.6
Military/Civil Aerospace	12.4	12.0	11.7	11.3	10.9
Transportation	3.5	3.6	3.6	3.7	3.7
Total Equipment	100.0	100.0	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 9
Regional Revenue from Production of Each Application Market, 1989-1991 (Millions of U.S. Dollars)

	1989	1990	1991
North America			
Data Processing	77,501	81,234	73,691
Communication	28,360	29,935	31,832
Industrial	32,302	33,687	33,909
Consumer	17,082	16,995	16,660
Military/Aerospace	59,876	60,569	55,257
Transportation	4,153	4,115	3,881
Total	219,274	226,535	215,230
Japan			
Data Processing	47,941	46,771	51,342
Communication	19,752	21,337	22,926
Industrial	24,861	26,412	28,719
Consumer	52,474	54,439	61,773
Military/Aerospace	1,825	1,602	1,583
Transportation	9,199	9,469	9,931
Total	156,052	160,031	176,275
Europe			
Data Processing	31,242	33,575	30,392
Communication	27,436	32,734	35,102
Industrial	31,111	35,981	36,356
Consumer	30,777	32,241	33,817
Military/Aerospace	21,749	20,976	21,171
Transportation	4,613	5,556	6,064
Total	146,928	161,063	162,902
Asia/Pacific-ROW			
Data Processing	24,954	27,356	30,826
Communication	8,944	10,455	11,480
Industrial	2,666	3,059	3,530
Consumer	23,893	27,773	32,204
Military/Aerospace	3,281	3,583	3,907
Transportation	1,625	1,852	2,124
Total	65,363	74,078	86,228
Worldwide			
Data Processing	181,638	188,936	188,409
Communication	84,492	94,461	101,340
Industrial	90,940	99,139	102,514
Consumer	124,226	131,448	144,454
Military/Aerospace	86,731	86,730	81,918
Transportation	19,590	20,992	22,000
Total	587,617	621,707	640,635
Exchange Rates:			
Yen/U.S.$	138	144	136
ECU/U.S.$	0.908	0.788	0.811

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 10
Regional Revenue from Production of Each Application Market, 1992-1996 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996
North America					
Data Processing	75,861	78,258	82,433	85,554	90,265
Communication	34,037	36,375	38,882	41,470	43,888
Industrial	35,483	37,959	40,548	43,396	46,479
Consumer	17,312	18,216	19,161	20,155	21,127
Military/Aerospace	54,937	56,068	57,463	58,924	60,132
Transportation	4,252	4,694	4,996	5,265	5,516
Total	218,245	228,842	239,959	251,865	263,913
Japan					
Data Processing	51,246	53,581	55,827	57,762	60,510
Communication	23,298	24,536	25,748	26,898	28,311
Industrial	27,646	29,848	32,270	34,591	37,357
Consumer	59,633	63,750	66,275	69,059	72,849
Military/Aerospace	1,567	1,603	1,595	1,612	1,635
Transportation	9,935	10,533	11,018	11,411	11,854
Total	173,325	183,849	192,732	201,334	212,516
Europe					
Data Processing	31,850	34,733	36,713	38,879	41,282
Communication	36,956	40,440	42,355	46,427	48,484
Industrial	37,756	40,878	43,382	45,335	47,593
Consumer	35,706	39,237	42,346	44,706	47,959
Military/Aerospace	21,544	22,893	23,851	24,531	25,266
Transportation	6,681	7,610	8,348	9,214	10,169
Total	170,493	185,791	196,995	209,092	220,753
Asia/Pacific-ROW					
Data Processing	37,798	41,691	46,089	51,230	57,075
Communication	13,224	15,543	17,627	20,035	22,772
Industrial	4,017	4,434	4,987	5,373	6,057
Consumer	36,567	42,600	47,923	53,634	60,041
Military/Aerospace	4,318	5,000	5,507	5,989	6,482
Transportation	2,451	2,856	3,296	3,780	4,186
Total	94,517	107,631	120,153	133,603	150,158
Worldwide					
Data Processing	196,755	208,263	221,062	233,425	249,132
Communication	107,515	116,893	124,612	134,831	143,455
Industrial	104,902	113,119	121,187	128,695	137,486
Consumer	149,218	163,803	175,705	187,554	201,976
Military/Aerospace	82,366	85,564	88,416	91,056	93,515
Transportation	23,319	25,693	27,658	29,670	31,725
Total	664,075	713,334	758,639	805,231	857,289
Exchange Rates:					
Yen/U.S.$	136	136	136	136	136
ECU/U.S.$	0.791	0.791	0.791	0.791	0.791

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 11
Regional Revenue Growth from Production of Each Application Market, 1989-1991 (Percentage Change)

	1989	1990	1991
North America			
Data Processing	6.0	4.8	-9.3
Communication	11.6	5.6	6.3
Industrial	6.3	4.3	0.7
Consumer	10.5	-0.5	-2.0
Military/Aerospace	2.9	1.2	-8.8
Transportation	0.5	-0.9	-5.7
Total	6.1	3.3	-5.0
Japan			
Data Processing	5.0	-2.4	9.8
Communication	-4.4	8.0	7.4
Industrial	9.0	6.2	8.7
Consumer	-5.9	3.7	13.5
Military/Aerospace	-8.8	-12.2	-1.2
Transportation	4.7	2.9	4.9
Total	0.3	2.5	10.2
Europe			
Data Processing	21.2	7.5	-9.5
Communication	9.7	19.3	7.2
Industrial	-0.5	15.7	1.0
Consumer	10.2	4.8	4.9
Military/Aerospace	0.7	-3.6	0.9
Transportation	17.1	20.4	9.1
Total	8.4	9.6	1.1
Asia/Pacific-ROW			
Data Processing	9.9	9.6	20.6
Communication	8.7	16.9	9.8
Industrial	8.8	14.7	15.4
Consumer	9.9	16.2	16.0
Military/Aerospace	4.7	9.2	9.0
Transportation	16.7	14.0	14.7
Total	9.6	13.3	16.4
Worldwide			
Data Processing	8.6	4.0	-0.3
Communication	6.5	11.8	7.3
Industrial	4.6	9.0	3.4
Consumer	2.8	5.8	9.9
Military/Aerospace	2.1	0	-5.5
Transportation	7.3	7.2	4.8
Total	5.4	5.8	3.0
U.S.$ Appreciation versus			
Yen (%)	6.2	4.3	-5.6
ECU (%)	7.3	-13.2	2.9

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 12
Regional Revenue Growth from Production of Each Application Market, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996
North America					
Data Processing	2.9	3.2	5.3	3.8	5.5
Communication	6.9	6.9	6.9	6.7	5.8
Industrial	4.6	7.0	6.8	7.0	7.1
Consumer	3.9	5.2	5.2	5.2	4.8
Military/Aerospace	-0.6	2.1	2.5	2.5	2.1
Transportation	9.6	10.4	6.4	5.4	4.8
Total	3.1	4.4	5.1	4.6	5.0
Japan					
Data Processing	-0.2	4.6	4.2	3.5	4.8
Communication	1.6	5.3	4.9	4.5	5.2
Industrial	-3.7	8.0	8.1	7.2	8.0
Consumer	-3.5	6.9	4.0	4.2	5.5
Military/Aerospace	-1.0	2.3	-0.5	1.1	1.4
Transportation	0	6.0	4.6	3.6	3.9
Total	-1.7	6.1	4.8	4.5	5.6
Europe					
Data Processing	4.8	9.1	5.7	5.9	6.2
Communication	5.3	9.4	4.7	9.6	4.4
Industrial	3.9	8.3	6.1	4.5	5.0
Consumer	5.6	9.9	7.9	5.6	7.3
Military/Aerospace	1.8	6.3	4.2	2.9	3.0
Transportation	10.2	13.9	9.7	10.4	10.4
Total	4.7	9.0	6.0	6.1	5.6
Asia/Pacific-ROW					
Data Processing	14.6	10.3	10.5	11.2	11.4
Communication	15.2	17.5	13.4	13.7	13.7
Industrial	13.8	10.4	12.5	7.7	12.7
Consumer	13.5	16.5	12.5	11.9	11.9
Military/Aerospace	10.5	15.8	10.1	8.8	8.2
Transportation	15.4	16.5	15.4	14.7	10.7
Total	14.1	14.0	11.9	11.6	11.8
Worldwide					
Data Processing	4.4	5.8	6.1	5.6	6.7
Communication	6.1	8.7	6.6	8.2	6.4
Industrial	2.3	7.8	7.1	6.2	6.8
Consumer	3.3	9.8	7.3	6.7	7.7
Military/Aerospace	0.5	3.9	3.3	3.0	2.7
Transportation	6.0	10.2	7.6	7.3	6.9
Total	3.7	7.4	6.4	6.1	6.5
U.S.$ Appreciation versus					
Yen (%)	0	0	0	0	0
ECU (%)	-2.4	0	0	0	0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 13
Regional Revenue from Production of Each Application Market as a Share of Worldwide Total Equipment, 1989-1991 (Percentage)

	1989	1990	1991
North America			
Data Processing	42.7	43.0	39.1
Communication	33.6	31.7	31.4
Industrial	35.5	34.0	33.1
Consumer	13.8	12.9	11.5
Military/Aerospace	69.0	69.8	67.5
Transportation	21.2	19.6	17.6
Total	37.3	36.4	33.6
Japan			
Data Processing	26.4	24.8	27.3
Communication	23.4	22.6	22.6
Industrial	27.3	26.6	28.0
Consumer	42.2	41.4	42.8
Military/Aerospace	2.1	1.8	1.9
Transportation	47.0	45.1	45.1
Total	26.6	25.7	27.5
Europe			
Data Processing	17.2	17.8	16.1
Communication	32.5	34.7	34.6
Industrial	34.2	36.3	35.5
Consumer	24.8	24.5	23.4
Military/Aerospace	25.1	24.2	25.8
Transportation	23.5	26.5	27.6
Total	25.0	25.9	25.4
Asia/Pacific-ROW			
Data Processing	13.7	14.5	17.5
Communication	10.6	11.1	11.3
Industrial	2.9	3.1	3.4
Consumer	19.2	21.1	22.3
Military/Aerospace	3.8	4.1	4.8
Transportation	8.3	8.8	9.7
Total	11.1	11.9	13.5
Worldwide			
Data Processing	100.0	100.0	100.0
Communication	100.0	100.0	100.0
Industrial	100.0	100.0	100.0
Consumer	100.0	100.0	100.0
Military/Aerospace	100.0	100.0	100.0
Transportation	100.0	100.0	100.0
Total	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 14

Regional Revenue from Production of Each Application Market as a Share of Worldwide Total Equipment, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
North America					
Data Processing	38.6	37.6	37.3	36.7	36.2
Communication	31.7	31.1	31.2	30.8	30.6
Industrial	33.8	33.6	33.5	33.7	33.8
Consumer	11.6	11.1	10.9	10.7	10.5
Military/Aerospace	66.7	65.5	65.0	64.7	64.3
Transportation	18.2	18.3	18.1	17.7	17.4
Total	33.4	32.5	32.1	31.6	31.2
Japan					
Data Processing	26.0	25.7	25.3	24.7	24.3
Communication	21.7	21.0	20.7	20.0	19.7
Industrial	26.4	26.4	26.6	26.9	27.2
Consumer	40.0	38.9	37.7	36.8	36.1
Military/Aerospace	1.9	1.9	1.8	1.8	1.7
Transportation	42.6	41.0	39.8	38.5	37.4
Total	26.1	25.8	25.4	25.0	24.8
Europe					
Data Processing	16.2	16.7	16.6	16.7	16.6
Communication	34.4	34.6	34.0	34.4	33.8
Industrial	36.0	36.1	35.8	35.2	34.6
Consumer	23.9	24.0	24.1	23.8	23.7
Military/Aerospace	26.2	26.8	27.0	26.9	27.0
Transportation	28.7	29.6	30.2	31.1	32.1
Total	25.7	26.0	26.0	26.0	25.8
Asia/Pacific-ROW					
Data Processing	19.2	20.0	20.8	21.9	22.9
Communication	12.3	13.3	14.1	14.9	15.9
Industrial	3.8	3.9	4.1	4.2	4.4
Consumer	24.5	26.0	27.3	28.6	29.7
Military/Aerospace	5.2	5.8	6.2	6.6	6.9
Transportation	10.5	11.1	11.9	12.7	13.2
Total	14.8	15.7	16.5	17.4	18.3
Worldwide					
Data Processing	100.0	100.0	100.0	100.0	100.0
Communication	100.0	100.0	100.0	100.0	100.0
Industrial	100.0	100.0	100.0	100.0	100.0
Consumer	100.0	100.0	100.0	100.0	100.0
Military/Aerospace	100.0	100.0	100.0	100.0	100.0
Transportation	100.0	100.0	100.0	100.0	100.0
Total	100.0	100.0	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 15
Regional Revenue from Production of Each Application Market as a Share of Regional Total Equipment, 1989-1991 (Percentage)

	1989	1990	1991
North America			
Data Processing	35.3	35.9	34.2
Communication	12.9	13.2	14.8
Industrial	14.7	14.9	15.8
Consumer	7.8	7.5	7.7
Military/Aerospace	27.3	26.7	25.7
Transportation	1.9	1.8	1.8
Total	100.0	100.0	100.0
Japan			
Data Processing	30.7	29.2	29.1
Communication	12.7	13.3	13.0
Industrial	15.9	16.5	16.3
Consumer	33.6	34.0	35.0
Military/Aerospace	1.2	1.0	0.9
Transportation	5.9	5.9	5.6
Total	100.0	100.0	100.0
Europe			
Data Processing	21.3	20.8	18.7
Communication	18.7	20.3	21.5
Industrial	21.2	22.3	22.3
Consumer	20.9	20.0	20.8
Military/Aerospace	14.8	13.0	13.0
Transportation	3.1	3.4	3.7
Total	100.0	100.0	100.0
Asia/Pacific-ROW			
Data Processing	38.2	36.9	38.3
Communication	13.7	14.1	13.3
Industrial	4.1	4.1	4.1
Consumer	36.6	37.5	37.3
Military/Aerospace	5.0	4.8	4.5
Transportation	2.5	2.5	2.5
Total	100.0	100.0	100.0
Worldwide			
Data Processing	30.9	30.4	29.4
Communication	14.4	15.2	15.8
Industrial	15.5	15.9	16.0
Consumer	21.1	21.1	22.5
Military/Aerospace	14.8	14.0	12.8
Transportation	3.3	3.4	3.4
Total	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 16
Regional Revenue from Production of Each Application Market as a Share of Regional Total Equipment, 1992-1996 (Percentage)

	1992	1993	1994	1995	1996
North America					
Data Processing	34.2	33.8	33.9	33.6	33.8
Communication	15.3	15.7	16.0	16.3	16.4
Industrial	16.0	16.4	16.7	17.0	17.4
Consumer	7.8	7.9	7.9	7.9	7.9
Military/Aerospace	24.8	24.2	23.6	23.1	22.5
Transportation	1.9	2.0	2.1	2.1	2.1
Total	100.0	100.0	100.0	100.0	100.0
Japan					
Data Processing	29.6	29.1	29.0	28.7	28.5
Communication	13.4	13.3	13.4	13.4	13.3
Industrial	16.0	16.2	16.7	17.2	17.6
Consumer	34.4	34.7	34.4	34.3	34.3
Military/Aerospace	0.9	0.9	0.8	0.8	0.8
Transportation	5.7	5.7	5.7	5.7	5.6
Total	100.0	100.0	100.0	100.0	100.0
Europe					
Data Processing	18.7	18.7	18.6	18.6	18.7
Communication	21.7	21.8	21.5	22.2	22.0
Industrial	22.1	22.0	22.0	21.7	21.6
Consumer	20.9	21.1	21.5	21.4	21.7
Military/Aerospace	12.6	12.3	12.1	11.7	11.4
Transportation	3.9	4.1	4.2	4.4	4.6
Total	100.0	100.0	100.0	100.0	100.0
Asia/Pacific-ROW					
Data Processing	38.4	37.2	36.7	36.6	36.4
Communication	13.4	13.9	14.1	14.3	14.5
Industrial	4.1	4.0	4.0	3.8	3.9
Consumer	37.2	38.0	38.2	38.3	38.3
Military/Aerospace	4.4	4.5	4.4	4.3	4.1
Transportation	2.5	2.5	2.6	2.7	2.7
Total	100.0	100.0	100.0	100.0	100.0
Worldwide					
Data Processing	29.6	29.2	29.1	29.0	29.1
Communication	16.2	16.3	16.4	16.7	16.7
Industrial	15.8	15.9	16.0	16.0	16.0
Consumer	22.5	23.0	23.2	23.3	23.6
Military/Aerospace	12.4	12.0	11.7	11.3	10.9
Transportation	3.5	3.6	3.6	3.7	3.7
Total	100.0	100.0	100.0	100.0	100.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 17
Revenue from North American Data Processing Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Data Processing			
Computers			
Supercomputers	945	1,081	990
Mainframe	18,517	19,065	15,491
Midrange	17,201	18,417	15,619
Workstation	4,335	5,037	5,048
Personal Computer	11,993	12,150	10,826
Total Computer	52,991	55,750	47,974
Data Storage/Subsystems			
Rigid Disk Drives			
14-inch	1,666	988	607
8-10-inch	1,240	2,147	2,617
5.25-inch	719	498	268
3.5-inch	1,026	913	623
2.5-inch	0	0	0
1.8-inch	0	0	0
Total Rigid Disk Drives	4,651	4,546	4,115
Optical Drives			
Rewrite Optical Disk Drives	9	14	16
WORM Optical Drives	13	15	17
CD-ROM	1	1	1
Total Optical Drives	23	30	34
Tape Drives	784	824	942
Total Data Storage/Subsystems	5,458	5,400	5,091
Terminals			
Graphics Terminals			
X Terminals	0	139	199
Other Graphics Terminals	557	452	307
Total Graphics Terminals	557	591	506
Alphanumeric Terminals	1,622	1,490	1,446
Total Terminals	2,179	2,081	1,952
Input/Output Devices			
Printers			
Serial Printers	1,802	1,596	1,644
Line Printers	989	912	1,004
Page Printers	5,516	6,984	7,473
Total Printers	8,307	9,492	10,121
Other Input/Output Devices	3,540	3,717	3,958
Total Input/Output Devices	11,847	13,209	14,079

(Continued)

Table 17 (Continued)
Revenue from North American Data Processing Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Dedicated Systems			
Copiers and Duplicators			
Personal Copiers	73	79	87
Segments 1-3	903	863	803
Segments 4-6	509	482	530
Total Copiers and Duplicators	1,485	1,424	1,420
Other Dedicated Systems	3,540	3,370	3,175
Total Dedicated Systems	5,025	4,794	4,595
Total Data Processing	77,500	81,234	73,691

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 18
Revenue from North American Data Processing Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Data Processing					
Computers					
Supercomputers	1,135	1,222	1,402	1,560	1,726
Mainframe	15,536	15,022	15,081	14,742	15,282
Midrange	15,889	16,133	16,947	17,459	18,614
Workstation	6,385	7,687	9,344	10,652	11,919
Personal Computer	11,731	12,624	13,982	15,178	16,607
Total Computer	50,676	52,668	56,756	59,591	64,148
Data Storage/Subsystems					
Rigid Disk Drives					
14-inch	255	50	5	0	0
8-10-inch	2,267	1,764	1,030	501	0
5.25-inch	160	89	47	42	28
3.5-inch	391	298	101	87	69
2.5-inch	0	0	0	0	0
1.8-inch	0	0	0	0	0
Total Rigid Disk Drives	3,073	2,201	1,183	630	97
Optical Drives					
Rewrite Optical Disk Drives	17	18	19	21	23
WORM Optical Drives	18	20	22	24	26
CD-ROM	2	3	5	6	6
Total Optical Drives	37	41	46	51	55
Tape Drives	971	1,013	1,036	1,062	1,088
Total Data Storage/Subsystems	4,081	3,255	2,265	1,743	1,240
Terminals					
Graphics Terminals					
X Terminals	341	460	536	560	589
Other Graphics Terminals	267	234	194	133	133
Total Graphics Terminals	608	694	730	693	722
Alphanumeric Terminals	1,438	1,425	1,413	1,400	1,365
Total Terminals	2,046	2,119	2,143	2,093	2,087
Input/Output Devices					
Printers					
Serial Printers	1,718	1,770	1,787	1,752	1,677
Line Printers	1,039	1,070	1,097	1,124	1,169
Page Printers	7,327	7,730	8,116	8,400	8,568
Total Printers	10,084	10,570	11,000	11,276	11,414
Other Input/Output Devices	4,215	4,616	4,985	5,359	5,681
Total Input/Output Devices	14,299	15,186	15,985	16,635	17,095

(Continued)

Table 18 (Continued)
Revenue from North American Data Processing Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Dedicated Systems					
Copiers and Duplicators					
Personal Copiers	89	91	93	94	96
Segments 1-3	811	819	828	836	844
Segments 4-6	541	552	563	574	586
Total Copiers and Duplicators	1,441	1,462	1,484	1,504	1,526
Other Dedicated Systems	3,318	3,567	3,799	3,988	4,168
Total Dedicated Systems	4,759	5,029	5,283	5,492	5,694
Total Data Processing	75,861	78,257	82,432	85,554	90,264

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 19
Revenue Growth from North American Data Processing Equipment Production, 1989-1991
(Percentage Change)

	1989	1990	1991
Data Processing			
Computers			
Supercomputers	1.2	14.4	-8.4
Mainframe	4.4	3.0	-18.7
Midrange	7.6	7.1	-15.2
Workstation	35.6	16.2	0.2
Personal Computer	3.7	1.3	-10.9
Total Computer	7.2	5.2	-13.9
Data Storage/Subsystems			
Rigid Disk Drives			
14-inch	-27.9	-40.7	-38.6
8-10-inch	5.4	73.1	21.9
5.25-inch	-30.7	-30.7	-46.2
3.5-inch	51.3	-11	-31.8
2.5-inch	NM	NM	NM
1.8-inch	NM	NM	NM
Total Rigid Disk Drives	-10.6	-2.3	-9.5
Optical Drives			
Rewrite Optical Disk Drives	200	55.6	14.3
WORM Optical Drives	8.3	15.4	13.3
CD-ROM	0	0	0
Total Optical Drives	43.8	30.4	13.3
Tape Drives	17.9	5.1	14.3
Total Data Storage/Subsystems	-7.2	-1.1	-5.7
Terminals			
Graphics Terminals			
X Terminals	NM	NM	43.2
Other Graphics Terminals	-18.2	-18.9	-32.1
Total Graphics Terminals	-18.2	6.1	-14.4
Alphanumeric Terminals	-0.6	-8.1	-3
Total Terminals	-5.8	-4.5	-6.2
Input/Output Devices			
Printers			
Serial Printers	-11.4	-11.4	3
Line Printers	-0.5	-7.8	10.1
Page Printers	36.2	26.6	7
Total Printers	17.4	14.3	6.6
Other Input/Output Devices	6.7	5	6.5
Total Input/Output Devices	14	11.5	6.6

(Continued)

Table 19 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1989-1991
(Percentage Change)

	1989	1990	1991
Dedicated Systems			
Copiers and Duplicators			
Personal Copiers	5.8	8.2	10.1
Segments 1-3	-2.8	-4.4	-7
Segments 4-6	3.7	-5.3	10
Total Copiers and Duplicators	-0.3	-4.1	-0.3
Other Dedicated Systems	-2.2	-4.8	-5.8
Total Dedicated Systems	-1.6	-4.6	-4.2
Total Data Processing	6.0	4.8	-9.3

Note: Columns may not add to totals shown because of rounding.
NM = Not meaningful
Source: Dataquest (August 1992)

Table 20
Revenue Growth from North American Data Processing Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Data Processing						
Computers						
Supercomputers	14.6	7.7	14.7	11.3	10.6	11.8
Mainframe	0.3	-3.3	0.4	-2.2	3.7	-0.3
Midrange	1.7	1.4	5.2	3.0	6.6	3.6
Workstation	26.5	20.4	21.6	14.0	11.9	18.7
Personal Computer	8.4	7.6	10.8	8.6	9.4	8.9
Total Computer	5.6	3.9	7.8	5.0	7.6	6.0
Data Storage/Subsystems						
Rigid Disk Drives						
14-inch	-58	-80.4	-90	NM	NM	-100
8-10-inch	-13.4	-22.2	-41.6	-51.4	NM	-100
5.25-inch	-40.3	-44.4	-47.2	-10.6	-33.3	-36.3
3.5-inch	-37.2	-23.8	-66.1	-13.9	-20.7	-35.6
2.5-inch	NM	NM	NM	NM	NM	NM
1.8-inch	NM	NM	NM	NM	NM	NM
Total Rigid Disk Drives	-25.3	-28.4	-46.3	-46.7	-84.6	-52.7
Optical Drives						
Rewrite Optical Disk Drives	6.3	5.9	5.6	10.5	9.5	7.5
WORM Optical Drives	5.9	11.1	10	9.1	8.3	8.9
CD-ROM	100	50	66.7	20	0	43.1
Total Optical Drives	8.8	10.8	12.2	10.9	7.8	10.1
Tape Drives	3.1	4.3	2.3	2.5	2.4	2.9
Total Data Storage/Subsystems	-19.8	-20.2	-30.4	-23	-28.9	-24.6
Terminals						
Graphics Terminals						
X Terminals	71.4	34.9	16.5	4.5	5.2	24.2
Other Graphics Terminals	-13	-12.4	-17.1	-31.4	0	-15.4
Total Graphics Terminals	20.2	14.1	5.2	-5.1	4.2	7.4
Alphanumeric Terminals	-0.6	-0.9	-0.8	-0.9	-2.5	-1.1
Total Terminals	4.8	3.6	1.1	-2.3	-0.3	1.3
Input/Output Devices						
Printers						
Serial Printers	4.5	3	1	-2	-4.3	0.4
Line Printers	3.5	3	2.5	2.5	4	3.1
Page Printers	-2	5.5	5	3.5	2	2.8
Total Printers	-0.4	4.8	4.1	2.5	1.2	2.4
Other Input/Output Devices	6.5	9.5	8	7.5	6	7.5
Total Input/Output Devices	1.6	6.2	5.3	4.1	2.8	4

(Continued)

Table 20 (Continued)
Revenue Growth from North American Data Processing Equipment Production, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Dedicated Systems						
Copiers and Duplicators						
Personal Copiers	2.3	2.2	2.2	1.1	2.1	2
Segments 1-3	1	1	1.1	1	1	1
Segments 4-6	2.1	2	2	2	2.1	2
Total Copiers and Duplicators	1.5	1.5	1.5	1.3	1.5	1.5
Other Dedicated Systems	4.5	7.5	6.5	5	4.5	5.6
Total Dedicated Systems	3.6	5.7	5.1	4	3.7	4.4
Total Data Processing	2.9	3.2	5.3	3.8	5.5	4.1

Note: Columns may not add to totals shown because of rounding.
NM = Not meaningful
Source: Dataquest (August 1992)

Table 21
Revenue from North American Communications Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Communication			
Premise Telecom Equipment			
Image & Text Communication			
Facsimile	196	207	234
Video Teleconferencing	60	76	120
Total Image & Text Communication	256	283	354
Data Communications Equipment			
Modems	1,115	1,277	1,356
Statistical Multiplexers	177	163	146
T-1 Multiplexers	446	434	416
Front-End Processors	482	479	466
DSU/CSU	140	171	211
Protocol Converters	164	153	141
Local Area Networks	3,774	4,469	5,045
Network Managememt	620	829	1,205
Packet Data Switching/WANs	291	306	320
Total Data Communications Equipment	7,209	8,281	9,306
Premise Switching Equipment			
PBX Telephone Equipment	2,178	2,060	1,896
Key Telephone Systems	808	780	753
Total Premise Switching Equipment	2,986	2,840	2,649
Call Processing Equipment			
Voice Messaging	563	765	857
Interactive Voice Response System	205	404	480
Call Accounting	260	269	273
Automatic Call Distributors	577	497	529
Total Call Processing Equipment	1,605	1,935	2,139
Desktop Terminal Equipment			
Telephone Sets/Pay Phones	395	387	385
Teleprinters	205	190	170
Total Desktop Terminal Equipment	600	577	555
Total Premise Telecom Equipment	12,656	13,916	15,003
Public Telecom Equipment			
Transmission Equipment			
Multiplex	1,435	1,465	1,503
Carrier Systems	1,840	2,010	2,192
Microwave Radio	510	547	585
Other (laser, infrared)	119	124	128
Satellite Communications Equipment	693	758	785
Total Transmission Equipment	4,597	4,904	5,193
Central Office Switching Equipment	2,423	2,313	2,385
Total Public Telecom Equipment	7,020	7,217	7,578

(Continued)

Table 21 (Continued)
Revenue from North American Communications Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Mobile Communications Equipment			
Mobile Radio Systems Equipment			
Cellular Telephones	211	236	255
Mobile Radios	800	860	924
Mobile Radio Base Station Equipment	919	790	825
Total Mobile Radio Systems Equipment	1,930	1,886	2,004
Portable Radio Receivers, Transmitters	725	769	814
Radio Checkout Equipment	315	318	320
Total Mobile Communications Equipment	2,970	2,973	3,138
Broadcast & Radio			
Audio Equipment	413	395	420
Video Equipment	480	460	489
Transmitters, RF Power Amps	104	124	131
Studio Transmitter Links	21	25	27
Cable TV Equipment	541	560	595
CCTV	145	164	174
Other (Studio, Theater)	82	87	87
Total Broadcast & Radio	1,786	1,815	1,923
Other Telecom			
Intercomm. Equip., Elec. Ampl.	368	344	365
Communications Equipment, NEC	3,560	3,670	3,825
Total Other Telecom	3,928	4,014	4,190
Total Communication	28,360	29,935	31,832

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 22
Revenue from North American Communications Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Communication					
Premise Telecom Equipment					
Image & Text Communication					
Facsimile	262	288	310	329	345
Video Teleconferencing	174	218	265	324	388
Total Image & Text Communication	436	506	575	653	733
Data Communications Equipment					
Modems	1,370	1,323	1,278	1,235	1,193
Statistical Multiplexers	130	114	96	85	76
T-1 Multiplexers	400	390	368	340	310
Front-End Processors	445	422	397	385	365
DSU/CSU	241	235	227	216	202
Protocol Converters	138	133	128	123	118
Local Area Networks	5,496	5,958	6,502	7,052	7,636
Network Managememt	1,477	1,732	1,910	2,063	2,228
Packet Data Switching/WANs	321	338	360	380	400
Total Data Communications Equipment	10,018	10,645	11,266	11,879	12,528
Premise Switching Equipment					
PBX Telephone Equipment	1,855	1,915	1,989	2,050	2,085
Key Telephone Systems	754	758	760	762	764
Total Premise Switching Equipment	2,609	2,673	2,749	2,812	2,849
Call Processing Equipment					
Voice Messaging	993	1,062	1,136	1,215	1,295
Interactive Voice Response System	529	645	791	984	1,218
Call Accounting	285	300	316	329	340
Automatic Call Distributors	560	602	661	728	809
Total Call Processing Equipment	2,367	2,609	2,904	3,256	3,662
Desktop Terminal Equipment					
Telephone Sets/Pay Phones	372	365	355	340	328
Teleprinters	127	97	65	46	31
Total Desktop Terminal Equipment	499	462	420	386	359
Total Premise Telecom Equipment	15,929	16,895	17,914	18,986	20,131
Public Telecom Equipment					
Transmission Equipment					
Multiplex	1,560	1,628	1,765	1,895	2,025
Carrier Systems	2,395	2,652	2,951	3,249	3,529
Microwave Radio	665	734	803	880	932
Other (laser, infrared)	134	142	148	156	162
Satellite Communications Equipment	983	1,145	1,250	1,362	1,448
Total Transmission Equipment	5,737	6,301	6,917	7,542	8,096
Central Office Switching Equipment	2,510	2,648	2,743	2,855	2,965
Total Public Telecom Equipment	8,247	8,949	9,660	10,397	11,061

(Continued)

Table 22 (Continued)
Revenue from North American Communications Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Mobile Communications Equipment					
Mobile Radio Systems Equipment					
Cellular Telephones	310	365	492	590	685
Mobile Radios	994	1,079	1,160	1,242	1,316
Mobile Radio Base Station Equipment	949	1,129	1,332	1,519	1,716
Total Mobile Radio Systems Equipment	2,253	2,573	2,984	3,351	3,717
Portable Radio Receivers, Transmitters	865	920	975	1,040	1,108
Radio Checkout Equipment	324	327	330	333	337
Total Mobile Communications Equipment	3,442	3,820	4,289	4,724	5,162
Broadcast & Radio					
Audio Equipment	442	463	481	500	518
Video Equipment	516	544	599	659	724
Transmitters, RF Power Amps	134	137	140	143	147
Studio Transmitter Links	28	29	30	31	32
Cable TV Equipment	646	694	743	783	827
CCTV	185	195	204	215	225
Other (Studio, Theater)	87	87	87	87	87
Total Broadcast & Radio	2,038	2,149	2,284	2,418	2,560
Other Telecom					
Intercomm. Equip., Elec. Ampl.	389	407	427	447	468
Communications Equipment, NEC	3,992	4,155	4,308	4,498	4,506
Total Other Telecom	4,381	4,562	4,735	4,945	4,974
Total Communication	34,037	36,375	38,882	41,470	43,888

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 23
Revenue Growth from North American Communications Equipment Production, 1989-1991 (Percentage Change)

	1989	1990	1991
Communication			
Premise Telecom Equipment			
Image & Text Communication			
Facsimile	-3	5.6	13
Video Teleconferencing	100	26.7	57.9
Total Image & Text Communication	10.3	10.5	25.1
Data Communications Equipment			
Modems	-10.5	14.5	6.2
Statistical Multiplexers	-8.3	-7.9	-10.4
T-1 Multiplexers	14.9	-2.7	-4.1
Front-End Processors	-1.2	-0.6	-2.7
DSU/CSU	12	22.1	23.4
Protocol Converters	0	-6.7	-7.8
Local Area Networks	46.3	18.4	12.9
Network Managememt	151	33.7	45.4
Packet Data Switching/WANs	9.4	5.2	4.6
Total Data Communications Equipment	26.5	14.9	12.4
Premise Switching Equipment			
PBX Telephone Equipment	-6.9	-5.4	-8
Key Telephone Systems	-0.2	-3.5	-3.5
Total Premise Switching Equipment	-5.2	-4.9	-6.7
Call Processing Equipment			
Voice Messaging	30.6	35.9	12
Interactive Voice Response System	NM	97.1	18.8
Call Accounting	1.6	3.5	1.5
Automatic Call Distributors	48.7	-13.9	6.4
Total Call Processing Equipment	49.3	20.6	10.5
Desktop Terminal Equipment			
Telephone Sets/Pay Phones	10	-2	-0.5
Teleprinters	-6.8	-7.3	-10.5
Total Desktop Terminal Equipment	3.6	-3.8	-3.8
Total Premise Telecom Equipment	17.9	10	7.8
Public Telecom Equipment			
Transmission Equipment			
Multiplex	4.2	2.1	2.6
Carrier Systems	9	9.2	9.1
Microwave Radio	4.7	7.3	6.9
Other (laser, infrared)	10.2	4.2	3.2
Satellite Communications Equipment	6.5	9.4	3.6
Total Transmission Equipment	6.6	6.7	5.9

(Continued)

Table 23 (Continued)
Revenue Growth from North American Communications Equipment Production, 1989-1991
(Percentage Change)

	1989	1990	1991
Central Office Switching Equipment	-0.2	-4.5	3.1
Total Public Telecom Equipment	4.2	2.8	5
Mobile Communications Equipment			
Mobile Radio Systems Equipment			
Cellular Telephones	5	11.8	8.1
Mobile Radios	12	7.5	7.4
Mobile Radio Base Station Equipment	94.3	-14	4.4
Total Mobile Radio Systems Equipment	39	-2.3	6.3
Portable Radio Receivers, Transmitters	20.2	6.1	5.9
Radio Checkout Equipment	0.6	1	0.6
Total Mobile Communications Equipment	28.9	0.1	5.5
Broadcast & Radio			
Audio Equipment	31.5	-4.4	6.3
Video Equipment	-16.4	-4.2	6.3
Transmitters, RF Power Amps	-16.8	19.2	5.6
Studio Transmitter Links	-51.2	19	8
Cable TV Equipment	27.9	3.5	6.3
CCTV	7.4	13.1	6.1
Other (Studio, Theater)	-13.7	6.1	0
Total Broadcast & Radio	4.5	1.6	6
Other Telecom			
Intercomm. Equip., Elec. Ampl.	NM	-6.5	6.1
Communications Equipment, NEC	NM	3.1	4.2
Total Other Telecom	NM	2.2	4.4
Total Communication	NM	5.6	6.3

Note: Columns may not add to totals shown because of rounding.
NM = Not meaningful
Source: Dataquest (August 1992)

Table 24
Revenue Growth from North American Communications Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Communication						
Premise Telecom Equipment						
Image & Text Communication						
Facsimile	12	9.9	7.6	6.1	4.9	8.1
Video Teleconferencing	45	25.3	21.6	22.3	19.8	26.5
Total Image & Text Communication	23.2	16.1	13.6	13.6	12.3	15.7
Data Communications Equipment						
Modems	1	-3.4	-3.4	-3.4	-3.4	-2.5
Statistical Multiplexers	-11	-12.3	-15.8	-11.5	-10.6	-12.2
T-1 Multiplexers	-3.8	-2.5	-5.6	-7.6	-8.8	-5.7
Front-End Processors	-4.5	-5.2	-5.9	-3	-5.2	-4.8
DSU/CSU	14.2	-2.5	-3.4	-4.8	-6.5	-0.9
Protocol Converters	-2.1	-3.6	-3.8	-3.9	-4.1	-3.5
Local Area Networks	8.9	8.4	9.1	8.5	8.3	8.6
Network Managememt	22.6	17.3	10.3	8	8	13.1
Packet Data Switching/WANs	0.3	5.3	6.5	5.6	5.3	4.6
Total Data Communications Equipment	7.7	6.3	5.8	5.4	5.5	6.1
Premise Switching Equipment						
PBX Telephone Equipment	-2.2	3.2	3.9	3.1	1.7	1.9
Key Telephone Systems	0.1	0.5	0.3	0.3	0.3	0.3
Total Premise Switching Equipment	-1.5	2.5	2.8	2.3	1.3	1.5
Call Processing Equipment						
Voice Messaging	15.9	6.9	7	7	6.6	8.6
Interactive Voice Response System	10.2	21.9	22.6	24.4	23.8	20.5
Call Accounting	4.4	5.3	5.3	4.1	3.3	4.5
Automatic Call Distributors	5.9	7.5	9.8	10.1	11.1	8.9
Total Call Processing Equipment	10.7	10.2	11.3	12.1	12.5	11.4
Desktop Terminal Equipment						
Telephone Sets/Pay Phones	-3.4	-1.9	-2.7	-4.2	-3.5	-3.2
Teleprinters	-25.3	-23.6	-33	-29.2	-32.6	-28.8
Total Desktop Terminal Equipment	-10.1	-7.4	-9.1	-8.1	-7	-8.3
Total Premise Telecom Equipment	6.2	6.1	6	6	6	6.1
Public Telecom Equipment						
Transmission Equipment						
Multiplex	3.8	4.4	8.4	7.4	6.9	6.1
Carrier Systems	9.3	10.7	11.3	10.1	8.6	10
Microwave Radio	13.7	10.4	9.4	9.6	5.9	9.8
Other (laser, infrared)	4.7	6	4.2	5.4	3.8	4.8
Satellite Communications Equipment	25.2	16.5	9.2	9	6.3	13
Total Transmission Equipment	10.5	9.8	9.8	9	7.3	9.3

(Continued)

Table 24 (Continued)
Revenue Growth from North American Communications Equipment Production, 1992-1996
(Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Central Office Switching Equipment	5.2	5.5	3.6	4.1	3.9	4.4
Total Public Telecom Equipment	8.8	8.5	7.9	7.6	6.4	7.9
Mobile Communications Equipment						
Mobile Radio Systems Equipment						
Cellular Telephones	21.6	17.7	34.8	19.9	16.1	21.9
Mobile Radios	7.6	8.6	7.5	7.1	6	7.3
Mobile Radio Base Station Equipment	15	19	18	14	13	15.8
Total Mobile Radio Systems Equipment	12.4	14.2	16	12.3	10.9	13.2
Portable Radio Receivers, Transmitters	6.3	6.4	6	6.7	6.5	6.4
Radio Checkout Equipment	1.3	0.9	0.9	0.9	1.2	1
Total Mobile Communications Equipment	9.7	11	12.3	10.1	9.3	10.5
Broadcast & Radio						
Audio Equipment	5.2	4.8	3.9	4	3.6	4.3
Video Equipment	5.5	5.4	10.1	10	9.9	8.2
Transmitters, RF Power Amps	2.3	2.2	2.2	2.1	2.8	2.3
Studio Transmitter Links	3.7	3.6	3.4	3.3	3.2	3.5
Cable TV Equipment	8.6	7.4	7.1	5.4	5.6	6.8
CCTV	6.3	5.4	4.6	5.4	4.7	5.3
Other (Studio, Theater)	0	0	0	0	0	0
Total Broadcast & Radio	6	5.4	6.3	5.9	5.9	5.9
Other Telecom						
Intercomm. Equip., Elec. Ampl.	6.6	4.6	4.9	4.7	4.7	5.1
Communications Equipment, NEC	4.4	4.1	3.7	4.4	0.2	3.3
Total Other Telecom	4.6	4.1	3.8	4.4	0.6	3.5
Total Communication	6.9	6.9	6.9	6.7	5.8	6.6

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 25
Revenue from North American Industrial Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Industrial			
Security/Energy Management			
Alarm Systems			
Intrusion Detection	804	875	904
Fire Detection	477	532	550
Total Alarm Systems	1,281	1,407	1,454
Energy Management Systems	2,209	2,284	2,327
Total Security/Energy Management	3,490	3,691	3,781
Manufacturing Systems			
Semiconductor Production	1,696	1,691	1,691
Controllers & Actuators	3,895	3,985	3,880
Sensor Systems	1,640	1,765	1,710
Management Systems	3,569	3,683	3,790
Robotics	256	275	295
Total Manufacturing Systems	11,056	11,399	11,365
Instrumentation			
ATE-Semiconductor Equipment	570	597	610
ATE-Other	1,517	1,547	1,488
Oscilloscopes & Waveform Analyzers	785	836	801
Nuclear Instruments	606	651	617
Electrical Test Instruments	1,003	1,029	972
Other Test & Measurement	3,295	3,509	3,391
Total Instrumentation	7,776	8,168	7,879
Medical Equipment			
X-Ray	1,725	1,756	1,846
Ultrasonic & Scanning	320	329	349
Blood & Body Fluid Analyzers	605	618	654
Patient Monitoring Equipment	305	313	331
Other Diagnostic & Therapeutic	3,400	3,664	4,002
Total Medical Equipment	6,355	6,680	7,182
Other Industrial Systems	3,625	3,749	3,702
Total Industrial	32,302	33,687	33,909

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 26
Revenue from North American Industrial Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Industrial					
Security/Energy Management					
Alarm Systems					
Intrusion Detection	947	1,023	1,102	1,170	1,242
Fire Detection	577	608	641	676	713
Total Alarm Systems	1,524	1,631	1,743	1,846	1,955
Energy Management Systems	2,405	2,513	2,634	2,761	2,894
Total Security/Energy Management	3,929	4,144	4,377	4,607	4,849
Manufacturing Systems					
Semiconductor Production	1,521	1,690	2,001	2,302	2,620
Controllers & Actuators	4,024	4,321	4,615	4,938	5,284
Sensor Systems	1,866	2,028	2,193	2,379	2,588
Management Systems	3,907	4,024	4,137	4,249	4,355
Robotics	325	359	395	432	474
Total Manufacturing Systems	11,643	12,422	13,341	14,300	15,321
Instrumentation					
ATE-Semiconductor Equipment	537	584	679	774	885
ATE-Other	1,533	1,692	1,826	1,912	2,019
Oscilloscopes & Waveform Analyzers	862	920	982	1,046	1,114
Nuclear Instruments	656	686	728	774	823
Electrical Test Instruments	1,030	1,068	1,110	1,151	1,194
Other Test & Measurement	3,676	3,954	4,233	4,558	4,908
Total Instrumentation	8,294	8,904	9,558	10,215	10,943
Medical Equipment					
X-Ray	1,922	1,966	2,005	2,043	2,082
Ultrasonic & Scanning	368	385	402	422	443
Blood & Body Fluid Analyzers	686	712	736	763	791
Patient Monitoring Equipment	346	354	361	369	377
Other Diagnostic & Therapeutic	4,332	4,804	5,288	5,848	6,467
Total Medical Equipment	7,653	8,220	8,791	9,444	10,160
Other Industrial Systems	3,964	4,269	4,481	4,830	5,206
Total Industrial	35,482	37,958	40,547	43,395	46,479

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 27
Revenue Growth from North American Industrial Equipment Production, 1989-1991 (Percentage Change)

	1989	1990	1991
Industrial			
Security/Energy Management			
Alarm Systems			
Intrusion Detection	6.9	8.8	3.3
Fire Detection	15.5	11.5	3.4
Total Alarm Systems	10	9.8	3.3
Energy Management Systems	1.9	3.4	1.9
Total Security/Energy Management	4.7	5.8	2.4
Manufacturing Systems			
Semiconductor Production	10.1	-0.3	0
Controllers & Actuators	6.6	2.3	-2.6
Sensor Systems	8.5	7.6	-3.1
Management Systems	4.8	3.2	2.9
Robotics	11.8	7.4	7.3
Total Manufacturing Systems	6.9	3.1	-0.3
Instrumentation			
ATE-Semiconductor Equipment	-1.8	4.6	2.2
ATE-Other	10	2	-3.8
Oscilloscopes & Waveform Analyzers	9.9	6.5	-4.2
Nuclear Instruments	-1.6	7.4	-5.2
Electrical Test Instruments	2.3	2.6	-5.5
Other Test & Measurement	7.2	6.5	-3.4
Total Instrumentation	5.9	5	-3.5
Medical Equipment			
X-Ray	4	1.8	5.1
Ultrasonic & Scanning	2.9	2.8	6.1
Blood & Body Fluid Analyzers	1.7	2.1	5.8
Patient Monitoring Equipment	3	2.6	5.8
Other Diagnostic & Therapeutic	8.9	7.8	9.2
Total Medical Equipment	6.2	5.1	7.5
Other Industrial Systems	7.1	3.4	-1.3
Total Industrial	6.3	4.3	0.7

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 28
Revenue Growth from North American Industrial Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Industrial						
Security/Energy Management						
Alarm Systems						
Intrusion Detection	4.8	8	7.7	6.2	6.1	6.6
Fire Detection	4.9	5.4	5.4	5.5	5.5	5.3
Total Alarm Systems	4.8	7	6.9	5.9	5.9	6.1
Energy Management Systems	3.3	4.5	4.8	4.8	4.8	4.5
Total Security/Energy Management	3.9	5.5	5.6	5.3	5.3	5.1
Manufacturing Systems						
Semiconductor Production	-10.1	11.1	18.4	15	13.8	9.2
Controllers & Actuators	3.7	7.4	6.8	7	7	6.4
Sensor Systems	9.1	8.7	8.1	8.5	8.8	8.6
Management Systems	3.1	3	2.8	2.7	2.5	2.8
Robotics	10.2	10.5	10	9.4	9.7	9.9
Total Manufacturing Systems	2.4	6.7	7.4	7.2	7.1	6.2
Instrumentation						
ATE-Semiconductor Equipment	-12	8.8	16.3	14	14.3	7.7
ATE-Other	3	10.4	7.9	4.7	5.6	6.3
Oscilloscopes & Waveform Analyzers	7.6	6.7	6.7	6.5	6.5	6.8
Nuclear Instruments	6.2	4.6	6.1	6.3	6.4	5.9
Electrical Test Instruments	6	3.7	3.9	3.7	3.7	4.2
Other Test & Measurement	8.4	7.6	7.1	7.7	7.7	7.7
Total Instrumentation	5.3	7.4	7.3	6.9	7.1	6.8
Medical Equipment						
X-Ray	4.1	2.3	2	1.9	1.9	2.4
Ultrasonic & Scanning	5.4	4.6	4.4	5	5.1	4.9
Blood & Body Fluid Analyzers	4.9	3.8	3.4	3.7	3.6	3.9
Patient Monitoring Equipment	4.4	2.3	2	2.2	2.4	2.6
Other Diagnostic & Therapeutic	8.2	10.9	10.1	10.6	10.6	10.1
Total Medical Equipment	6.6	7.4	6.9	7.4	7.6	7.2
Other Industrial Systems	7.1	7.7	5	7.8	7.8	7.1
Total Industrial	4.6	7	6.8	7	7.1	6.5

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 29
Revenue from North American Consumer Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Consumer			
Audio			
Compact Disk Players	8	9	9
Radio	228	233	205
Stereo Components	208	207	204
Musical Instruments	235	240	235
Tape Recorders	19	18	18
Total Audio	698	707	671
Video			
VTRs, VCRs	245	265	266
Videodisk Players	1	1	1
Color Televisions	3,160	3,110	3,115
Total Video	3,406	3,376	3,382
Personal Electronics			
Games	301	316	335
Cameras	25	25	24
Watches	100	90	82
Clocks	53	50	48
Total Personal Electronics	479	481	489
Appliances			
Air Conditioners	1,846	1,935	1,683
Microwave Ovens	619	531	478
Washers & Dryers	2,981	3,032	2,973
Refrigerators	4,024	3,923	3,962
Dishwashers	979	981	971
Range & Ovens	982	956	966
Total Appliances	11,431	11,358	11,033
Other Consumer			
Automatic Garage Door Openers	255	263	260
Other Consumer Equipment, NEC	813	810	825
Total Other Consumer	1,068	1,073	1,085
Total Consumer	17,082	16,995	16,660

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 30
Revenue from North American Consumer Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Consumer					
Audio					
Compact Disk Players	9	9	9	9	9
Radio	212	219	227	235	243
Stereo Components	214	227	238	248	260
Musical Instruments	238	253	265	277	289
Tape Recorders	17	17	17	17	17
Total Audio	690	725	756	786	818
Video					
VTRs, VCRs	272	290	309	329	350
Videodisk Players	0	0	0	0	0
Color Televisions	3,193	3,337	3,487	3,644	3,808
Total Video	3,465	3,627	3,796	3,973	4,158
Personal Electronics					
Games	347	359	371	384	398
Cameras	24	25	26	27	28
Watches	75	70	65	60	55
Clocks	48	49	49	49	49
Total Personal Electronics	494	503	511	520	530
Appliances					
Air Conditioners	1,758	1,855	1,957	2,065	2,168
Microwave Ovens	500	527	556	587	616
Washers & Dryers	3,106	3,277	3,457	3,648	3,830
Refrigerators	4,141	4,368	4,609	4,862	5,105
Dishwashers	1,015	1,071	1,130	1,192	1,251
Range & Ovens	1,009	1,065	1,123	1,185	1,244
Total Appliances	11,529	12,163	12,832	13,539	14,214
Other Consumer					
Automatic Garage Door Openers	272	284	297	310	324
Other Consumer Equipment, NEC	862	914	969	1,027	1,083
Total Consumer	17,312	18,216	19,161	20,155	21,127

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 31
Revenue Growth from North American Consumer Equipment Production, 1989-1991 (Percentage Change)

	1989	1990	1991
Consumer			
Audio			
Compact Disk Players	166.7	12.5	0
Radio	-9.2	2.2	-12
Stereo Components	1	-0.5	-1.4
Musical Instruments	4.4	2.1	-2.1
Tape Recorders	5.6	-5.3	0
Total Audio	-0.7	1.3	-5.1
Video			
VTRs, VCRs	-7.5	8.2	0.4
Videodisk Players	-88.9	0	0
Color Televisions	22	-1.6	0.2
Total Video	18.9	-0.9	0.2
Personal Electronics			
Games	32.6	5	6
Cameras	8.7	0	-4
Watches	0	-10	-8.9
Clocks	-3.6	-5.7	-4
Total Personal Electronics	18.3	0.4	1.7
Appliances			
Air Conditioners	6.8	4.8	-13
Microwave Ovens	-13.5	-14.2	-10
Washers & Dryers	3.2	1.7	-1.9
Refrigerators	20.8	-2.5	1
Dishwashers	11.1	0.2	-1
Range & Ovens	4.7	-2.6	1
Total Appliances	9.1	-0.6	-2.9
Other Consumer			
Automatic Garage Door Openers	-3.8	3.1	-1.1
Other Consumer Equipment, NEC	10.5	-0.4	1.9
Total Other Consumer	6.7	0.5	1.1
Total Consumer	10.5	-0.5	-2

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 32
Revenue Growth from North American Consumer Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Consumer						
Audio						
Compact Disk Players	0	0	0	0	0	0
Radio	3.4	3.3	3.7	3.5	3.4	3.5
Stereo Components	4.9	6.1	4.8	4.2	4.8	5
Musical Instruments	1.3	6.3	4.7	4.5	4.3	4.2
Tape Recorders	-5.6	0	0	0	0	-1.1
Total Audio	2.8	5.1	4.3	4	4.1	4
Video						
VTRs, VCRs	2.3	6.6	6.6	6.5	6.4	5.6
Videodisk Players	NM	NM	NM	NM	NM	-100
Color Televisions	2.5	4.5	4.5	4.5	4.5	4.1
Total Video	2.5	4.7	4.7	4.7	4.7	4.2
Personal Electronics						
Games	3.6	3.5	3.3	3.5	3.6	3.5
Cameras	0	4.2	4	3.8	3.7	3.1
Watches	-8.5	-6.7	-7.1	-7.7	-8.3	-7.7
Clocks	0	2.1	0	0	0	0.4
Total Personal Electronics	1	1.8	1.6	1.8	1.9	1.6
Appliances						
Air Conditioners	4.5	5.5	5.5	5.5	5	5.2
Microwave Ovens	4.6	5.4	5.5	5.6	4.9	5.2
Washers & Dryers	4.5	5.5	5.5	5.5	5	5.2
Refrigerators	4.5	5.5	5.5	5.5	5	5.2
Dishwashers	4.5	5.5	5.5	5.5	4.9	5.2
Range & Ovens	4.5	5.6	5.4	5.5	5	5.2
Total Appliances	4.5	5.5	5.5	5.5	5	5.2
Other Consumer						
Automatic Garage Door Openers	4.6	4.4	4.6	4.4	4.5	4.5
Other Consumer Equipment, NEC	4.5	6	6	6	5.5	5.6
Total Other Consumer	4.5	5.6	5.7	5.6	5.2	5.3
Total Consumer	3.9	5.2	5.2	5.2	4.8	4.9

Note: Columns may not add to totals shown because of rounding.
NM = Not meaningful
Source: Dataquest (August 1992)

Table 33
Revenue from North American Military/Civil Aerospace Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Military/Civil Aerospace			
Military Aerospace			
Radar/Sonar	9,326	9,000	7,182
Missile-Weapon	6,461	6,280	6,085
Space	5,552	5,608	5,022
Communication/Navigation	6,546	6,317	5,230
Electronic Warfare	5,571	5,627	4,628
Aircraft Systems	4,312	4,204	3,390
Computer Systems	2,308	2,421	2,430
Simulation	845	946	1,004
Misc. Equipment, NEC	10,806	10,698	9,662
Total Military Aerospace	51,727	51,101	44,633
Civil Aerospace			
Radar	2,080	2,288	2,495
Space	2,818	3,114	3,343
Communication/Navigation	808	990	1,165
Flight Systems	2,198	2,791	3,291
Simulation	245	285	330
Total Civil Aerospace	8,149	9,468	10,624
Total Military/Civil Aerospace	59,876	60,569	55,257

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 34
Revenue from North American Military/Civil Aerospace Equipment Production, 1992-1996
(Millions of Dollars)

	1992	1993	1994	1995	1996
Military/Civil Aerospace					
Military Aerospace					
Radar/Sonar	6,643	6,411	6,186	5,970	5,761
Missile-Weapon	6,420	6,709	7,010	7,326	7,656
Space	4,595	4,687	4,781	4,805	4,757
Communication/Navigation	4,969	4,919	4,870	4,821	4,676
Electronic Warfare	4,420	4,353	4,332	4,288	4,203
Aircraft Systems	3,237	3,205	3,173	3,189	3,125
Computer Systems	2,527	2,628	2,733	2,843	2,956
Simulation	1,054	1,107	1,162	1,220	1,281
Misc. Equipment, NEC	9,324	8,904	8,459	7,952	7,395
Total Military Aerospace	43,189	42,923	42,706	42,414	41,810
Civil Aerospace					
Radar	2,695	2,897	3,114	3,301	3,466
Space	3,711	4,397	5,277	6,332	7,598
Communication/Navigation	1,270	1,371	1,467	1,570	1,680
Flight Systems	3,702	4,073	4,460	4,839	5,080
Simulation	370	407	439	468	498
Total Civil Aerospace	11,748	13,145	14,757	16,510	18,322
Total Military/Civil Aerospace	54,937	56,068	57,463	58,924	60,132

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 35
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1989-1991 (Percentage Change)

	1989	1990	1991
Military/Civil Aerospace			
Military Aerospace			
Radar/Sonar	-1.9	-3.5	-20.2
Missile-Weapon	1.2	-2.8	-3.1
Space	7.8	1	-10.4
Communication/Navigation	2.3	-3.5	-17.2
Electronic Warfare	0.6	1	-17.8
Aircraft Systems	-0.3	-2.5	-19.4
Computer Systems	4.6	4.9	0.4
Simulation	13.6	12	6.1
Misc. Equipment, NEC	0	-1	-9.7
Total Military Aerospace	1.3	-1.2	-12.7
Civil Aerospace			
Radar	14	10	9
Space	14.1	10.5	7.4
Communication/Navigation	13.3	22.5	17.7
Flight Systems	16.2	27	17.9
Simulation	13.4	16.3	15.8
Total Civil Aerospace	14.5	16.2	12.2
Total Military/Civil Aerospace	2.9	1.2	-8.8

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 36
Revenue Growth from North American Military/Civil Aerospace Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Military/Civil Aerospace						
Military Aerospace						
Radar/Sonar	-7.5	-3.5	-3.5	-3.5	-3.5	-4.3
Missile-Weapon	5.5	4.5	4.5	4.5	4.5	4.7
Space	-8.5	2	2	0.5	-1	-1.1
Communication/Navigation	-5	-1	-1	-1	-3	-2.2
Electronic Warfare	-4.5	-1.5	-0.5	-1	-2	-1.9
Aircraft Systems	-4.5	-1	-1	0.5	-2	-1.6
Computer Systems	4	4	4	4	4	4
Simulation	5	5	5	5	5	5
Misc. Equipment, NEC	-3.5	-4.5	-5	-6	-7	-5.2
Total Military Aerospace	-3.2	-0.6	-0.5	-0.7	-1.4	-1.3
Civil Aerospace						
Radar	8	7.5	7.5	6	5	6.8
Space	11	18.5	20	20	20	17.8
Communication/Navigation	9	8	7	7	7	7.6
Flight Systems	12.5	10	9.5	8.5	5	9.1
Simulation	12.1	10	7.9	6.6	6.4	8.6
Total Civil Aerospace	10.6	11.9	12.3	11.9	11	11.5
Total Military/Civil Aerospace	-0.6	2.1	2.5	2.5	2.1	1.7

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 37
Revenue from North American Transportation Equipment Production, 1989-1991 (Millions of Dollars)

	1989	1990	1991
Transportation			
Entertaiment	490	442	403
Vehicle Controls	397	463	481
Body Controls	57	74	78
Driver Information	710	705	645
Powertrain	2,073	1,875	1,704
Safety & Convenience	426	556	570
Total Transportation	4,153	4,115	3,881
Total Electronic Equipment	219,273	226,535	215,230

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 38
Revenue from North American Transportation Equipment Production, 1992-1996 (Millions of Dollars)

	1992	1993	1994	1995	1996
Transportation					
Entertaiment	429	446	458	466	475
Vehicle Controls	566	737	846	966	1,051
Body Controls	82	85	88	91	118
Driver Information	710	749	777	800	817
Powertrain	1,806	1,889	1,945	1,977	2,019
Safety & Convenience	659	788	882	965	1,036
Total Transportation	4,252	4,694	4,996	5,265	5,516
Total Electronic Equipment	221,881	231,568	243,481	254,763	267,406

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 39
Revenue Growth from North American Transportation Equipment Production, 1989-1991 (Percentage Change)

	1989	1990	1991
Transportation			
Entertaiment	-3.9	-9.8	-8.8
Vehicle Controls	5.3	16.6	3.9
Body Controls	35.7	29.8	5.4
Driver Information	1	-0.7	-8.5
Powertrain	-2.4	-9.6	-9.1
Safety & Convenience	13.3	30.5	2.5
Total Transportation	0.5	-0.9	-5.7
Total Electronic Equipment	6.1	3.3	-5.0

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Table 40
Revenue Growth from North American Transportation Equipment Production, 1992-1996 (Percentage Change)

	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Transportation						
Entertaiment	6.5	4	2.7	1.7	1.9	3.3
Vehicle Controls	17.7	30.2	14.8	14.2	8.8	16.9
Body Controls	5.1	3.7	3.5	3.4	29.7	8.6
Driver Information	10.1	5.5	3.7	3	2.1	4.8
Powertrain	6	4.6	3	1.6	2.1	3.5
Safety & Convenience	15.6	19.6	11.9	9.4	7.4	12.7
Total Transportation	9.6	10.4	6.4	5.4	4.8	7.3
Total Electronic Equipment	3.1	4.4	5.1	4.6	5.0	4.4

Note: Columns may not add to totals shown because of rounding.
Source: Dataquest (August 1992)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Incorporated Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
United States
Phone: 01-714-957-0171
Facsimile: 01-714-957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: 61-2-959-4544
Facsimile: 61-2-929-0635

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: 33-1-48-97-3100
Facsimile: 33-1-48-97-3400

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 49-89-930-9090
Facsimile: 49-89-930-3277

Dataquest Germany
In der Schneithohl 17
6242 Kronberg 2
Germany
Phone: 49-6173/61685
Facsimile: 49-6173/67901

Dataquest Hong Kong
Rm. 4A01
HKPC Building
78 Tat Chee Avenue
Kowloon, Hong Kong
Phone: 852-788-5432
Facsimile: 852-788-5433

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo, 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Daeheung Building 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul 135-080, Korea
Phone: 82-2-556-4166
Facsimile: 82-2-552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 65-4597181
Telex: 38257
Facsimile: 65-4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sec. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: 886-2-501-7960
886-2-501-5592
Facsimile: 886-2-505-4265

Dataquest Thailand
300/31 Rachdapisek Road
Bangkok 10310
Thailand
Phone: 66-2-275-1904/5
66-2-277-8850
Facsimile: 66-2-275-7005

Dataquest

Semiconductor Application Markets *Worldwide*

Dataquest Perspective

Dataquest

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, CA 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

United Kingdom
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Nr Uxbridge,
Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

France
Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (01)48 97 34 00

Germany
Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
011 49 89 93 09 09 0
Fax: 011 49 89 930 3277

Japan
Dataquest Japan Limited
Shinkawa Sanko Building 2 Fl
1-3-17 Shinkawa
Chuo-kuTokyo 104
Japan
011-81-3-5566-0411
Telex: 781-32768
Fax: 011-81-3-5566-0425

Korea
Dataquest Korea
Dacheung Building Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-80
Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
(508) 370-5555
Fax: (508) 370-6262

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Dataquest Perspective Index

Semiconductor Application Markets *Worldwide*

SAWW-SVC-IX-9201 April 30, 1992

How to Use This Index

This is a cumulative index of key industry terms, companies, and products for the first quarter 1992 issues of *Dataquest Perspective*. Entries are followed by the date of publication and the page number(s). Product names are listed under the company that manufactures/publishes the product. General information about a company itself is found under the full company name. Each citation indicates only the beginning page of a discussion of a topic (the range of page numbers is not cited). A Table of Contents for the first quarter 1992 issues of *Dataquest Perspective*—listing each issue number, date, and article title—is included at the end of the index.

A

B

C

D

E

F

H

I

L

M

N

O

P

R

S

T

U

V

W

Dataquest Perspective issues covered in this index:

Dataquest
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Dataquest Perspective

Semiconductor Application Markets
Worldwide
Index

October-December 1991 January 31, 1992

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D

E

F

G

H

I

J

L

M

N

O

P

R

S

T

U

V

W

X

Z

***Dataquest Perspective* issues covered in this index:**

Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9212 December 14, 1992

In This Issue...

Market Analysis

Personal Computer Market Update

Personal computers have become the "leading economic indicator" for the entire electronics industry in recent years, and as a result, a PC market snapshot and forecast is quite handy.

This article presents a PC revenue and shipment forecast provided by Dataquest's Personal Computer group. The overall PC market has seen anemic unit growth recently, along with severe pricing pressure that has forced a number of vendors to exit the market, or as in the case of IBM and Compaq, reevaluate their strategy and product pricing/offerings. The short-term outlook remains cloudy, although there are some pockets of hope and some things are clear.

The notebook PC is a fast-growing market. But what, in terms of growth, is next? The personal information and communications devices (PICDs) class of machines (also known as personal communicators or personal digital assistants) represent a likely candidate. They promise to integrate the power of the PC with that of the telephone and, perhaps further out in time, that of TV/video.

Meanwhile, this article explains what is expected to unfold in the next couple of years, given what we know today.

Table 1 shows regional PC revenue and unit shipments. Historical data for the years 1989 through 1991 are presented, along with the near-term forecast for 1992 and 1993. The United States shows the lowest unit and factory revenue growth—6.2 percent and 0.73 percent, respectively, over the period from 1989 to 1993.

Table 2 is the worldwide revenue and shipment forecast by product type. It comes as no surprise that the highest growth rate is expected in

Table 1
Revenue and Shipments of Personal Computers to Each Region

Region	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
United States						
Units (K)	9,330	9,849	10,183	10,987	11,866	6.20
ASP ($K)	1.96	1.89	1.81	1.66	1.59	
Factory Revenue ($M)	18,296	18,661	18,428	18,218	18,836	0.73
Canada						
Units (K)	814	858	884	1,008	1,084	7.44
ASP ($K)	1.51	1.69	1.67	1.59	1.57	
Factory Revenue ($M)	1,227	1,448	1,474	1,603	1,699	8.47
Western Europe						
Units (K)	6,855	7,955	8,572	9,167	9,834	9.44
ASP ($K)	1.94	1.97	1.75	1.53	1.49	
Factory Revenue ($M)	12,210	14,810	14,519	13,990	14,696	4.74
Japan						
Units (K)	1,892	2,244	2,363	2,491	2,711	9.41
ASP ($K)	1.56	1.79	1.96	1.96	1.89	
Factory Revenue ($M)	2,955	4,017	4,631	4,875	5,116	14.71
Other Asia/Pacific						
Units (K)	665	783	971	1,004	1,025	11.41
ASP ($K)	1.45	1.48	1.29	1.38	1.23	
Factory Revenue ($M)	967	1,157	1,257	1,383	1,258	6.80
Rest of World						
Units (K)	1,771	1,918	2,018	2,809	3,335	17.15
ASP ($K)	1.58	1.58	1.52	1.48	1.41	
Factory Revenue ($M)	2,790	3,029	3,077	4,157	4,702	13.94
Worldwide						
Units (K)	21,327	23,606	24,991	27,466	29,855	8.77
ASP ($K)	1.80	1.83	1.74	1.61	1.55	
Factory Revenue ($M)	38,446	43,121	43,386	44,225	46,308	4.76

Source: Dataquest (December 1992)

notebook PCs, with hand-helds coming in second. Transportable, laptop AC, and laptop DC PCs are expected to follow a rather steep decline, both in terms of unit shipments and factory revenue. In 1993 these categories will account for just 1.7 percent of all PC unit shipments and 1.7 percent of factory revenue.

Table 3 breaks out worldwide PC shipments and revenue by input device, splitting them into two categories: PCs that use the keyboard, and PCs that use a pen as the primary input device. It is worth noting that this represents a definitional change that has resulted in the elimination of "pen-based PCs" as a product type. PCs that use

Table 2
Worldwide Revenue and Shipments of Personal Computers, by Product Type

Product Type	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
Transportable						
Units (K)	151	117	77	42	24	-37.00
ASP ($K)	3.07	3.58	4.32	4.25	4.15	
Factory Revenue ($M)	463	418	332	179	99	-32.05
Laptop AC						
Units (K)	352	353	120	65	37	-43.12
ASP ($K)	2.74	3.08	3.07	3.00	2.75	
Factory Revenue ($M)	965	1,089	370	194	101	-43.06
Laptop DC						
Units (K)	1,568	2,028	1,757	712	445	-27.01
ASP ($K)	1.97	2.03	1.55	1.35	1.31	
Factory Revenue ($M)	3,094	4,110	2,724	960	582	-34.13
Notebook						
Units (K)	86	972	2,310	3,669	5,981	189.03
ASP ($K)	1.74	1.52	1.71	1.59	1.53	
Factory Revenue ($M)	149	1,472	3,939	5,845	9,146	179.76
Hand-Held						
Units (K)	82	222	237	332	482	55.71
ASP ($K)	0.20	0.20	0.35	0.32	0.31	
Factory Revenue ($M)	17	44	82	106	148	72.73
Desktop						
Units (K)	18,796	19,259	19,433	21,262	21,239	3.10
ASP ($K)	1.73	1.71	1.65	1.52	1.46	
Factory Revenue ($M)	32,426	33,003	32,061	32,273	30,949	-1.16
Deskside						
Units (K)	291	654	1,057	1,383	1,648	54.20
ASP ($K)	4.57	4.56	3.67	3.38	3.21	
Factory Revenue ($M)	1,333	2,985	3,879	4,670	5,283	41.10
Total						
Units (K)	21,327	23,606	24,991	27,466	29,855	8.77
Factory Revenue ($M)	38,446	43,121	43,386	44,225	46,308	4.76

Source: Dataquest (December 1992)

a pen instead of a keyboard are becoming more popular as operating systems, hardware, and application software become readily available (and affordable). The main "pen-based" operating systems suppliers are GO, which offers PenPoint, Microsoft with Pen for Windows, and CIC with PenDOS.

Pen-centric PCs will exhibit very high growth rates, both in terms of unit shipments and revenue. However, the volume (and most of the revenue) in the short term will come from PCs that use a keyboard as their primary input device.

Table 4 breaks out worldwide PC shipments and revenue by microprocessor type. As expected, PCs using anything below an 80386 will exhibit a rapid decline. The highest growth will be found in PCs that use the 80486 class of microprocessor. The 486 is now the processor of choice for notebook PCs. The 68xxx microprocessor-based PCs show a healthy growth pattern, led of course by Apple. A couple of new entrants (not included in this discussion) worth noting, because they appear to be the microprocessors of choice for PICDs, are AT&T's Hobbit RISC microprocessor used by EO

Table 3
Worldwide Revenue and Shipments of Personal Computers, by Input Device

Input Device	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
Pen-Based						
Units (K)	1	10	27	87	450	360.58
ASP ($K)	1.85	1.68	1.90	2.20	2.30	
Factory Revenue ($M)	2	17	51	191	1,035	386.54
Keyboard						
Units (K)	21,326	23,596	24,964	27,379	29,405	8.36
ASP ($K)	1.80	1.83	1.74	1.61	1.54	
Factory Revenue ($M)	38,445	43,104	43,335	44,034	45,273	4.17
Total						
Units (K)	21,327	23,606	24,991	27,466	29,855	8.77
ASP ($K)	1.80	1.83	1.74	1.61	1.55	
Factory Revenue ($M)	38,446	43,121	43,386	44,225	46,308	4.76

Source: Dataquest (December 1992)

Table 4
Worldwide Revenue and Shipments of Personal Computers, by Microprocessor Type

Microprocessor	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
8088/8086						
Units (K)	4,733	3,497	1,148	610	308	-49.47
ASP ($K)	1.08	1.11	0.80	0.67	0.37	
Factory Revenue ($M)	5,094	3,874	913	409	114	-61.32
80286						
Units (K)	7,883	7,101	4,101	1,345	423	-51.86
ASP ($K)	1.95	1.69	1.32	0.79	0.56	
Factory Revenue ($M)	15,401	12,023	5,424	1,067	235	-64.85

(Continued)

Table 4 (Continued)
Worldwide Revenue and Shipments of Personal Computers, by Microprocessor Type

Microprocessor	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
80386SX/SL						
Units (K)	1,482	4,629	8,624	8,724	5,823	40.79
ASP ($K)	2.37	2.02	1.70	1.39	1.13	
Factory Revenue ($M)	3,519	9,351	14,629	12,152	6,554	16.82
80386DX						
Units (K)	2,629	3,756	4,544	5,285	2,760	1.22
ASP ($K)	3.34	2.89	2.46	1.92	1.49	
Factory Revenue ($M)	8,769	10,843	11,163	10,128	4,113	-17.24
80486 SX/SL						
Units (K)	0	0	413	3,203	10,682	NM
ASP ($K)	0	0	2.19	1.86	1.61	
Factory Revenue ($M)	0	0	904	5,957	17,230	NM
80486 (DX/DX2)						
Units (K)	2	230	1,487	2,892	3,812	554.45
ASP ($K)	5.31	5.42	3.04	2.36	2.01	
Factory Revenue ($M)	11	1,248	4,518	6,826	7,647	413.05
Pentium (P5) (80586)						
Units (K)	0	0	0	0	372	NM
ASP ($K)	0	0	0	0	5.40	
Factory Revenue ($M)	0	0	0	0	2,010	NM
68xxx						
Units (K)	2,494	2,929	3,674	4,952	5,497	21.85
ASP ($K)	1.70	1.71	1.53	1.53	1.52	
Factory Revenue ($M)	4,251	5,016	5,610	7,577	8,344	18.36
Others						
Units (K)	2,104	1,463	1,002	453	177	-46.18
ASP ($K)	0.67	0.52	0.22	0.24	0.35	
Factory Revenue ($M)	1,402	767	224	109	61	-54.26
Total						
Units (K)	21,327	23,606	24,991	27,466	29,855	8.77
Factory Revenue ($M)	38,446	43,121	43,386	44,225	46,308	4.76

NM = Not meaningful
Source: Dataquest (December 1992)

Inc. in the EO-440 and EO-880 Personal Communicators, and VLSI's ARM RISC microprocessor used by Apple in its Newton PDA. Future inclusion of these micros may change the slope of the "Others" category in Table 4.

Table 5 shows the worldwide revenue and shipment PC forecast by bus type. Here the volume and majority of the revenue is shifting rapidly from the AT bus to the Busless/PCMCIA/Other type, which appears to be the configuration of choice for both notebook and hand-held PCs.

Figure 1 is a graphic representation of the estimated 1993 personal computer factory revenue derived from sales into each region of the world. Sales into the United States comprise 40 percent of all factory PC revenue, while 32 percent is derived from sales into Western Europe, and only 11 percent from sales into Japan.

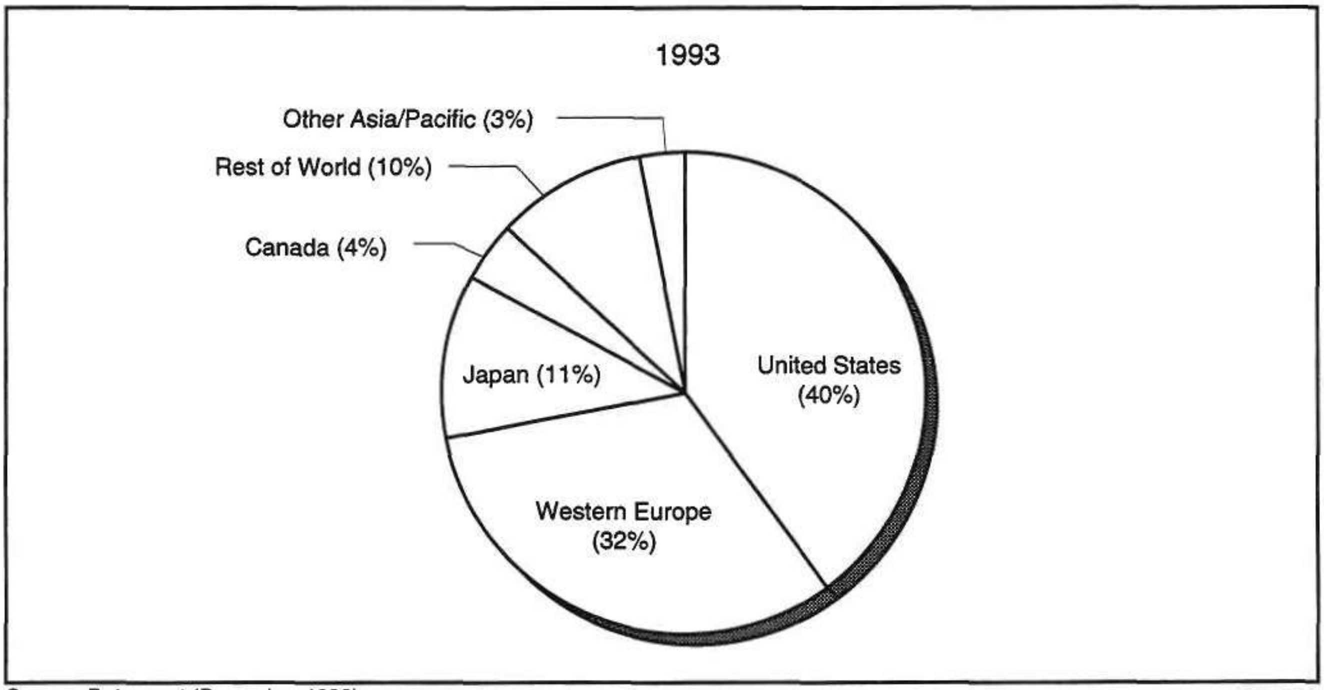
Figure 2 shows estimated 1993 worldwide revenue by product type. Worth noting is that the hand-held PC sales will still be below 1 percent of total PC sales, while in terms of

Table 5
Worldwide Revenue and Shipments of Personal Computers, by Bus Type

Bus Type	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
PC/XT						
Units (K)	3,906	2,061	536	285	0	-100.00
ASP ($K)	1.08	0.98	0.83	0.51	0	
Factory Revenue ($M)	4,234	2,026	444	145	0	-100.00
AT						
Units (K)	10,001	11,007	12,977	15,177	15,537	11.64
ASP ($K)	2.27	2.24	1.88	1.36	1.13	
Factory Revenue ($M)	22,703	24,655	24,378	20,575	17,481	-6.33
MCA (16-bit)						
Units (K)	867	516	131	0	0	-100.00
ASP ($K)	2.59	2.27	2.09	1.79	1.53	
Factory Revenue ($M)	2,245	1,173	274	0	0	-100.00
MCA (32-bit)						
Units (K)	1,121	1,936	2,050	1,927	1,830	13.03
ASP ($K)	4.26	3.14	3.03	2.76	2.51	
Factory Revenue ($M)	4,773	6,083	6,220	5,313	4,587	-0.99
EISA						
Units (K)	4	272	474	593	693	258.43
ASP ($K)	6.82	6.27	5.58	4.41	3.78	
Factory Revenue ($M)	29	1,707	2,644	2,613	2,620	209.24
Busless/PCMCIA/Others						
Units (K)	5,427	7,814	8,823	9,484	11,794	21.42
ASP ($K)	0.82	0.96	1.07	1.64	1.83	
Factory Revenue ($M)	4,463	7,477	9,426	15,579	21,619	48.35
Total						
Units (K)	21,327	23,606	24,991	27,466	29,855	8.77
Factory Revenue ($M)	38,446	43,121	43,386	44,225	46,308	4.76

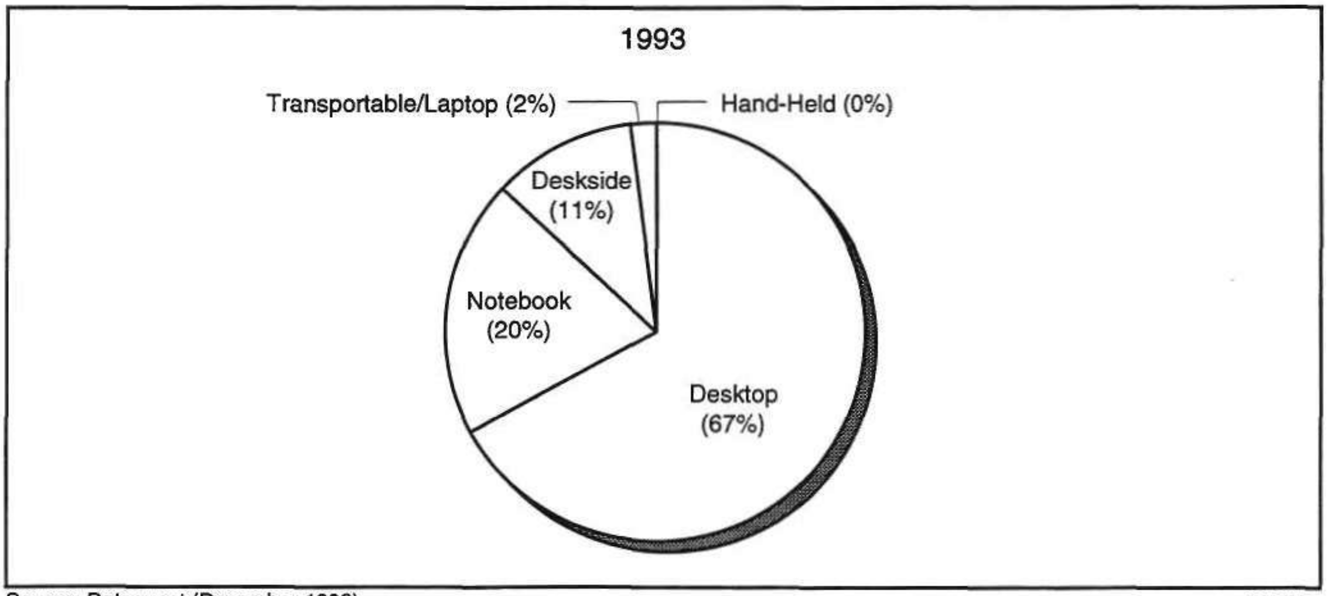
Source: Dataquest (December 1992)

Figure 1
Worldwide Factory Revenue: Personal Computers to Each Region



Source: Dataquest (December 1992) G2001980

Figure 2
Personal Computer Worldwide Revenue, by Product Type



Source: Dataquest (December 1992) G2001981

unit shipments they will account for 2 percent of total PCs shipped. The lion's share will be still represented by desktop PCs, with 67 percent, followed by notebooks at 20 percent of the total.

Dataquest Perspective

Personal computer vendors are still under substantial pricing pressures. Even though in 1993 we expect to see an overall worldwide unit growth of 8.77 percent, revenue will grow only by 4.76 percent, lagging well behind unit shipments. In the United States, the figures are expected to be even lower. Unit sales will grow 6.2 percent while revenue growth will be just under 1 percent.

The good news is that there are pockets of hope. Major vendors such as IBM, Compaq, Apple, and Toshiba have substantial PC backlogs. Another recent phenomenon is the shift of notebooks to 486SL, and at COMDEX in Las Vegas Intel's booth hosted nearly 40 new notebooks designed around the 486SL. Notebook PCs will grow by nearly 190 percent in 1993 in terms of units and 180 percent in terms of revenue. Notebooks are hot and represent the area of opportunity for semiconductor vendors in the immediate future. Further out, tablet-type PCs using the "pen" as the main input device and PICDs are expected to spur growth for the PC industry and semiconductor vendors alike.

By Nicolas Samaras

Interactive Multimedia Players: An "Edu-tainment Opportunity"

A new type of interactive consumer electronic product is emerging, targeted at the gap between TV-based video game systems and personal computers. These systems provide a sophisticated interactive access for users of CD-ROM titles laden with animation, sound, images, and eventually motion video. These titles encompass games, home-based early education, art, music, and "living" references such as encyclopedias and how-to guides. These systems can either be hooked up to a TV or be portable, with their own color LCDs. They range in price from $600 to $2,500.

This market is in its infant stage. Various approaches are vying for control of title developer commitment and sales channels. The battling solutions include upgrades of existing video game and PC offerings, as well as a new type of product called an interactive multimedia player, which, from a capability standpoint, falls in between. Dataquest projects that the worldwide market for the latter category could reach nearly 2.5 million units by 1996, with a corresponding chip consumption of nearly $270 million.

Interactive Choices

The two principal suppliers of these systems are Philips (and partners) and Commodore. New entrants are planned for 1993, one of them a new concern called The 3DO Company based in San Mateo, California. The following paragraphs focus on the Philips CD-I, Commodore CDTV, and the recently introduced Tandy VIS offerings to exemplify the status of the market.

Compact Disc Interactive

Compact disc interactive (CD-I) is a TV-top system that incorporates a CD-ROM player capable of interactive output of CD-quality sound, animation, images, and limited motion video. The player can use regular CD audio-disks, a CD-I disk, and a PhotoCD disk (a feature jointly developed with the Eastman Kodak Company that allows customers to send photos to a service bureau such as Kodalux for encoding onto a disk for display on the home TV set at a cost of $29 service for 24 exposures). Kodak also is producing a dedicated PhotoCD player.

About 60 titles are available for CD-I in the United States, with a total of 100 expected by the end of 1992, and 200 by the end of 1993. The title prices range from $20 to $60 and comprise children's, game, and informational offerings. CD-I is targeted at middle-income families and will be available through 2,000 consumer electronic outlets in the United States by the end of 1992. Philips has also enlisted outlets such as Blockbuster to promote CD-I, complete with interactive kiosks. A multimillion-dollar national TV advertising campaign was also launched to continue building awareness. Philips also has a business/industrial version of CD-I. It just introduced a portable version complete with built-in LCD. In the summer of 1992, CD-I 1992 rolled out in Japan and Europe after being introduced in the United States in October 1991. The suggested retail U.S. price of consumer CD-I players as of November 1992 was $699.

Because multimedia is highly dependent on culture and language, regional titles need to be developed. CD-I associations have been set up in each region to work with title developers.

Planned upgrades include a plug-in MPEG decompression module for full-motion, full-screen video (up to 74 minutes) that is due out in early 1993. Future CD-Is could incorporate other interactive features such as modems for dial-up access a la video/teletext. The technology (called Green Book) is licensed with several Japanese consumer electronics companies including Sony (cofounder), Nintendo, Kyocera, Sanyo, JVC, Japan Marantz, Matsushita, and Yamaha. These companies are expected to enter the market in 1992 and 1993 with many variations, including other portables.

The CD-I player centers on the Motorola 68000 16/32-bit architecture and employs a 68070 16-bit processor, several custom ASICs, 1MB of RAM, and 8KB of EEPROM. We can expect the architecture to move to 32 bits and integrate the MPEG decoder module functionality for full-motion support. Figure 1 shows a block diagram.

Commodore Dynamic Total Vision

Commodore Dynamic Total Vision (CDTV) conceptually is similar to CD-I. Commodore claims 92 titles, with that many more on the way. It also claims that it has 1,000 outlets in the United States. CDTV is built around the Amiga 500 computer and is based on a 68000 MPU and three video-processing ASICs, with 1MB of RAM. Commodore has begun to roll out the A750 disk CD-ROM drive ($600), which attaches to existing Amigas and allows them CDTV capability. Underscoring the latter opportunity are the 3 million installed Amigas.

Video Information System

Tandy, working with Microsoft and a modular version of Windows software, has just introduced a home interactive system called Video Information System (VIS). Anchored on a CD-ROM variant and a 12-MHz 286 processor, and employing several ASICs, the system will be priced at about $700. Claiming that 50 software titles are on the way, Tandy hopes to leverage its large retail presence and user familiarity with Windows to its advantage.

CD-ROM Enhanced Video Games

The TV video game business also is moving into multimedia. Dataquest estimates that 16.5 million TV video games were produced in 1991 in Japan, which dominates production. About half were the new 16-bit variety on a unit basis. Nintendo has an estimated 73 percent share of the unit market; Sega (JVC manufacturer) has 22 percent. NEC, Sharp, and NEO-GEO round out the list of secondary manufacturers. Growth in the video game business is toward CD-ROM enhanced versions with 650MB storage capability. CD-ROM brings the capacity to greatly enhance the animation and to add images and motion video, plus CD-quality sound.

The video game industry has stated that it could ship 1 million units of CD-ROM attachments ($200 to $300 retail) from mid-1992 through mid-1993. Title development is still under way to support further growth. Dataquest further estimates that about 90 percent of the TV video games shipped in 1996 will incorporate CD-ROM or CD-I. Plans include moving to 32-bit architectures and perhaps adding communications capability such as built-in modems to tap into the TV-based video/teletext movement.

In a recent move, Nintendo and Sony have agreed to set differences aside and Nintendo will have Sony build CD-ROM drives for future updates of their system. The drives will be based on the XA or extended audio standard, which allows compressed ADPCM audio to be interleaved with animation for higher performance, more interactive title usage.

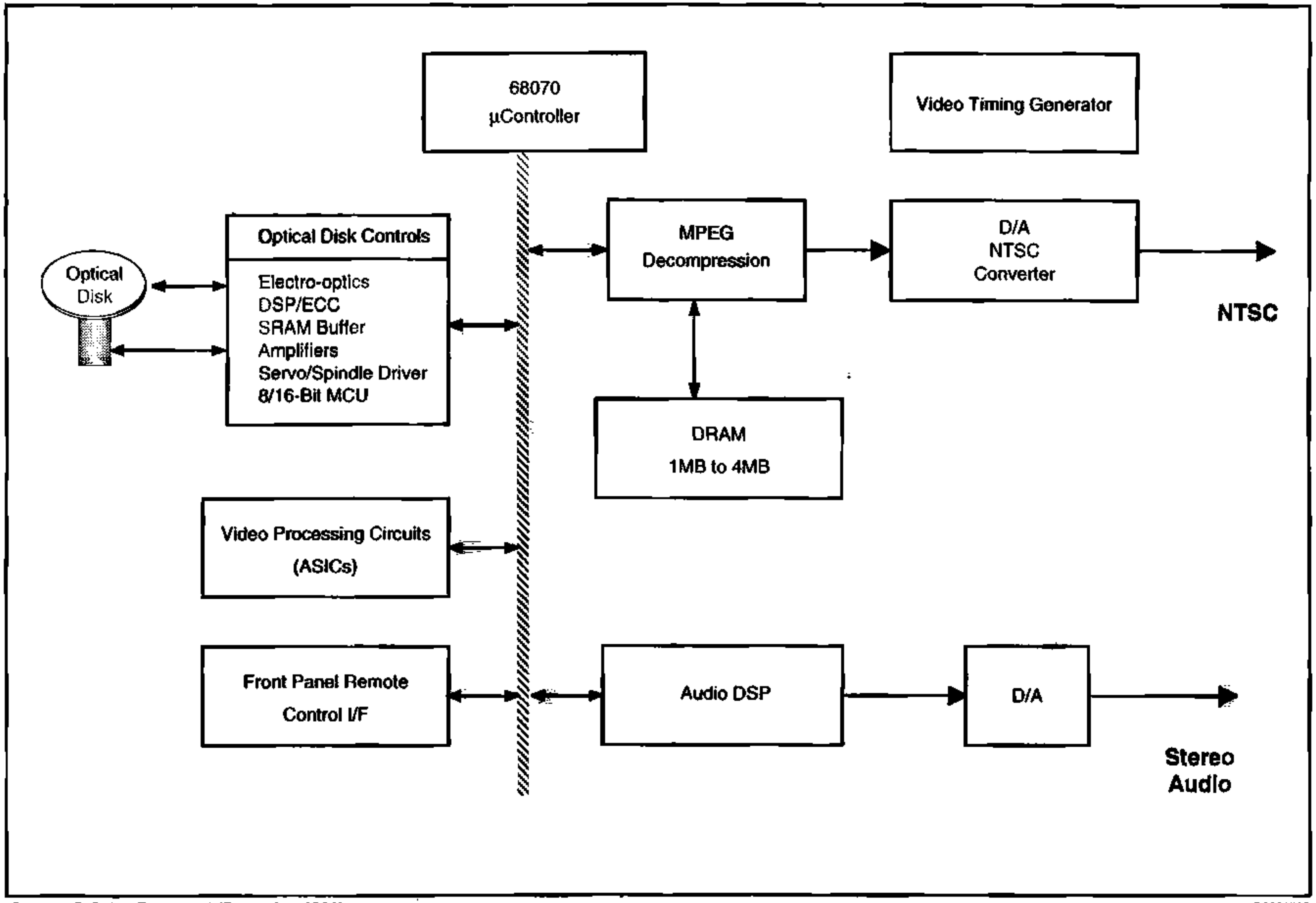
Enhanced Multimedia PCs

PC-based video game playing is a sizable business, as the million-plus Sound Blaster cards already shipped worldwide can attest. We expect this to continue, along with further home penetration as users hunger for improved quality including 16 bits and sampled sound (when the price is right).

Forecast and Chip Opportunities

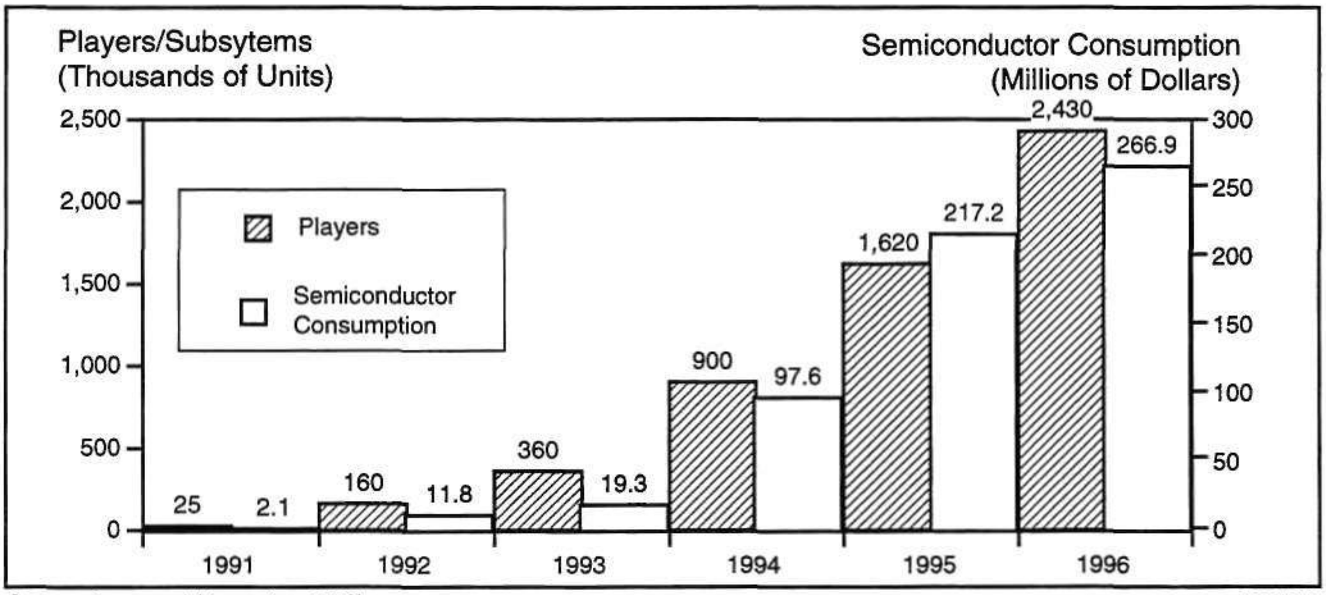
Figure 2 presents Dataquest's forecast of interactive multimedia players and the accompanying

Figure 1
CD-I Player Block Diagram



Source: C-Cube, Dataquest (December 1992)
G2001593

Figure 2
Worldwide Consumer Multimedia Player Semiconductor Forecast



Source: Dataquest (December 1992)

G2001602

semiconductor demand. Key assumptions include the following:

- High-performance, interactive animation, motion video, and accompanying CD-quality sound will be sufficient features to motivate consumers to upgrade from alternatives such as cartridge-based video game systems.
- Sufficient and compelling CD-ROM titles will emerge for these players, including those that draw in adult users as well as entertain and educate future generations.
- One or two product standards will prevail.
- The video game industry will turn to these types of integrated players during their next product generation.

Table 1 and Figure 3 present more detail on the specific chip opportunities of these players. Highlights and trends include the following:

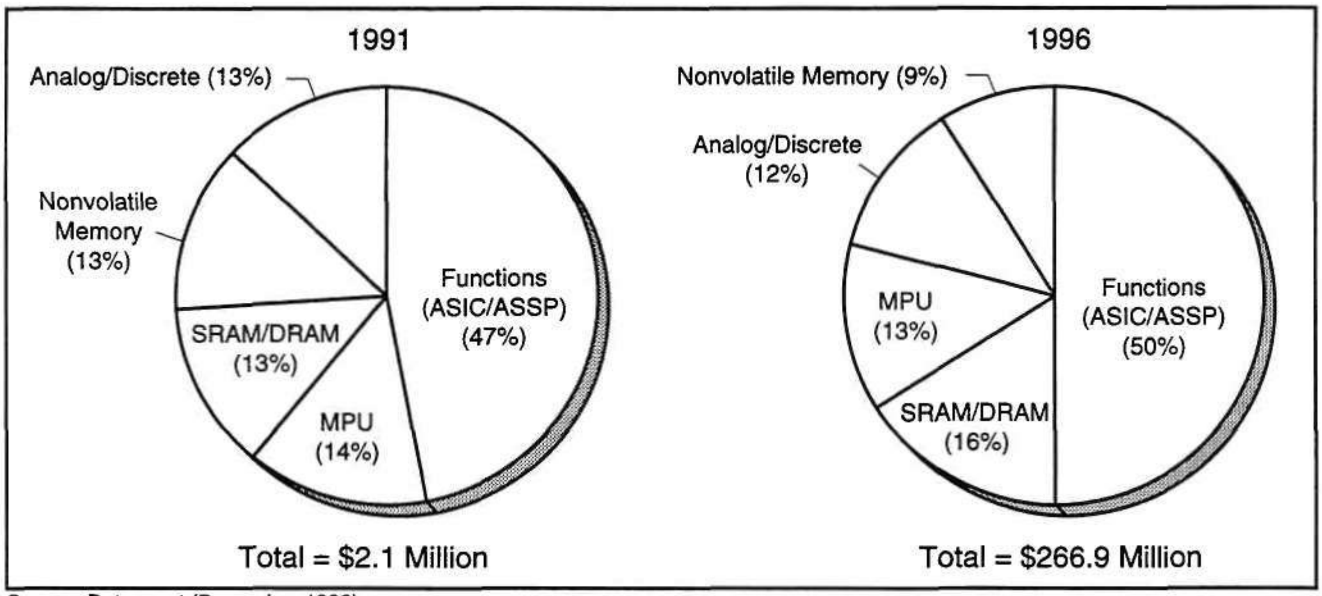
- CMOS ASICs and ASSPs, primarily in the form of video/graphics and audio subsystem I/O compression, buffer processors, and digital signal processing-based CD-ROM controllers (for CD-I, CD-ROM/XA, CD-R, among others), will comprise about half the opportunity. They currently run four to six separate 100-plus-pin packages; opportunities exist to integrate two to three ICs. MPEG processors are now available as a user add-in module option for CD-I.
- The early versions are using the 16/32-bit 68K (because of video game software porting) and the 16-bit x86 (because of Microsoft Windows programming interfaces) MPU architectures. Next-generation products will be based on 32-bit MPUs for the extra performance need for real-time update of VCR-quality video frames. The 32-bit MPU may preclude the need for separate MPEG decompression chips as software CODECS are employed. This is a similar trend as seen in PC video.
- At least 1MB of DRAM main memory and in some cases an additional 1MB of VRAM will be required for high-speed video bit-mapped buffer management. PCMCIA slots could be employed as user upgrades.
- Key analog/mixed-signal components such as audio and video DACs and A/D, mixers (pixel and sound), and various amplifiers could be joined by SCCs, modems, and other communications interfaces such as N-ISDN in future generations. The portable versions also will need LCD driver interfaces.

Table 1
Worldwide Consumer Multimedia Player Semiconductor Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
SRAM/DRAM	0.3	1.4	2.7	15.6	34.8	42.7	178
EE/Flash/ROM	0.3	1.4	1.9	8.8	19.6	24.0	148
MPU	0.3	1.8	2.7	12.7	28.2	34.7	155
Functions (ASIC/ASSP)	1.0	5.4	9.4	48.8	108.6	133.5	167
Analog/Discrete	0.3	1.8	2.5	11.7	26.1	32.0	151
Total	2.1	11.8	19.3	97.6	217.2	266.9	162

Source: Dataquest (December 1992)

Figure 3
Worldwide Consumer Multimedia Player Semiconductor Forecast, by Type



Source: Dataquest (December 1992) G2001603

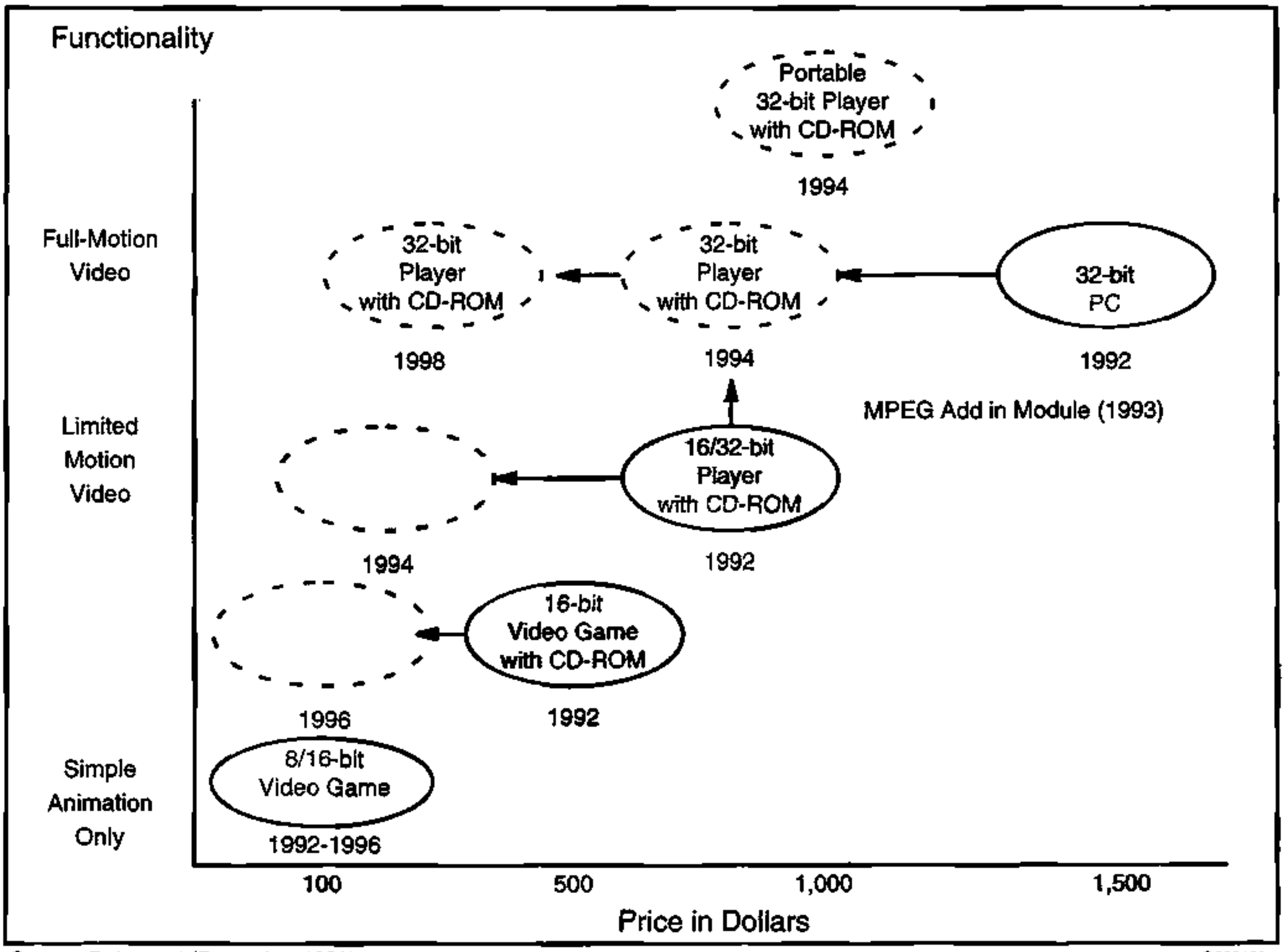
Dataquest Perspective

Figure 4 presents a possible road map for interactive multimedia systems. In all cases, these systems are vying for the discretionary household dollar, which is competing with a new genre of interactive entertainment delivered from cable, satellite, and wireless service providers. We are bullish on the standalone full-motion systems doing well in the marketplace. Future systems could incorporate network interfaces (cable decoder, for example) so that consumers can eliminate clutter on the TV top. Our overarching assumption is that households will upgrade to integrated full-motion systems in the 1994 time frame. The systems will be positioned as more than video games and as TV-based family entertainment and information systems.

The opportunity for chip vendors will be shaped heavily by strategic partnerships and foundry relationships as OEMs strive to hit increasingly more aggressive price points and development cycles.

By Gregory Sheppard

Figure 4
Interactive Multimedia Player Market Dynamics



Source: Dataquest (December 1992) G2001936

News and Views

EO Inc. Enters the Personal Communicator Market

EO Inc. has announced the EO-440 and EO-880, its first two personal communicators that include integrated fax, e-mail, cellular phone, and personal computing capabilities. The EO-440 weighs 2.2 pounds and the EO-880 weighs 4 pounds.

Each product comes packed with GO Corporation's PenPoint operating system, a built-in microphone and speaker for voice annotation, 4/8MB of DRAM expandable to 12MB, a high-speed serial port, a parallel port, a type-2 PCMCIA slot, and the following nine bundled applications in flash memory:

- GO Mail
- GO FAX
- EO phone
- EO sound
- EO Calc
- EO Lock
- GO MiniNote
- Sitka Pen Tops/PenCentral (spreadsheet program)
- Pensoft Personal Perspective (calendar, to-do list, address book, note-taker)

The keyboard is one option! The EO personal communicators run on batteries that can last up to 4 hours and be recharged in 90 minutes. The EO-880 features an additional PCMCIA slot, a VGA port for connecting a full-size VGA monitor for presentations, and a SCSI II port for connecting external hard drives. The EO personal communicators will be distributed through an extensive beta program starting in December 1992, with broad-based availability in the second quarter of 1993. EO's personal communicators will be offered in various configurations. Suggested list prices are $1,999 for the EO-440 with 4MB RAM, $2,499 for the internal modem version, and $2,799 for the 8MB RAM, internal modem version; and $2,999 for the EO-880 with 4MB RAM and internal modem, and $3,299 with 8MB RAM and internal modem. All EO users receive a free subscription to an AT&T EasyLink Services AT&T Mail electronic mail box, accessible through an 800 number in the United States, for sending and receiving e-mail and faxes.

EO intends to address the mobile professional market with a couple of potent personal communicators it has rolled out. It is worth noting that EO is targeting the mobile professional user, arguing (perhaps correctly) that what we often call consumer products begin their lives as business/professional tools.

Apple recently attempted to reposition its Newton PDA to address the mobile professional user as well. This business of what constitutes a consumer product can be rather confusing; at times it appears to be the perfect excuse for the success or failure of a product. Does price determine whether a product is a consumer item? We suggest that the market bears a "price" that depends on the actual/perceived value and need of a product. One can argue that the automobile is a consumer product, albeit one that costs thousands of dollars. Yet everyone has to have one, and price is not a barrier. Wouldn't it be nice if everyone needed a PC?

Two products with similar price points and electronic content can be compared: video cameras and personal computers. More consumers spend $800 to $1,500 for a video camera than for a similarly priced PC. Why? Because the perceived value of the video camera is higher than that of a PC in a typical home. Family events can be recorded on videotape using a camcorder. On the other hand, the PC can be used to balance a checkbook. Most people, however, can do this without a PC. Applications of questionable value have held the PC away from homes for a long time now. PCs have not been and are not yet consumer items.

Nevertheless, companies such as Apple, EO, Casio, Sharp, and Sony are trying to change that fact, and will undoubtedly succeed shortly by bundling entertainment and communications attributes to these small form factor PCs.

Dataquest Perspective

Regarding EO's introductions, from a hardware standpoint they are a boost for AT&T's Hobbit processor. Flash memory is used to store the whole operating system and the bulk of the applications needed. From a software standpoint, it is nice to see an easy-to-use (transparent to the user) OS that fits in semiconductor memory along with nine applications programs. EO's personal communicators also feature good human engineering and industrial design. We wonder whether their introduction will force Microsoft to rethink its strategy of ever-expanding-size operating systems to address personal information and communications devices (PICDs).

Note: Dataquest examined the PICD market in a focus report released on October 1992. For more information, contact your Dataquest sales or account manager.

By Nicolas Samaras

In Future Issues

The following topic will be discussed in a future issue of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- High-performance networking

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Internal Distribution

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On the topics in this issue .... Greg Sheppard, Sr. Industry Analyst (408) 437-8261
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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9211 November 9, 1992

In This Issue...

Product Analysis

GO and AT&T Ally to Embrace Personal Communications

Several PC industry announcements in recent months indicate that the world of personal communications devices, or personal information processors, or what Apple Computer refers to as Personal Digital Assistants (PDAs), is heating up. Perhaps the most significant of these announcements, however, is the one from AT&T Microelectronics and GO Corporation on July 13 detailing plans to develop a personal communications platform.

(Related developments in the industry include Apple's heralding of its first PDA—called Newton—at the end of May, with plans to ship in the first quarter of 1993; the Casio, GeoWorks, and Tandy plans for an alliance announced May 27; and the Day Runner and Texas Instruments announcement of a "cooperative development agreement" on July 14.)

None of these announcements involves products that exist to touch and feel today, although a prototype of the Apple hardware product was shown at Apple's Las Vegas launch. The AT&T-GO announcement did not include any hardware products, nor did the announcement hint at which vendors might be developing hardware for this integrated computing platform.

Tight Integration

Although the announcement did not include any hardware for the world to marvel at, or even a demonstration of what was being introduced, the announcement may turn out to be as important as—if not more important than—the Apple Newton announcement made a month and a half earlier.

At the base of this alliance is the coupling of GO's PenPoint mobile operating system and the Hobbit microprocessor from AT&T. This was not just a "here is the hardware platform, and over here is the operating system" announcement. It was, instead, "here is a very powerful, very low-powered microprocessor, and here is the operating system that will be integrated to form a powerful, portable communications and computing platform."

The Name

AT&T has chosen to name its future hand-held devices "Personal Communicators," which will be "rich in communication and will integrate voice, data, handwriting recognition, fax, electronic mail, still images, and in the future, full-motion video. These devices will provide anytime, anywhere communication to a whole new class of business users and consumers who need to constantly stay in touch," according to AT&T.

The Meat

In a nutshell, GO has optimized a version of its PenPoint operating system for both the Hobbit architecture and communications applications. AT&T has developed a series of low-powered microprocessors that work with digital signal processors (DSPs) and other technologies required for communications-oriented devices.

Even the Hobbit chips were not announced this time around. Instead, AT&T addressed the near future and the power that its new C-language Rational Instruction Set Processor (CRISP) CPU line will bring to mobile computing and how tightly it will be integrated with the GO operating system.

For its part, GO Corporation talked about the configuration of its PenPoint operating system for the mobile communications market. Special support for mobile computing has been added to the operating system, and it now supports intermittent connections via wired and/or wireless links. In addition, the operating system permits multiple simultaneous communications links, and it can store and forward messages, files, and information when connections are established (or re-established).

Interesting, But...

AT&T and GO Corporation have fired a volley in response to Apple's Newton introduction. But if they are not showing a product, or even discussing specific products or delivery dates, then why is their alliance perhaps more important than the Newton announcement?

First the Hardware

Dataquest believes that companies such as EO (the hardware spin-off from GO) will announce and demonstrate their fully integrated products prior to the end of this year and that they may even ship a small quantity of their offerings by the beginning of next year.

However, both AT&T and GO acknowledge that the first hardware platforms to offer the combination of GO's PenPoint and AT&T's Hobbit processor will have a larger form factor than Apple's Newton. They discussed upcoming products in vague terms but indicated that we should expect to see larger, clipboard-size products first, followed over time by smaller and lighter units.

These units will be "very powerful" (says AT&T) and—with the proper power management—battery life should be better than acceptable. Although AT&T did not, in fact, announce the Hobbit chip except to acknowledge that it does exist, AT&T did discuss the architecture of the chip and why it is "ideally" suited for the mobile computing environment.

Designed into the chip, according to AT&T, are the following capabilities:

- Fast context switching to move quickly from one process task to another is an important feature for personal communications devices, because the processor needs to service multiple processes—for handwriting recognition and several communications connections—simultaneously.
- Fast interrupt response allows personal communications devices to quickly respond to and service interruptions (such as incoming calls) while still allowing the operating system to provide a smooth, responsive interface.
- Low bus activity makes the system bus available for DSP or other communications hardware components to send communications process-handling information and other data to memory without interference from the main processor.
- Processing headroom to handle real-time communications tasks, especially those that involve rich data types—such as graphics, voice, and video—that require tremendous

amounts of processing power. Hobbit represents a leap forward in providing this processing power at a cost low enough for consumer products.

- High code density allows products to be built with smaller memory systems resulting in lower overall system cost.
- Low power dissipation is achieved through an efficient power management architecture, which is controlled by GO's PenPoint operating system.
- Stack cache optimizes function call efficiency. Instead of operating with registers that are visible to the user, the Hobbit provides a run-time stack cache. This approach minimizes the overhead associated with procedure calls, which account for 1 out of every 20 instructions (or more in C language operating systems). PenPoint's object-oriented design allows an application programmer to send a single message that will result in the automatic performance of many functions by inherited classes in the system. The Hobbit stack cache makes resulting function calls highly efficient and fast.

All of these features of the Hobbit CPU, according to AT&T, make this platform the "perfect" fit for mobile communications and computing.

Systems, in addition to the main processor, that make use of the Hobbit chip can also include other low-power chips developed by AT&T Microelectronics, including a family of DSPs that AT&T claims will add a high degree of intelligence to both the product and its communications capabilities.

The Operating System

When GO's PenPoint operating system was first announced, the potential scalability of the system was one of the primary features discussed. The use of PenPoint on a hand-held platform has been a part of GO's plans since the inception of the operating system, and while scalability is important, the other features added to PenPoint during the past year are also a vital part of the package.

Because PenPoint uses object-oriented programming to provide a tightly knit core of reusable classes from which all applications and communications services are built, all types of documents, regardless of the application, become "communications enabled." This means that a document can be sent as a fax, printed material, an electronic mail message, a pager message, or a file to a desktop computer.

The other features of the operating system that have been specifically built in for mobile computing include automatic detection of device and media attachment and detachment (the ability to dynamically load and execute protocols in response to external hardware events, such as a wireless connection being made).

The AT&T-GO Vision

The press materials addressed the ways in which personal communicators will be used and how easy it will be to make a connection and take advantage of the built-in systems communications "smarts." AT&T and GO also envision a series of Hobbit-GO-based products, varying greatly from each other but all with a common focus: mobility and communication. Some of the ideas that they presented include pocket-size cellular telephone and notepad devices and notebook-size multipurpose communicators that include both data and voice communication and interaction.

AT&T and GO believe that this combination of tightly integrated hardware and software will provide their customers (who will be designing and selling the end-user products) the ability to differentiate their products and, as a result, help prevent the price wars that are now thinning out the ranks of PC vendors.

Several statements were made both during and after the press event indicating that hardware products based on this combination of the Hobbit chip and the PenPoint operating system will be introduced by the end of this year. Certainly, there has been much speculation regarding the GO spin-off EO, which is reported to be building a product based on this architecture.

The Real Deal

The press event was held just prior to the start of the Mobile '92 trade show and was well attended. A short time was spent discussing the "real" reason that people should be excited about this announcement, but not much attention was really drawn to the total communications picture.

Both AT&T and GO talked briefly about communication, indicating that they understand the need for robust communications links. Their

joint statement regarding communication seems to sum up their approach to the importance of moving information from one point to another: "If personal communications are to be successful, they will need to work hand in hand with today's existing wired communications infrastructure and be poised for the emerging wireless revolutions. Together, AT&T Microelectronics and GO will work with third-party partners so that the new platform will connect to key network resources and services."

The press release also reveals plans to incorporate features to make the Hobbit-based systems "wireless ready" using any of the wireless choices that are, or will be, available. Current choices are wired, infrared, and wireless connections, with the wireless option including cellular, packet radio networks such as RAM Mobile Data and Ardis; paging networks such as SkyTel and Embarc; and future networks such as those that rely on satellites.

Missing from this discussion, however, is the fact that AT&T owns and operates the largest wired communications system in existence and is involved in many cellular systems, paging, and point-to-point networks. Dataquest believes that AT&T has not yet played its trump card in this area.

If personal communications devices are to become as important as many people in the industry believe that they will, then it is the networks (as much as the technology and magic contained within them) that will enable these devices. AT&T understands this perhaps better than any other company. During its long history of being *the* telephone company before the divestiture, and even since its breakup, AT&T has been a provider of the network used for communication, and AT&T wants to continue to use this network. When it was the only provider, it rented telephone instruments to customers to plug into its networks. When customers first developed a need for radio paging or mobile telephone service, they purchased or leased equipment from AT&T and used its network.

Shortly before and certainly after the divestiture, AT&T was faced with competition in all areas. Many other companies moved in to provide the hardware necessary to connect to their own networks, and several other companies have even emerged to challenge the supremacy of AT&T's networks. However, it is still true today that AT&T's main strength is its networks, especially now that access to information is key to corporate success. The challenge still remains the ability to move information from one place to another.

AT&T does not just own networks, it also owns services—such as AT&T Mail—that run on top of the networks. At present, AT&T Mail competes with MCI Mail for electronic delivery of e-mail on a worldwide basis. Some companies are using either AT&T Mail or MCI Mail to virtually run and coordinate their operations.

AT&T Mail, as well as AT&T's other communications networks, can serve as the point of contact for many personal communications devices. Users would not have to make decisions about the type of communications network that they needed—access to AT&T Mail could provide a gateway to any of the other services.

Access to AT&T Mail can be accomplished by wire, direct phone connection, LAN computer systems, and other networks. Access through wireless systems is easy enough to accomplish. After all, the wireless connection is an extension of the network, running through the air instead of on a pole, but part of the network nonetheless.

If AT&T couples the power of the Hobbit with the power of PenPoint and then provides easy access to its own network, the combination is one that will give it a decided advantage in the personal information processor field. AT&T will have the opportunity to sell the chip sets, help OEMs build the products, and then sit back and collect the rent for the use of its networks from all of the Hobbit users.

Dataquest believes that AT&T will work with all of the other service providers but that its main thrust will be to provide the missing link: the communications path from the hand-held device to the desktop or network device—as an integral part of the rollout of products.

Dataquest Perspective

As with the Apple Newton announcement, the AT&T-GO press event left as many questions unanswered as it answered. The two companies did not elaborate on exactly what vendors will provide hardware, or when the products will become available, or about the type of "seamless" communication that the products will offer.

Both AT&T and GO gave the distinct impression that they intend to handle every piece of information that goes into and comes out of the personal communicator as a document of one form or another. The operation to move a document from a remote base station to a hand-held system, as it was explained, involves having the document arrive at the personal communicator and be exposed to all of the applications in residence, and then have each application alert the user as to whether it can or cannot provide a home for the document. In this way, information can be sent to and received from the personal communicator, recognized by an application, and "attached" to that application.

What AT&T and GO did not discuss or demonstrate is an understanding that communication goes way beyond the transmission and reception of documents. Much of the information that will be received by and sent from personal communications devices will not be isolated or standalone but will be a piece of a larger pie that needs to be integrated with other information that often exists in a different form.

It is not clear that AT&T and GO have taken the communications metaphor far enough yet. There is still time, and AT&T does understand how to move enormous amounts of data from anywhere to anywhere. It will be interesting to discover whether or not the combination of AT&T and GO will be able not only to move the information but also to move it smartly, seamlessly, and quickly.

Without having seen the software or the hardware, it is impossible to declare the AT&T and GO alliance a success. In some ways, Apple has set higher expectations within its potential user community because it has demonstrated its concept of mobile computing on a hardware platform that is supposed to become real in the first quarter of 1993. On the other hand, AT&T and GO have announced an alliance that, when coupled with a third-party hardware supplier, will provide a product with just as much sizzle and even "more functionality" (their words) than the Newton. If the first efforts are not quite right, then the alliance has a chance to work with hardware vendors to correct problems while continuing to work with other vendors to improve existing products.

All of these personal communications/information devices are still evolving. AT&T and GO have provided a hardware and operating system platform that hardware vendors can add value to and bring to market—and probably connect to an AT&T network.

By Andrew Seybold

Market Analysis

Video Conferencing: Standards + Lower Costs = Expanded Market

Video communication pertains principally to video teleconferencing, desktop teleconferencing, and video phones. Initially the province of a group of start-up companies, the hardware and supporting telco services are becoming a sizable global market. The market is being enabled by the strong shipment growth of 56-Kbps N-ISDN lines with accompanying service charges as low as 7 cents for 3 minutes in Japan and 19 cents per hour in the United States. One source of growth is a desire to reduce corporate travel budgets and time spent traveling to meetings, especially intracompany meetings.

Market Split

The market is moving in two directions, as follows:

- Improved high-end systems for formal/customer conferences based on proprietary compression techniques and high transmission rates
- Cost-effective desktop and video phone systems migrating to CCITT international standards and N-ISDN transmission rates

With the firming of a host of CCITT standards concerning signaling, audio and video compression, and multipoint protocol, among others, and the availability of VLSI silicon to implement them, lower-cost equipment is on its way. To date, the bulk of video conferencing equipment has been incompatible from vendor to vendor (that is, no interoperability). This will probably continue for higher-performance equipment with proprietary technologies that feature video bit streams of 384 Kbps or greater. For desktop and video phone applications however, the new CCITT standards (see Table 1) should help stimulate low-cost hardware development and thus broad-scale use. Engineering and design markets will be the early adopters of modestly priced systems in an effort to avoid the costs of travel in money and time.

Different Performance Classes

As in all matters involving multimedia and compression, teleconferencing involves a tradeoff between compressed bit rate bandwidth and

Table 1
Open Video Conference Standards

Standard Name	Description	Status
H.261	Video coding	Adopted 1990
H.221	Framing information	Adopted 1990
H.230	Control and indication signals	Adopted 1990
H.242	Call setup and disconnect	Adopted 1990
H.320	Overall requirements for N-ISDN systems	Adopted 1990
G.711	64 Kbps PCM audio	Adopted 1984
G.722	48/56/64 Kbps ADPCM audio	Adopted 1986
G.728	16 Kbps audio	Adopted 4/92
H.223	Encryption	In development
H.232/H.243	Multipoint conferencing	In development
H.261 Option	Still-frame graphics	No formal activity

Source: CCITT

quality. In this case, quality refers to the frame size and frame rate. It is generally believed that the closer video teleconferencing comes to TV broadcast frame sizes and rates, the better the perceived quality. The CCITT standards define two quality levels with frame rates up to 30 frames per second (fps): CIF (352 × 288 pixels) and QCIF (176 × 144 pixels). QCIF is generally suited for desktop video and video phone usage and CIF is for low-end conference room-type systems. High-performance systems such as Compression Labs' Rembrandt II offers 368 × 480-pixel resolution (NTSC mode) and a maximum of 30 fps. The bit bandwidth on these high-performance systems can run from 384 Kbps to 2.048 Mbps. High-performance systems currently run $25,000 and up.

Compression Labs' Cameo Personal Video system for Apple computers exemplifies QCIF-like desktop systems. Costing $2,000, the system comprises a small vertical coder box that attaches to the Nubus backplane and a CCD camera module that attaches to the top of the computer. It employs CLI's proprietary PV2 video compression technology, 64-Kbps u-law audio PCM coding, and has 2B + D ISDN interface. Apple and Windows/OS/2 video conferencing software from third parties is also enabling easier adoption.

As for video phones, the AT&T 2500 offers 128 × 112 resolution. It operates at 15 fps and retails for $1,500. Its target market is early adopters and young parents. British Telecom (with GEC Marconi), NTT, and nearly all the Japanese handset manufacturers have either entered or are about to enter this market. Dataquest believes that the picture quality will need to reach the QCIF level before consumers start buying in earnest. The market should behave like the fax market: Enough people will have them in five to seven years that they can begin shipping in the millions.

Key players in the video conferencing market include: Compression Labs, PictureTel, GPT, Video Telecom, and NEC. Other companies principally playing in the midrange to low end are: Fujitsu, IBM (Japan and United Kingdom with BT), Mitsubishi Electric, Oki, British Telecom, NTT, Siemens/Rolm, Concept Communications, and EyeTel. Other high-end players include: Broadband Technology, Northern Telecom, ABL Engineering, Grass Valley Group, and Rockwell.

Compression

The principal open standard regarding video compression for real-time video conferencing is H.261 (also known as Px64), a CCITT standard. It operates similarly to MPEG (uses DCTs), except that it is optimized for real-time encoding and decoding. The principal difference is that H.261 does its interframe comparison with only past and current frames and not future (unknown in real-time) frames, making for smaller compression ratios.

H.261 is designed to be efficient, with resolutions to CIF and rates to 30 fps while generating a 56-Kbps compressed output stream for transmission. Several proprietary compression algorithms are used today, including Compression Labs' CTX, CTX plus, and PV2, and PictureTel's SG3. Table 2 is a representative list of semiconductor offerings in video codec technology. Codec alliances are strategic and necessary for differentiation.

The programmable approaches appear to be gaining favor as silicon vendors enable the OEMs to encode their proprietary algorithms or migrate to H.261. The programmable approaches utilize a DSP architecture with RISC-like features. The AT&T and IIT chip sets are good examples of this. In some cases, only software updates by users are required to make the bandwidth-quality trade-off. The recently announced Motorola/British Telecom 3 chip set ($100, scheduled for 1994 shipment) implements MPEG, JPEG, and H.261 compression, plus all audio and other CCITT standards, to form a video conferencing engine.

The direction of video conferencing technology, with the exception of programmable building blocks, remains firmly in the control of the OEMs. That is to say, the tricks needed to make a system perform require specialized systems knowledge. As volumes and design expertise develop, perhaps this may change as chip vendors unveil integrated "engines" for mass applications.

Semiconductor Opportunities

Video telephones have a semiconductor content of about $150. The desktop versions ($2,000 to $5,000 price range) run 10 to 12 percent of value, and high-end versions run $25,000 and up with about 7 to 8 percent content. Figure 1 shows Dataquest's projection of the worldwide semiconductor consumption by video telecommunications systems. Other silicon function opportunities in video conferencing include the following:

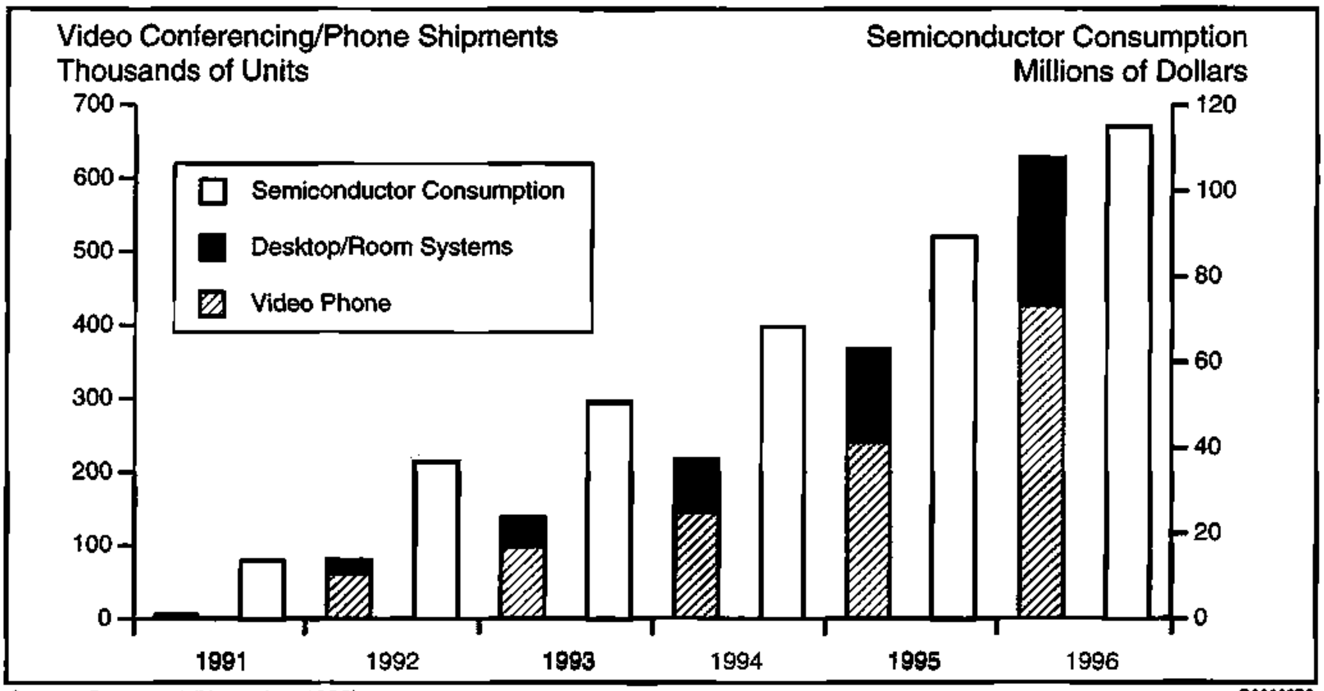
- 8- to 16-bit A/D and D/A (perhaps integrated with filtering-processing functions) for audio and video
- Audio codec (u-law, a-law PCM, ADPCM, Dolby adaptive delta modulation) 16 Kbps, 56 Kbps to 200 Kbps
- Signaling and protocols functions (proprietary: ASIC; CCITT: programmable)
- Preprocessing filtering ASIC (spatial and temporal) for unneeded detail and postprocessing artifact removal (adding back information to smooth the image)
- Audio-video synchronization (perhaps the biggest secret maintained by OEMs)
- ISDN functions such as S/T interfaces and link control
- 19.2 or V.Fast modem in lieu of ISDN
- DRAM/VRAM frame buffer (1-8MB)

Table 2
Video Codec/Compression Semiconductor Offerings and Alliances

Semiconductor Company	Type	OEM Patron
Graphic Comm. Tech. (GCT)	CCITT	IBM Japan
Motorola	Programmable	British Telecom/IBM
Intel	Programmable	PictureTel (Canceled)
IIT	Programmable	Compression Labs
LSI Logic	CCITT	
GEC	Hardwired	Japanese OEM, Bellcore
NEC	Programmable	Captive
NTT	Programmable	Captive
Texas Instruments	Programmable	Video Telecom
AT&T	Programmable	Captive
SGS-Thomson	Hardwired	

CCITT = H.261, etc.
Source: PictureTel, Dataquest (November 1992)

Figure 1
Worldwide Video Teleconferencing/Phone Opportunity



Source: Dataquest (November 1992)

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Dataquest Perspective

Because we are in the early stages of this market's development, alliances will be most important as OEMs seek "proprietary" methods to implement international standards. The other key ingredient we observed at the recent Telecon XII conference, where new hardware abounded, is that time-to-market is as important as ever. Clearly, OEMs want design-programmable solutions that are quick to market and allow them to hit aggressive cost targets. The risk that appears on the horizon is an inevitable OEM shakeout three or four years down the road as the more efficient manufacturers and marketers take over. We will keep watching this market; stay tuned for more information.

By Gregory Sheppard

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9210 October 5, 1992

In This Issue...

Market Analysis

Market Analysis

Semiconductor Consumption, by Application Market

The six major application segments for semiconductors—data processing, consumer, communication, industrial, transportation, and military—grew 9.4 percent in 1991 over 1990 (see Table 1). Worldwide revenue from semiconductor sales into the six major applications markets grew from $54.5 billion to $59.7 billion dollars.

The Big Picture

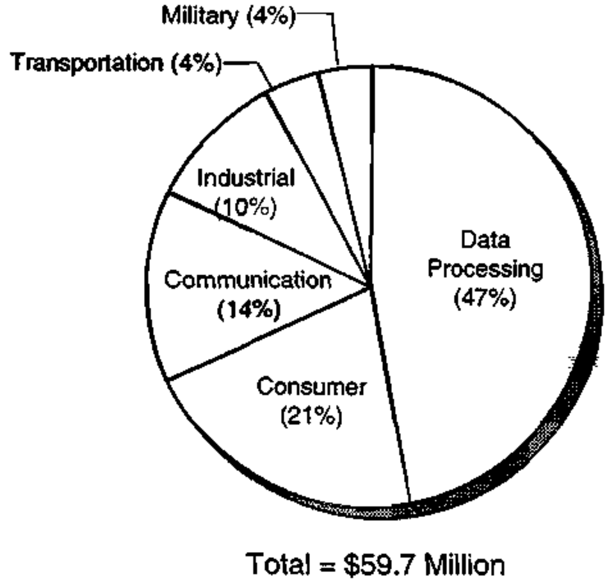
Figure 1 shows the split of the $59.7 billion in semiconductor components that made up the six application segments for calendar year 1991. Perhaps it comes as no surprise that the data processing segment consumed the lion's share of semiconductors. The semiconductor content decreases down the list of application segments, as the relative contribution of electronics gives way to other nonelectronic components and subassemblies. The semiconductor content of a car or a military aircraft, for example, is far smaller than that of a personal computer or a mainframe. Figure 1 also shows that semiconductor sales into the top three applications

Table 1
Worldwide Semiconductor Shipments, by Application Segment (Millions of Dollars)

	1990	1991	1990-1991 Growth (%)
Data Processing	24,207	26,742	10.5
Consumer	11,318	12,791	13.0
Communication	7,474	8,136	8.9
Industrial	5,847	6,159	5.3
Transportation	2,815	3,054	8.5
Military	2,882	2,811	-2.5
Total	54,545	59,694	9.4

Source: Dataquest (October 1992)

Figure 1
1991 Worldwide Semiconductor Shipments, by Application Segment (Millions of Dollars)



Source: Dataquest (October 1992)

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account for more than 80 percent of all semiconductor worldwide sales.

Figure 2 shows each market segment's performance for the calendar years 1990 and 1991, along with relative contribution.

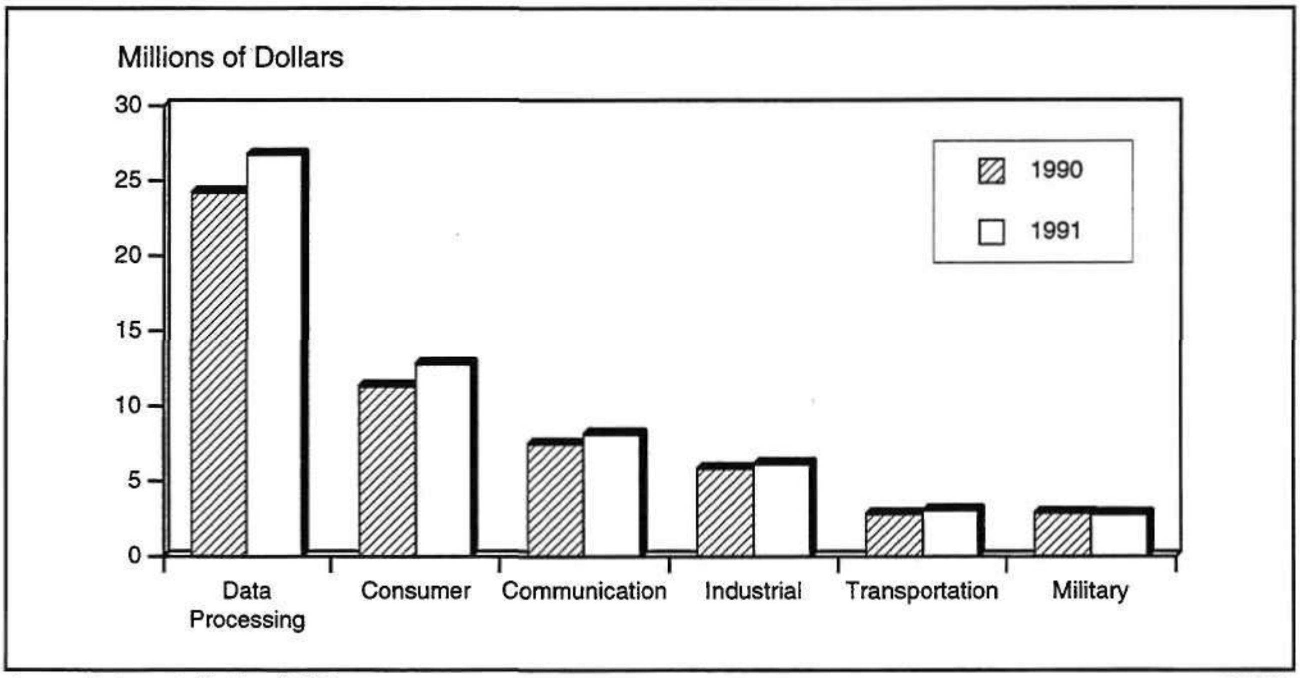
Tables 2 through 7 list the top 10 semiconductor companies for each major applications segment for the calendar years 1990 and 1991. The tables provide growth rates and market share information, along with the collective market share of the top 10 and top 3 players.

Application Segment Highlights

Application segment highlights are as follows:

- Intel was the top player for 1991 in data processing with 11.7 percent market share.
  - The top three semiconductor vendors controlled 27.8 percent of the market.
  - The top 10 accounted for 60.3 percent of the market.
- Matsushita was the top player for 1991 in consumer with 11.3 percent market share.
  - The top three semiconductor vendors controlled 29.9 percent of the market.
  - The top 10 accounted for 63.6 percent of the market.
- Motorola was the top player for 1991 in communication with 12.6 percent market share.
  - The top three semiconductor vendors controlled 31.6 percent of the market.
  - The top 10 accounted for 69.1 percent of the market.
- Toshiba was the top player for 1991 in industrial with 11.2 percent market share.
  - The top three semiconductor vendors controlled 28.2 percent of the market.
  - The top 10 accounted for 62.1 percent of the market.
- Motorola was the top player for 1991 in transportation with 13.7 percent market share.
  - The top three semiconductor vendors controlled 29.8 percent of the market.
  - The top 10 accounted for 50.4 percent of the market.

Figure 2
Worldwide Semiconductor Shipments to the Six Major Application Segments (Millions of Dollars)



Source: Dataquest (October 1992)

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Table 2
Worldwide Semiconductor Shipments to Data Processing Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Intel	2,332	3,135	34.4	11.7	27.8
NEC	2,175	2,387	9.7	8.9	-
Hitachi	1,863	1,920	3.1	7.2	-
Fujitsu	1,588	1,650	3.9	6.2	-
Toshiba	1,511	1,603	6.1	6.0	-
Texas Instruments	1,361	1,470	8.0	5.5	-
Motorola	917	1,087	18.6	4.1	-
Mitsubishi	1,026	1,082	5.5	4.0	-
Samsung	853	956	12.1	3.6	-
Advanced Micro Devices	684	846	23.7	3.2	-
Top 10 Total	14,310	16,137	12.8	60.3	-
Worldwide Total	24,207	26,742	10.5	-	-

Source: Dataquest (October 1992)

Table 3
Worldwide Semiconductor Shipments to Consumer Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Matsushita	1,297	1,446	11.5	11.3	29.9
Toshiba	1,216	1,374	13.0	10.7	-
NEC	913	1,003	9.8	7.8	-
Sanyo	801	913	13.9	7.1	-
Philips	861	890	3.3	7.0	-
Sharp	613	803	30.9	6.3	-
Sony	530	718	35.4	5.6	-
Hitachi	633	715	13.0	5.6	-
Mitsubishi	611	714	16.8	5.6	-
Motorola	539	536	-0.5	4.2	-
Rohm	372	467	25.5	3.7	-
Top 10 Total	7,089	8,131	14.7	63.6	-
Worldwide Total	11,318	12,791	13.0	-	-

Source: Dataquest (October 1992)

Table 4
Worldwide Semiconductor Shipments to Communications Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Motorola	896	1,027	14.6	12.6	31.6
NEC	783	859	9.7	10.6	-
Toshiba	624	687	10.1	8.4	-
Fujitsu	624	649	4.0	8.0	-
AT&T	539	520	-3.4	6.4	-
Hitachi	457	452	-1.1	5.6	-
Texas Instruments	397	411	3.5	5.0	-
SGS-Thomson	352	359	2.0	4.4	-
National Semiconductor	364	352	-3.2	4.3	-
Philips	297	303	2.1	3.7	-
Top 10 Total	5,333	5,620	5.4	69.1	-
Worldwide Total	7,474	8,136	8.9	-	-

Source: Dataquest (October 1992)

Table 5
Worldwide Semiconductor Shipments to Industrial Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Toshiba	624	687	10.1	11.2	28.2
Motorola	642	635	-1.1	10.3	-
Hitachi	316	414	31.1	6.7	-
Texas Instruments	325	356	9.5	5.8	-
Mitsubishi	316	345	9.3	5.6	-
NEC	304	334	9.9	5.4	-
Intel	289	313	8.5	5.1	-
SGS-Thomson	275	287	4.4	4.7	-
Philips	234	243	3.7	3.9	-
Siemens	136	207	52.3	3.4	-
Top 10 Total	3,461	3,822	10.4	62.1	-
Worldwide Total	5,847	6,159	5.3	-	-

Source: Dataquest (October 1992)

Table 6
Worldwide Semiconductor Shipments to Transportation Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Motorola	390	418	7.2	13.7	29.8
Hitachi	247	264	6.7	8.6	-
Toshiba	203	229	12.8	7.5	-
SGS-Thomson	144	172	19.7	5.6	-
NEC	121	143	18.4	4.7	-
Texas Instruments	124	137	10.4	4.5	-
Siemens	174	134	-23.1	4.4	-
Philips	118	121	2.8	4.0	-
Intel	122	121	-1.2	3.9	-
National Semiconductor	115	112	-2.5	3.7	-
Oki	103	106	2.9	3.5	-
Top 10 Total	1,471	1,539	4.6	50.4	-
Worldwide Total	2,815	3,054	8.5	-	-

Source: Dataquest (October 1992)

Table 7
Worldwide Semiconductor Shipments to Military Applications (Millions of Dollars)

	1990	1991	Growth (%) 1990-1991	Market Share (%)	Top Three Suppliers (%)
Harris	263	212	-19.5	7.5	18.4
National Semiconductor	165	160	-2.9	5.7	-
Texas Instruments	154	145	-5.8	5.2	-
Analog Devices	140	144	2.5	5.1	-
GEC Plessey	120	120	0.0	4.3	-
Motorola	155	114	-26.4	4.1	-
LSI Logic	100	101	0.5	3.6	-
SGS-Thomson/TMS	93	88	-5.0	3.1	-
Advanced Micro Devices	124	86	-30.8	3.1	-
Intel	77	80	4.4	2.9	-
Philips	54	61	12.3	2.2	-
Top 10 Total	1,182	1,099	-7.1	39.1	-
Worldwide Total	2,882	2,811	-2.5	-	-

Source: Dataquest (October 1992)

- Harris was the top player for 1991 in military with 7.5 percent market share.
  - The top three semiconductor vendors controlled 18.4 percent of the market.
  - The top 10 accounted for 39.1 percent of the market.

The Market Segments

Table 2 lists the top 10 semiconductor companies selling components for data processing applications. Intel is No. 1 and continued to be the dominant vendor of microprocessors for personal computers. With significant sales of 386 and 486 devices, it captured by some accounts nearly 80 percent of the semiconductor content (in terms of dollars) per PC motherboard. Similarly, Advanced Micro Devices (AMD) enjoyed strong growth that can be attributed primarily to its 386 microprocessor sales. Other companies with substantial growth include Motorola and Samsung.

The top three suppliers captured 27.8 percent of the data processing market segment; the top 10 companies were responsible for 60.3 percent of semiconductor sales to data processing applications.

Motorola's sales into the communications marketplace grew by almost 15 percent in 1991 (see Table 4). NEC and Toshiba also grew substantially in what was a rather average year for communication, with 8.9 percent overall semiconductor market growth.

Table 7 tells a story that will probably not surprise anyone. The collapse of the Soviet Union and the Eastern Bloc and the accompanying reduction in East-West tensions brought the axe to the military budget in the United States. This is reflected in the overall decline of 2.5 percent in the military market segments. Nearly every vendor selling into this market experienced a negative growth. Hardest hit were Harris, Motorola, and AMD.

Dataquest Perspective

All but one of the major semiconductor application segments—military—grew in a difficult worldwide economic environment, a fact that underlines today's reality: Semiconductors have become indispensable in our everyday life. We expect a lower overall semiconductor growth of 5.4 percent (dollar based) in 1992. With respect to the application segments, data processing is expected to lead the pack again, growing by 7.3 percent. Communication will grow 5.1 percent, industrial 4.6 percent, consumer 3.4 percent, and transportation 5.9 percent. The military segment is expected to show no growth.

However, the 1993 forecast is much brighter, with double-digit growth rates in the mid-teens for all but the military segment, which, by the way, is forecast to grow by nearly 6 percent. The 1994 picture is just as bright, with an overall semiconductor market growth rate of 13.7 percent.

There is no question that the industry has gone through some trying times and has undergone significant structural changes. In the process most vendors have emerged and are emerging better equipped to handle today's markets. The good news for semiconductor vendors is that relative prosperity is ahead.

By Nicolas Samaras

Computer Platform Sound: A Multimedia Reality

Nearly all PCs and workstations are capable of generating sound from a small embedded speaker. Most often this sound capability is 8-bit monaural and can only be accessed via application program calls such as those generated by most video games. The majority of systems cannot accept user sound inputs such as voice or music, but things are changing. The use of sound is expected to evolve, becoming more sophisticated as it expands beyond its video game roots into applications such as voice annotation, CD quality music, and interactive training (see Figure 1).

Sound Developments: Standards and DSP Rollout

The huge success of Creative Labs' Sound Blaster add-in board products has captured the interest of the computer industry. Creative Labs and its competitors capitalized on the large installed base of home PCs and sound-laden entertainment titles. The success has helped stimulate establishment of sound standards. Standardized operating system environments (for example, Quicktime, DOS Multimedia Extensions, and Windows 3.1 MCI) and application program interfaces (APIs) in particular are stimulating the development of sound-embedded software programs and titles. Object linking and embedding within advanced, multitasking operating systems will further stimulate sound in mainstream business desktop applications.

Figure 1
The Evolution of Computer Sound

Today

Sound board: add-on
Microphone: add-on
Speaker: mono/add-on
Standard GUI
MIDI: Add-on, synthesized
Limited speech recognition

Tomorrow

Embedded sound subsystem
Embedded microphone
Embedded stereo speakers
Sound user interface
MIDI: command processor, sampled
Continuous word speech recognition
Text-to-speech
Voice mail

Source: Dataquest (October 1992)
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Several important recent announcements within the world of computer sound are as follows:

- Apple Computer is understood to be working with AT&T Microelectronics for incorporation of its DSP technology on certain high-end offerings to be introduced soon.
- IBM is incorporating Texas Instruments' DSP-based mWave technology into its platforms for 1993. The DSP subsystem will also manage modem and fax processing.
- Microsoft is rumored to be working on a next-generation sound board capability known as "Foghorn."
- Over the last year the IBM-compatible platform market has witnessed Creative Labs' Sound Blaster become a de facto standard claiming more than 1,000 compatible software titles and shipment of more than 1 million boards. Media Vision and others have joined Creative Labs in offering compatible products for the Windows 3.1 environment. Yamaha's OPL 3 FM synthesis technology also became a de facto standard. Media Vision has a relationship with Cirrus Logic to design and market a multimedia audio chip set.
- Analog Devices, Compaq Computer, and Microsoft have joined forces on a project known as "Business Audio." The purpose of this project is to develop hardware and software that enriches business applications under Windows 3.1 with sound "annotations" or files. Based on Analog Devices' SoundPort chip, this sound subsystem is capable of 16-bit, 44.1-KHz (CD-quality) sound I/O. Lernout and Hauspie is working with Analog Devices to provide speech recognition and speech-to-text software for its DSP processors.
- Apple's line, the Commodore Amiga, and NeXT's Cube are the best early examples of sophisticated sound use by platforms. NeXT employs a Motorola 56001 DSP MPU in all its computers for processing speech and music.
- In Japan, Fujitsu's FM Towns multimedia PC with CD-quality sound is shipping well into the education market. More than 200,000 units are claimed to have shipped through mid-1992.
- Built into Tandy's new Sensation PC is Yamaha's Magic chip set for sound processing.

Sound Technology and the Future

The basic trend is toward 16-bit stereo (or more channels), with CD-quality sampling at 44.1 KHz and a musical instrument digital interface (MIDI)—despite a lack of 16-bit stereo applications. Another trend is toward the use of more sophisticated synthesis and sampled sound to replace or complement FM synthesis in reproducing sound (see Figure 2). This addresses the complaint that computer sound has an "arcade game" quality. Sampled sound uses actual ROM-captured sound elements of instruments, among others, to produce higher-fidelity music and sounds.

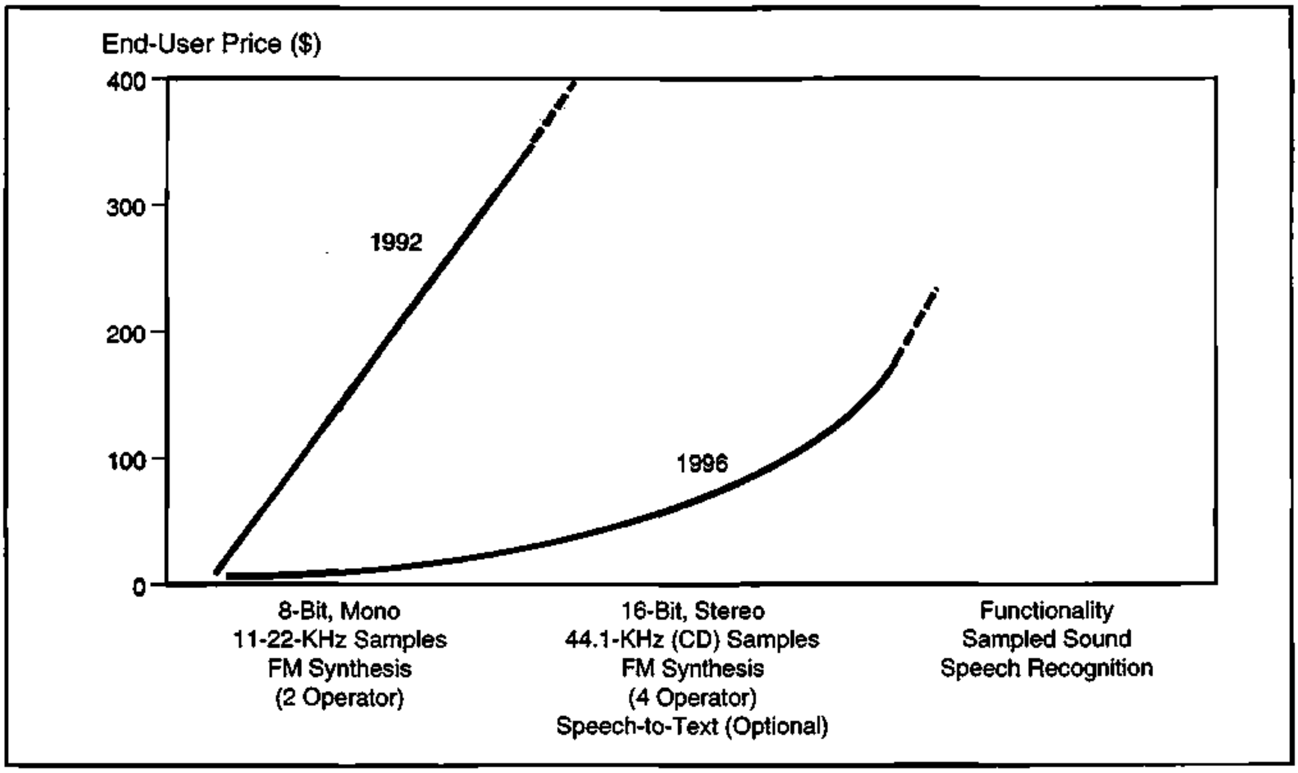
The key assumption behind these trends is that a higher performance standard will emerge beyond the MPC current specification. A key enabler will be development of titles that take advantage of the higher CD-quality sound.

Sound processing functions will be implemented in both standard ICs or ASSP chip sets with DSP cores, or as programmable DSPs, or as cell-based ASICs. The ASIC solution is the most popular as proprietary technologies battle for market dominance. However, it is giving way to ASSP approaches (see Figure 3). ASSP chip sets for digital sound processing and MIDI synthesis range in price from $20 to $60 (sampled sound is more). Companies with computer sound chip sets include: Cirrus Logic/Media Vision, Analog Devices, Yamaha, Matsushita, Sierra Semiconductor, AOM, E-mu Systems, Roland, Zoran, Philips, Integrated Circuit Systems, Information Storage Devices, and Ensoniq. Yamaha OPL 3 chips are the most widely used.

Sound is also migrating to programmable DSP-based motherboard subsystems that can time-share among sound/music capture and output, fax, modem, voice mail, speech recognition, and speech-to-text. Time-sharing this hardware investment is making it possible to add all these features at once. Likely hardware vehicles for executing that functionality are DSP MPU ICs varying from 16 to 32 bits and integer and floating point in capability. The amount of time-sharing tasks and compression processing will determine the performance level.

Numerous digital, mixed-signal, and analog semiconductor opportunities are available on

Figure 2
Computer Sound Technology Trend



Source: Dataquest (October 1992)

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sound add-in boards and sound subsystems of motherboards, as follows:

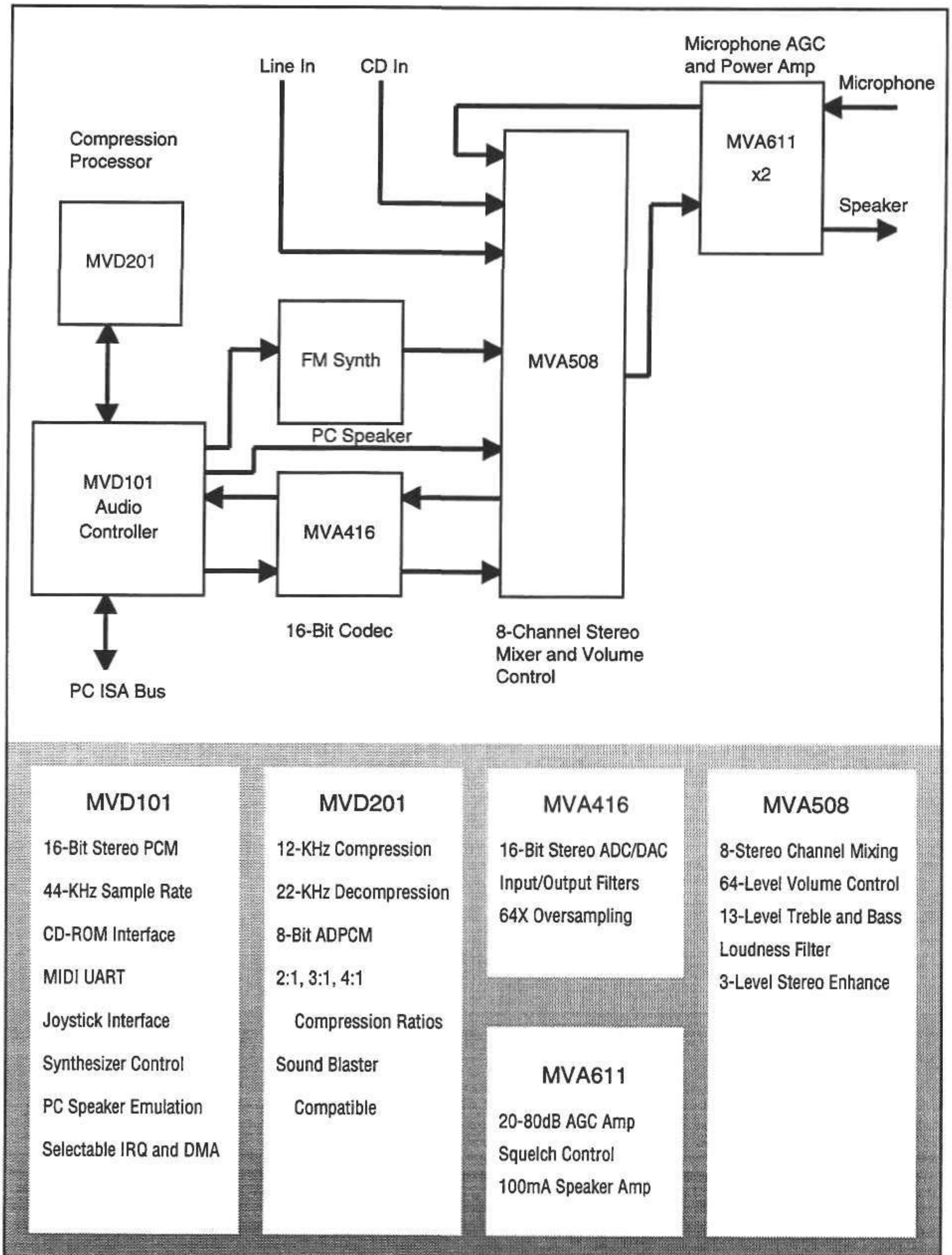
- DSP MPUs or custom versions with DSP cores (16- to 32-bit)
- Cell-based ASICs (CMOS, 40,000 gates)
- 8, 12, 16 A/D and D/A converters (up to 44.1-KHz sample rate)
- ADPCM codec (up to 4:1 compression)
- FM synthesizers (for MIDI), sampled sound (0.5-4MB of ROM, EPROM, flash)
- Sound source mixer, audio filters, amplifiers (up to 5W)
- FIFO (64 bytes), buffer (up to 1M slow SRAM)
- MIDI interface (UART), MIDI command processor
- Host bus transceivers/buffers
- Optional: SCSI interface

Independent Algorithms: Have Standard, Will Travel

Companies such as AT&T with its DSP32 VCOS software environment, Texas Instruments' 320xxx series ICs with its mWave software, and Analog Devices with its Signal Computing approach are providing hardware alternatives bundled with second-party-developed software algorithm libraries. These "living" and "updatable" libraries can be invoked by user application via one of the standard APIs and can include the following algorithms (from AT&T Microelectronics):

- MPEG audio
- DTMF decode/generate
- G.722 audio coding
- V.32 9600-baud fax modem
- V.29 9600-baud fax modem
- MPC music synthesizer
- Speech recognizer

Figure 3
Sound Subsystem 16-Bit Block Diagram



Source: Media Vision

G2001580

- HQ call process detection
- Handwriting recognition
- Video and image handling
- SBC speech coder telephone interface
- Sample rate conversion
- CD-ROM/XA audio coding
- V.22bis 2400-baud modem
- MPC MIDI interface
- LD CELP speech coder
- Text-to-speech synthesis
- Caller ID
- Speakerphone AEC

Sound Board Players

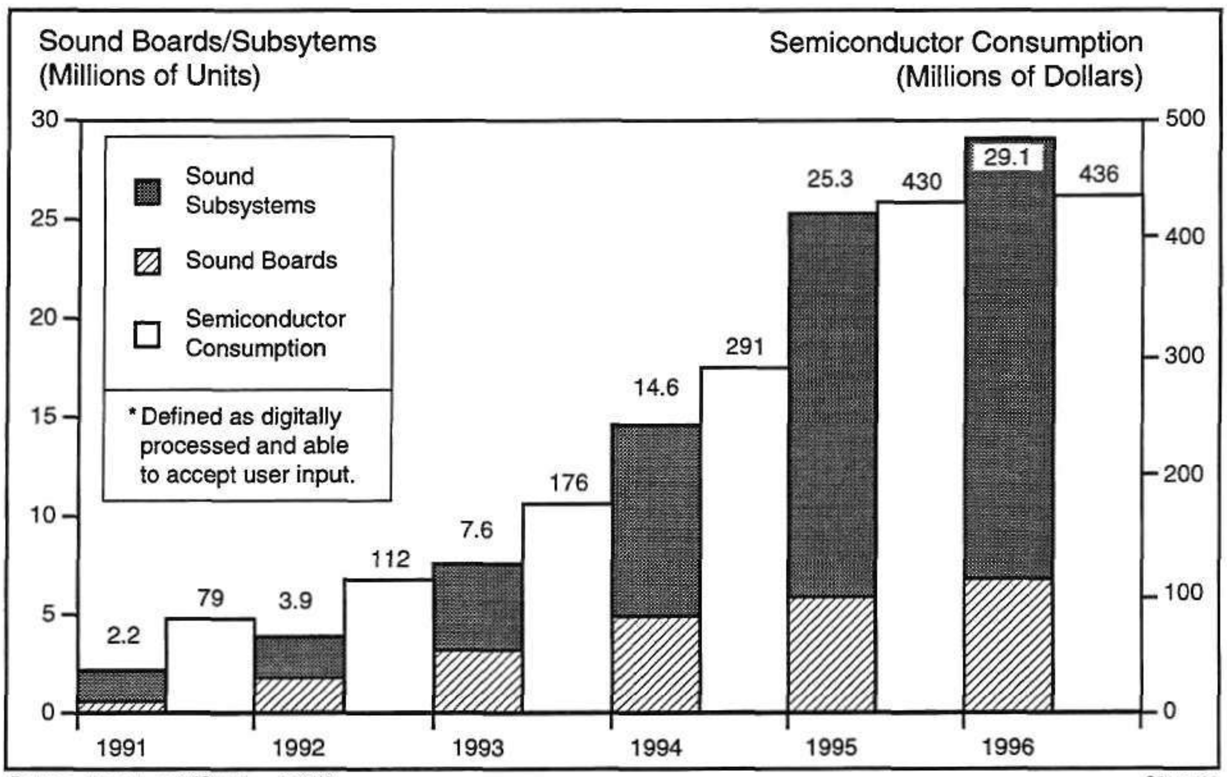
The sound board market was launched into its current state by offerings from Creative Labs and AdLib. Since then, AdLib has had financial trouble and Creative Labs has zoomed to million-plus volumes with its Sound Blaster line. We estimate that Creative Labs will have 50 percent of the 1992 market and Media Vision 30 percent. Other OEMs include: ATI Technologies, Cardinal Technologies, Digitan Systems, Digidesign, E-mu Systems, IBM, Roland, RTM, Spectral Synthesis, Sunrize Industries, Turtle Beach, Video Associates, VocalTec, and Zoltrix.

A Sound Forecast

Figures 4 and 5 show the semiconductor opportunity for sound processing on computer platforms. Key assumptions and observations include the following:

- Demand for sound processing (principally voice and music input and output) will migrate from home upgrades to business audio.
- Critical mass of uses will develop, including existing applications that incorporate sound annotation; sounds will become treated as objects within operating system environments (that is, sound icons).

Figure 4
Worldwide Computer Sound* Semiconductor Forecast



Source: Dataquest (October 1992)

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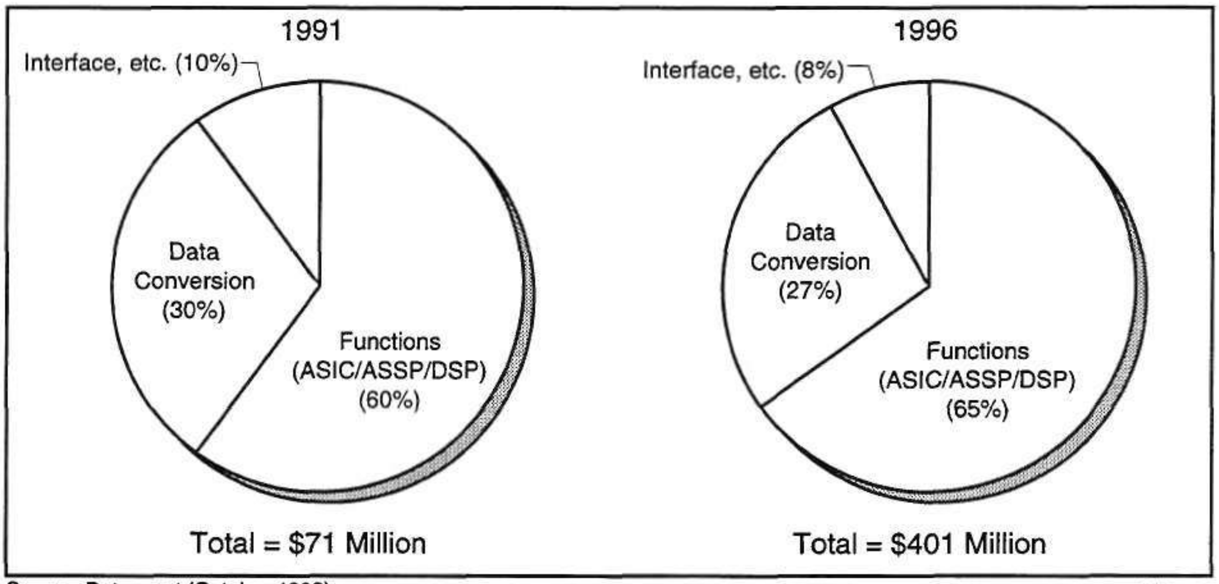
Figure 5
Worldwide Computer Sound Semiconductor Forecast, by Type



Source: Dataquest (October 1992) G2001599

- Sound will become a standard feature on nearly every motherboard toward the end of the decade. DSP-based subsystems that can be shared with fax/modem will be employed utilizing software-processing algorithms.
- Compressed 16-bit and stereo sound applications will become more prevalent.
- Sampled sound and other more sophisticated techniques will eventually replace FM synthesizers in MIDI applications.

Dataquest Perspective

The time is now to form strategic partnering and supplier relationships. With second-generation sound board and motherboard products coming out soon and the third generation on the drawing board, the opportunities for volume design wins need to be pursued closely. There is plenty of opportunity to add value with tailored and multifunctional semiconductor products. We recommend that semiconductor companies try to work with a major patron before defining new integrated products and leave some room for other OEMs to customize variants of the core technology. Time-to-market and price might be one thing for the customer, but differentiation is another.

By Gregory Sheppard

In Future Issues

The following topic will be discussed in a future issue of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Personal information and communication devices

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On the topics in this issue.. Greg Sheppard, Sr. Industry Analyst (408) 437-8261
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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9209 September 7, 1992

In This Issue...

Market Analysis

Winds of Change in Mass Storage

Emerging micro rigid disk drives (micro RDDs), as exemplified by the 1.3-inch RDD recently launched by Hewlett-Packard, are challenging memory cards and solid-state disks used in hand-held PCs. How will RDD and semiconductor manufacturers react to this challenge? We will address that question in this article, but first we examine the RDD forecast provided by Dataquest's Computer Storage group.

Table 1 shows the actual 1991 unit shipments as well as the forecast through 1996 (1.3-inch drives are not included because they have yet to be shipped). It is evident that the 1.8-inch form factor is expected to be on a rapid growth curve; Dataquest projects a compound annual growth rate (CAGR) of 345.8 percent from 1991 to 1996.

Demand, of course, is driven primarily by need in portable computing. The 1.8-inch drives represent the first new RDD form factor designed from the ground up to address ruggedness (or abuse), low power consumption, size constraints, and weight. However, these drives will remain relatively more expensive on a cost-per-megabyte basis when compared with the 3.5-inch drives, which are expected to dominate desktop PC applications for the forecast period. Gigabyte-class 3.5-inch drives are now finding their way into workstations, servers, and disk arrays.

The 2.5-inch drive is expected to be the medium of choice for notebook-size and pen-based PCs. Both the 5.25- and 8- to 10-inch drives are on a steep decline. The 14-inch form factor should be gone by 1995.

The 1.8-inch drives shown in this forecast for the first time indicate how quickly new form factors materialize as life cycles shrink along with size. The pace of innovation and new product introductions remains relentless.

Table 1
Worldwide Rigid Disk Drive Market Shipments (in Thousands)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
1.8-Inch	4	332	1,410	4,793	6,072	7,394	345.8
2.5-Inch	3,378	5,672	9,660	12,060	13,260	14,800	34.4
3.5-Inch	25,421	28,416	31,332	33,960	39,020	46,960	13.0
5.25-Inch	3,154	2,584	1,714	1,000	840	574	-28.9
8-10-Inch	466	421	382	286	212	94	-27.4
14-Inch	80	39	10	1	0	0	-
Total	32,504	37,465	44,508	52,101	59,404	69,822	16.5

Source: Dataquest (September 1992)

Table 2
Rigid Disk Drive Market Worldwide Consumption (Factory Revenue in Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
1.8-Inch	1	90	313	684	782	799	254.5
2.5-Inch	816	1,150	2,169	2,834	3,186	3,260	31.9
3.5-Inch	5,663	6,521	7,441	10,061	11,547	13,790	19.5
5.25-Inch	2,435	2,289	1,476	936	882	562	-25.4
8-10-Inch	8,725	8,396	7,671	5,148	3,338	1,377	-30.9
14-Inch	1,841	946	217	26	0	0	-
Total	19,482	19,392	19,287	19,689	19,735	19,788	0.3

Source: Dataquest (September 1992)

Worldwide revenue from RDD sales is expected to grow marginally at a 0.3 percent CAGR for the forecast period as a result of current and expected future significant pricing pressures on drive manufacturers from PC vendors (see Table 2). In essence the PC price wars will be felt all the way down the food chain by semiconductor component suppliers and could force some weaker players out of the RDD market.

Semiconductor Component Market for RDDs

The good news for semiconductor vendors is that the disk drive market is growing at a healthy rate. As seen in Table 1, the small form factor drives show significant growth, both in terms of units as well as revenue. This in turn translates to a stable market for vendors that provide disk drive semiconductor components. Revenue will grow from about $2.4 billion in 1991 to almost $2.6 billion by 1996 (see Table 3). Semiconductor vendors should focus their energy on the smaller form factor drives—3.5-inch and below. The need for integration and new component development is most urgent at this micro RDD level. Opportunities exist for providing customized DSPs (for RDDs) to handle needs for drive control, as well as for servo and motor control. Another opportunity is the bus interface for SCSI, PCMCIA or IDE types, functions that need further integration. The PCMCIA interface is gaining acceptance and is expected to be perhaps dominant in the Personal Information and Communications Device (PicDee, or PICD) class of machines.

Semiconductor Opportunities

Changes in the disk drive market—domination by large form factor drives to mainly small drives—must be reflected in the portfolio of devices supplied by semiconductor vendors. The move clearly is to reduce the number of components per drive. This is necessary for

Table 3
Rigid Disk Drive Worldwide Semiconductor Market Factory Revenue (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
1.8-Inch	0.3	17	59	121	126	130	236.8
2.5-Inch	146	193	340	434	477	488	27.3
3.5-Inch	839	948	1,053	1,375	1,522	1,770	16.1
5.25-Inch	338	313	192	109	106	68	-27.4
8-10-Inch	872	840	767	515	334	138	-30.8
14-Inch	202	104	24	3	0	0	-
Total	2,398	2,414	2,434	2,557	2,565	2,594	1.6

Source: Dataquest (September 1992)

power and cost reduction and because there is no space to accommodate a large number of (lower-level integration and often less expensive) components.

In an earlier treatment of this subject we suggested that movement was toward a single-chip disk drive component, and there is evidence that such chips will be introduced shortly. However, we should clarify what we mean by a single-chip disk drive controller: not a single-chip solution (that is, one IC per drive) but rather a mixed-signal device that integrates whatever functions are technologically and economically possible. That in essence leaves a two- or three-chip solution, depending on whether the drive is in the "super low end" or the low to midrange of performance and capacity. The components of the three-chip solution would be the preamp IC, the drive controller IC, and a memory IC. For the two-chip solution, the memory would be integrated into the controller. This configuration is not meant to address all disk drives but it will be suited for RDDs that will go into PicDees and other low-cost, lightweight devices. The higher-performance and -density drives will undoubtedly use more ICs. Figure 1 shows AT&T Microelectronics' vision of how such integration is expected to take place over a short period, integrating in the process 15 separate devices into three MOS ASSPs.

Figure 2 shows relative changes in disk drive semiconductor content. The actual dollar value is expected to change very little for the forecast horizon. The semiconductor content for small drives is about $40.

The Winds of Change

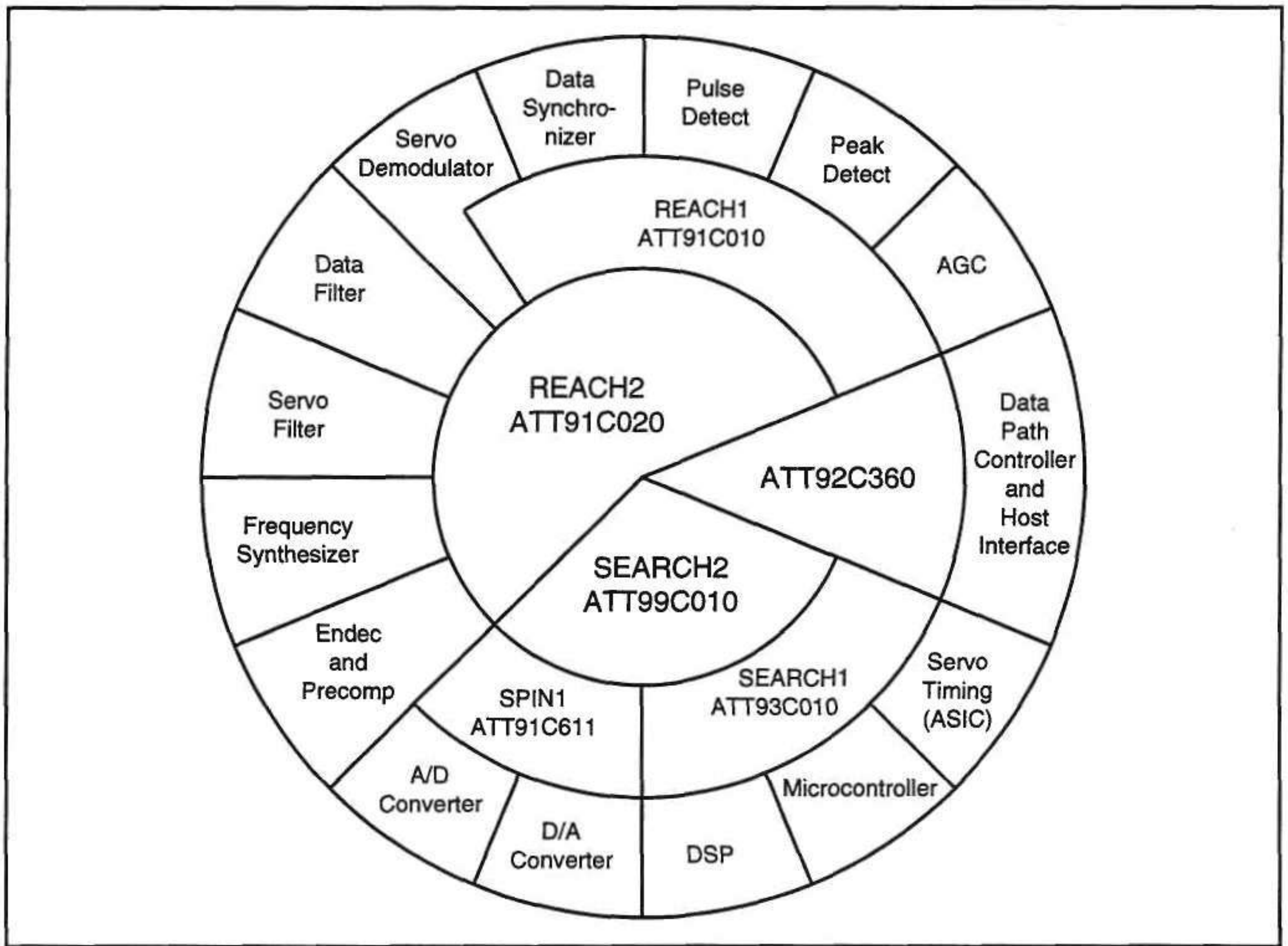
Is there any evidence to suggest changes in the mass storage industry, and what sort of changes are we seeing? The answers to the first question depends on how a disk drive, or better yet a mass storage device, is defined. If the traditional definition is expanded to include flash memory (semiconductor)-based solid-state disks (SSDs), then the answer is yes. Further confusing the issue is what one considers to be a mass storage company. For example, is Intel also a mass storage company? What about SunDisk, whose products are silicon-based?

No one is taking chances, if the Intel-Conner Peripherals joint venture is any indication. It is very unlikely that Conner feels threatened by flash memory-based SSD alternatives to RDDs for the near future. However, it early on realized the potential of the new technology and opted to capitalize on the opportunities to expand sales. Besides, the chosen route (teaming with Intel) offered the most logical and symbiotic relationship, with each company contributing strengths to the partnership: flash memory technology from Intel and subsystems storage expertise from Conner. More such alliances should be on the way in an attempt to serve the needs of the mass storage marketplace, and should come as no surprise to the participants. For companies looking at entering the market, this is food for thought.

Forecast Uncertainties

The 3.5-inch hard disk drives represent the dominant form factor, at least through 1996 (see

Figure 1
MOS ASSP Mass Storage Product Functions



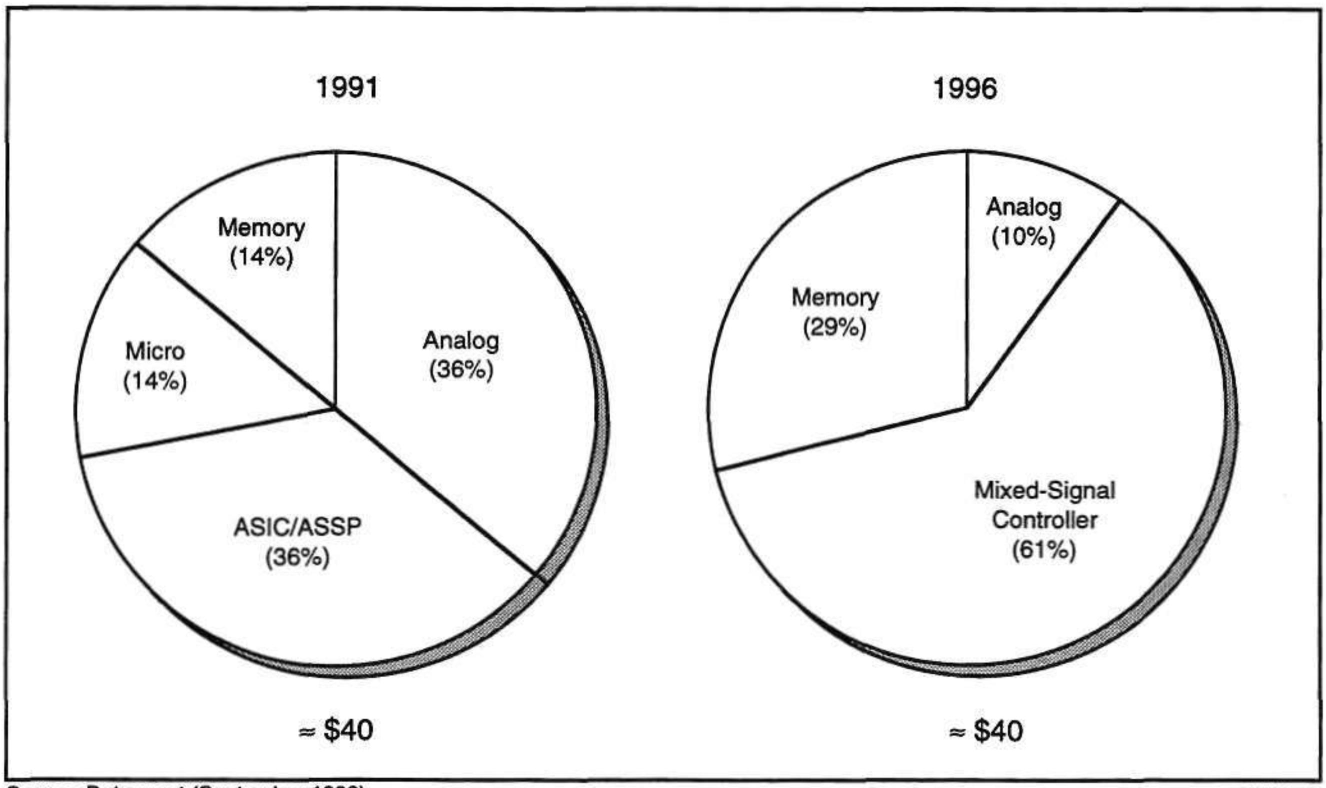
Source: AT&T Microelectronics G2001501

Figure 3). From a Semiconductor Applications Service standpoint the wild card in this market forecast is the emergence and quick acceptance of the new small form factor hand-held computers, that is, the PicDee.

As a category, PicDees describe hand-held PCs such as Apple's Newton and future HP-95LX type derivatives, as well as small pen-based machines. Will such devices be in volume production by 1996? If they are, what form of mass storage will they use? The answers may depend on one's point of view.

For PicDees to be successful, they must be small, light, easy to use (intuitive), and relatively inexpensive. They also must possess good communications capabilities. The need for portability and light weight dictates the mass storage requirements. PICDs are not meant to replace desktop PCs and as a result are not required to incorporate excessive amounts of software. The bare minimum amount of mass storage is needed. Because PicDees will communicate over wireless (or wired) networks with mainframes, home, and office computers, embedding massive amounts of storage solves no problems. Indeed, it adds weight, power consumption, and cost. Forecast uncertainty results from the possibility of early PICDs' success, which may consume substantial volumes of 1.3-inch (or smaller) drives. In such a case, this forecast may be conservative because it does not fully address that new PC subcategory.

Figure 2
Estimated RDD Semiconductor Dollar Content, 1991 and 1996



Source: Dataquest (September 1992) G2001502

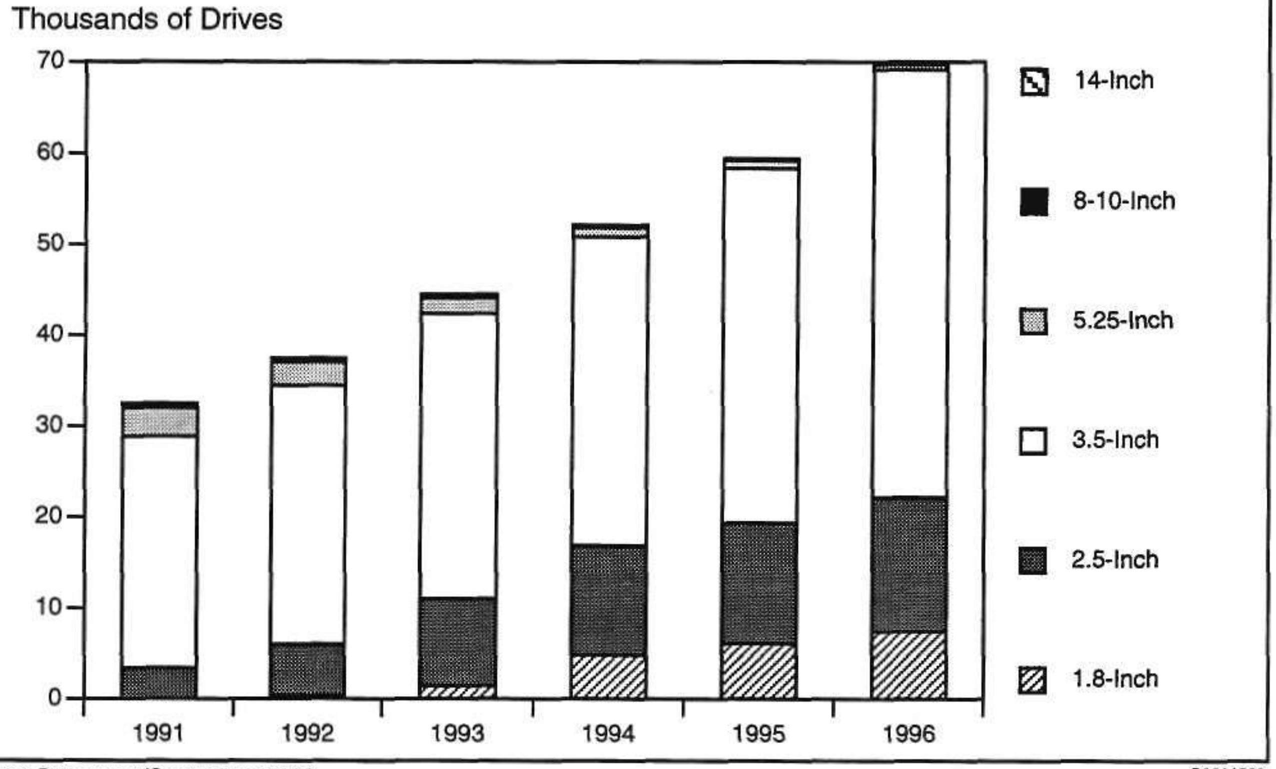
Cost Alternatives: Micro Drives versus Solid-State Storage

We know that at present semiconductor storage is a much more expensive form of mass storage than are RDDs, so why discuss the matter? The reason is that the new generation of PICDs may or may not use RDDs for mass storage, depending on the outcome of a head-on competition to satisfy the following conditions, which are seen as necessary for adopting a mass storage medium: Mass storage devices for use in PICDs must be rugged, small and lightweight, low in power consumption, and inexpensive.

So far RDDs have not satisfied these requirements. SSDs do well with the first three, but are about five times the price of RDDs. The 1.3-inch RDDs are expected to do better addressing the conditions. But SSDs are expected to close the cost gap to 3.5 times that of the 1.8-inch drives by 1996 and perhaps to do even better when compared with 1.3-inch or smaller RDDs. Ultimately, of course, cost determines whether a particular technology gets used or not. But are we talking about the cost per megabyte or the overall system cost? This is the key question and it involves a bit of an understanding and prediction of the ways PICDs will be used.

Because PICDs are not going to replace desktop PCs but instead will be the take-along device, there is no need to duplicate the power of the desktop. Instead we need to tap into that power remotely, thus the emphasis on the communications capabilities of PICDs, which in turn dictates that only a small amount of mass storage may be needed for local processing. Thus, 10- to 20MB may suffice (effective storage of 20- to 40MB with compression). The SSD cost of the system should be $50 to $100 by 1995. It is unlikely that a 20MB, 1.8-inch drive will cost $30 (20 times $1.50), as such a cost is based on a much higher disk density. The most likely scenario is that the SSD and the HDD will cost the same for that density. If that happens, then solid-state storage will be the medium of choice, because it fares much better for the requirements delineated earlier.

Figure 3
Worldwide RDD Market Shipments (in Thousands)



Source: Dataquest (September 1992)

G2001503

So, is it time for semiconductor vendors to celebrate? RDD manufacturers offer formidable competition for anyone that ventures into the mass storage arena with SSD solutions. And so far RDD makers have been able to come up with substantial cost and technology breakthroughs whenever the requirements demanded. The infamous cost per megabyte curves for RDDs and SSDs have been drawn so as to cross over at some point, and that point has been moving forward for the past 20 years (see Figure 4), sparking many heated debates in the process. The real question is whether these two curves must cross. Given the preceding discussion, the answer may be no.

Figure 5 shows Dataquest's cost-per-megabyte estimates for flash memory-based SSDs and RDDs. The 1.8-inch drive is used for comparison because it represents the current candidate (along with the 1.3-inch) for head-on competition with solid-state storage in the emerging PICD market.

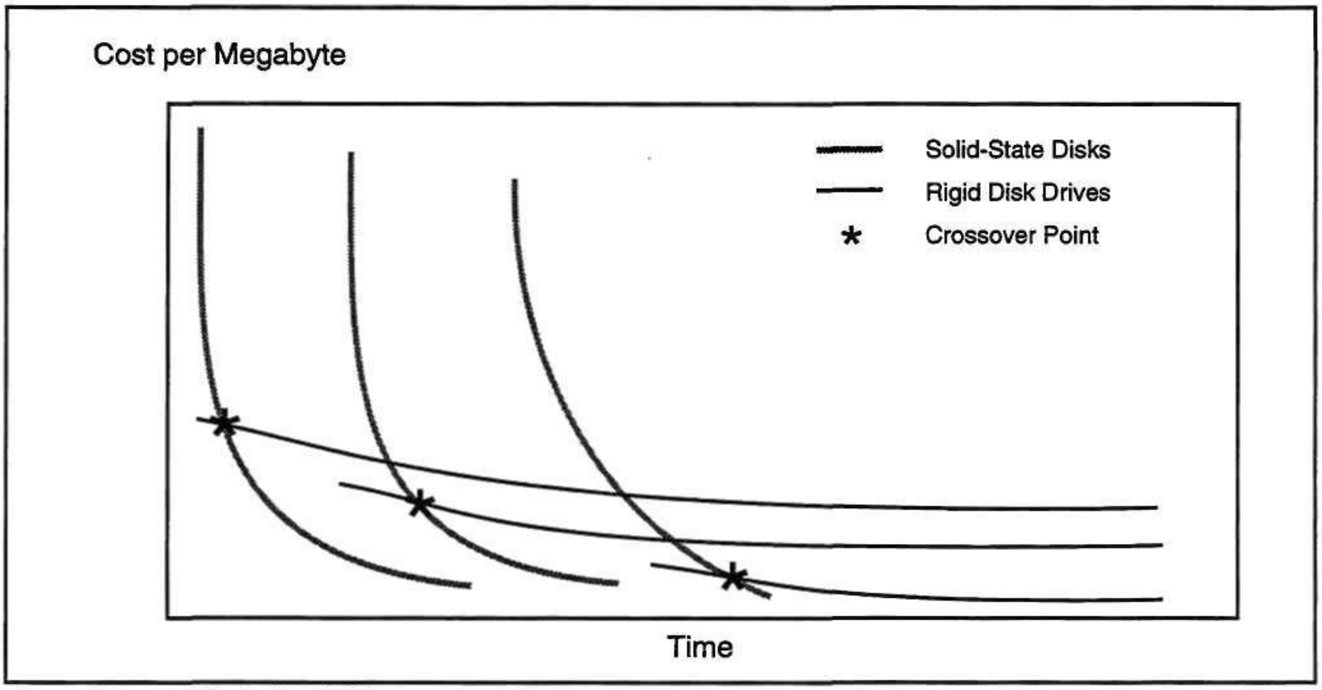
Dataquest Perspective

Business as usual continues for RDD vendors, with volumes going up for the new micro RDDs, severe price pressures from users, and shrinking life cycles. Semiconductor vendors face a similar fate. What seems to be a bit different now is that these two groups of vendors might be developing an identity problem. It used to be easy telling a disk drive mass storage company from a semiconductor company, but not any more. Semiconductor vendors are becoming mass storage houses and RDD companies are becoming suppliers of solid state storage—it may be the only way to stay in the mass storage business (in the long run) and make money.

Earlier we suggested that there may be a move to single-chip disk drive controllers. This suggestion appears to be backed now by plans for such silicon from semiconductor vendors. That should be good news for everybody.

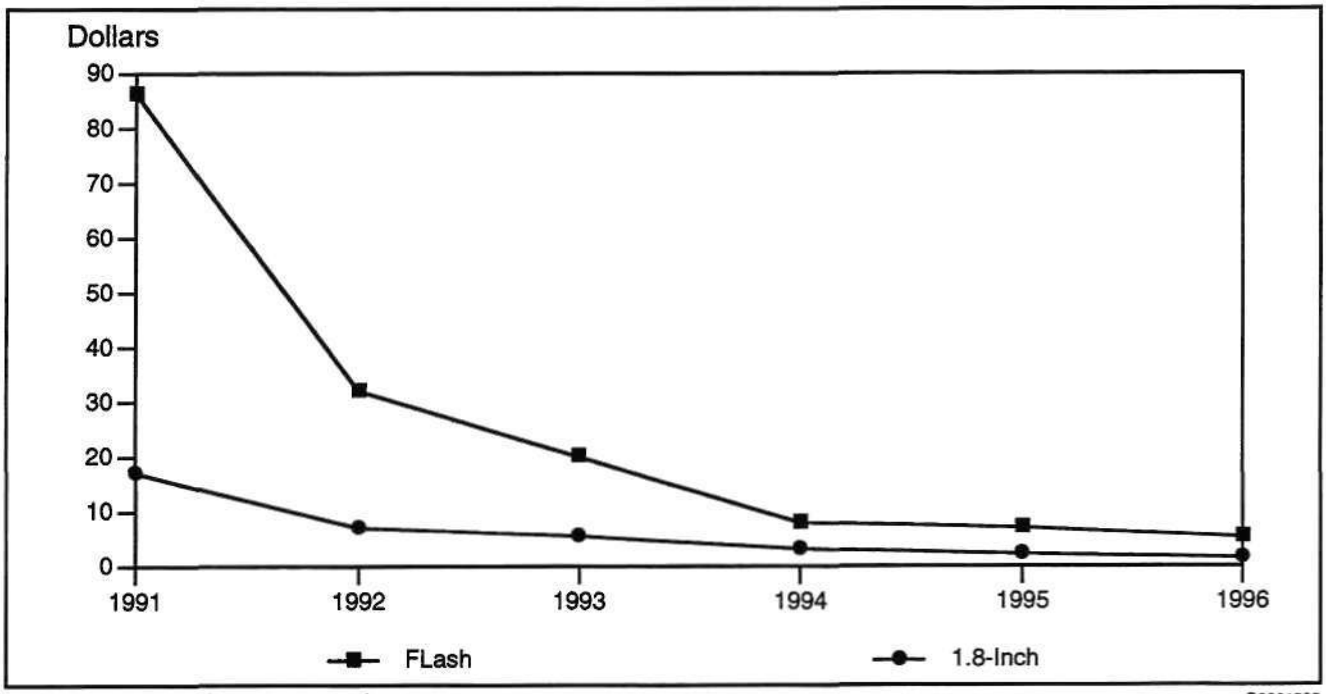
By Nicolas Samaras

Figure 4
Cost per Megabyte, RDDs and Solid-State Disks



Source: Dataquest (September 1992) G2001504

Figure 5
Cost per Megabyte, 1.8-Inch RDDs versus Flash Cards



Source: Dataquest (September 1992) G2001505

Worldwide Electronics Production: A Mixed Recovery

Dataquest expects electronic equipment production to recover modestly from growth of 3.0 percent in 1991 to 3.7 percent growth in 1992 (see Figure 1). Valued at $641 billion in 1991, global electronics production is expected to reach $857 billion in 1996. However, 1992 growth will be geographically sporadic, with North America's market recovering, Japan declining, Europe being mixed but sluggish, and Asia-Pacific/Rest of World continuing its double-digit growth (see Figure 2). Selected electronics categories are ranked by growth rate in Figure 3.

Dataquest projects global recovery in capital and consumer spending for 1993 in each region of the world, with each hardware category benefiting.

North America: Modest Recovery, Niche Opportunities

Expected GDP growth rates for the United States and Canada in 1992 are 2.1 percent and 1.6 percent, and 4.0 and 2.2 percent in 1993. Valued at $215 billion in 1991, North American electronic equipment production is expected to reach $267 billion in 1996. Capital investment growth is leading these economies out of the recession, while higher-than-average unemployment helps curtail consumer spending. Election year optimism is having less of a positive effect. Key growth factors for electronics over the near term will be as follows:

- Surging PC unit demand during summer 1992 as most vendors cut prices 25 to 30 percent; demand is expected to slow by fall
- Surging workstation demand along with high-performance networking such as FDDI, and internetworking equipment
- Rebounding domestic production (up 10 percent year-to-date) of automobiles and accompanying electronics
- Retrenching military spending not being made up by civil space and aircraft industries

North American Free Trade Agreement

Now signed by the leaders of the United States, Mexico, and Canada, this agreement offers the potential of creating the world's largest free trade bloc. There is still some uncertainty as to whether the legislative bodies of the countries will ratify the agreement, as there remains much fear about job loss. The U.S. congress will not begin deliberations until after the November elections.

The primary impact on electronics will be local content requirements on circuit boards and automotive subassemblies.

Europe: EC Mandates, Automation Continues

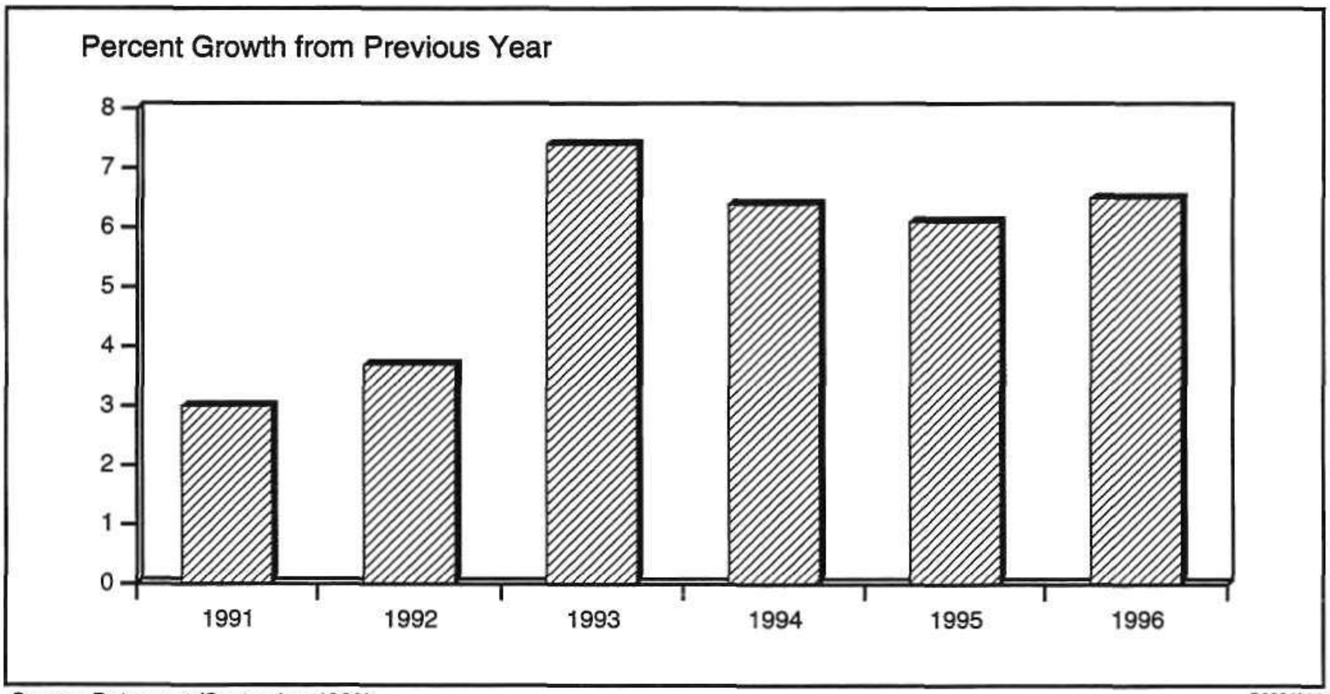
High interest rates caused by Germany's reunification borrowing is putting a damper on most of Europe's national economies, whose currencies have become tied to the deutsche mark. Expected growth rates for the U.K., German, and French economies are 0.5 percent, 2.1 percent, and 1.1 percent, respectively, in 1992, with acceleration to 2.2 percent, 2.7, and 2.8 percent in 1993. Valued at $163 billion in 1991, European electronic equipment production is expected to reach $221 billion in 1996. Key drivers of Europe's electronic production include the following:

- Ongoing EC mandates for local content continues to add several percentage points of growth as U.S. and Japanese companies continue building or contacting European production capability (for circuit board assembly)
- Ongoing office automation penetration as PCs, workstations, and peripherals remain underdiffused relative to the United States
- Ongoing strength of European telecom companies such as Ericsson as they take a leadership position in the global market for communications equipment
- Slowly rising consumer demand out of Eastern Europe

Japan: Bubble Bursts

Japan's gross domestic product will grow 2.0 percent in 1992 and accelerate to 3.3 percent in 1993. Domestic capital and consumer spending will remain sluggish while exports remain slow because of trading partner sluggishness. At press time the Nikkei index continued to fall, dramatically impacting Japanese management thinking about capital investment. Saturated consumer markets abroad are not picking up the slack in domestic electronics demand. Valued at

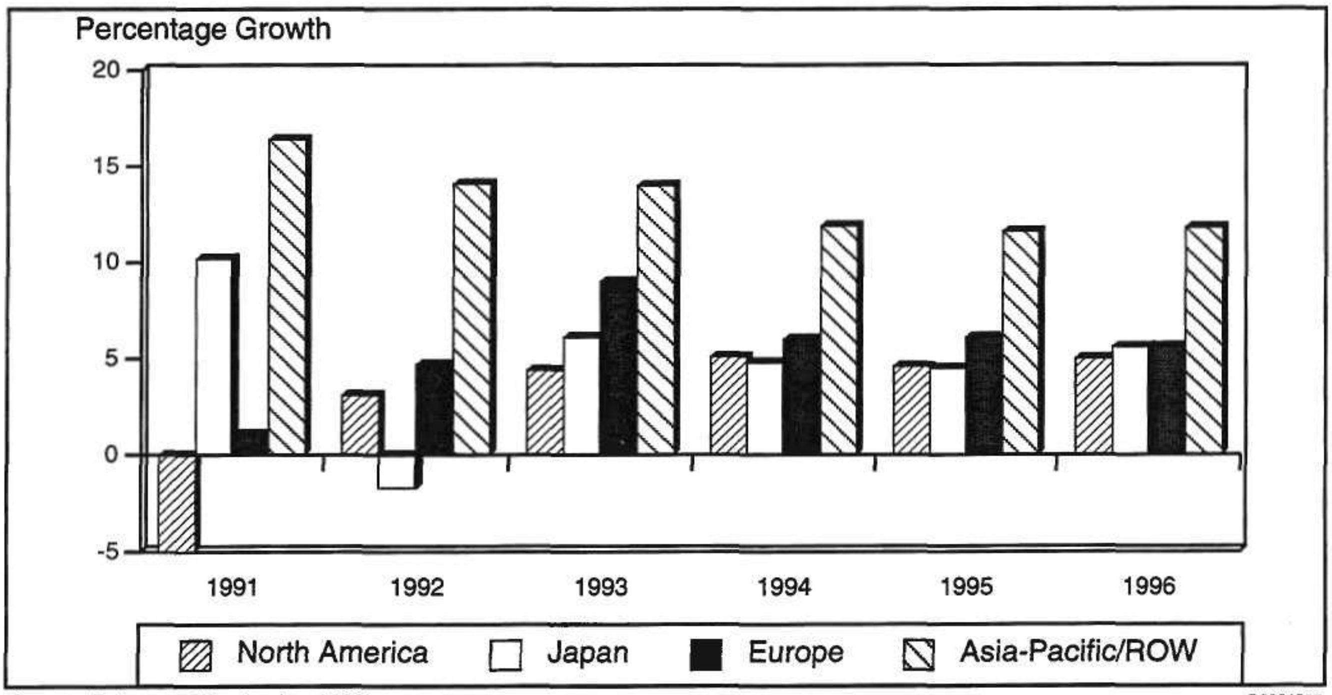
Figure 1
Worldwide Electronic Equipment Production Forecast



Source: Dataquest (September 1992)

G2001506

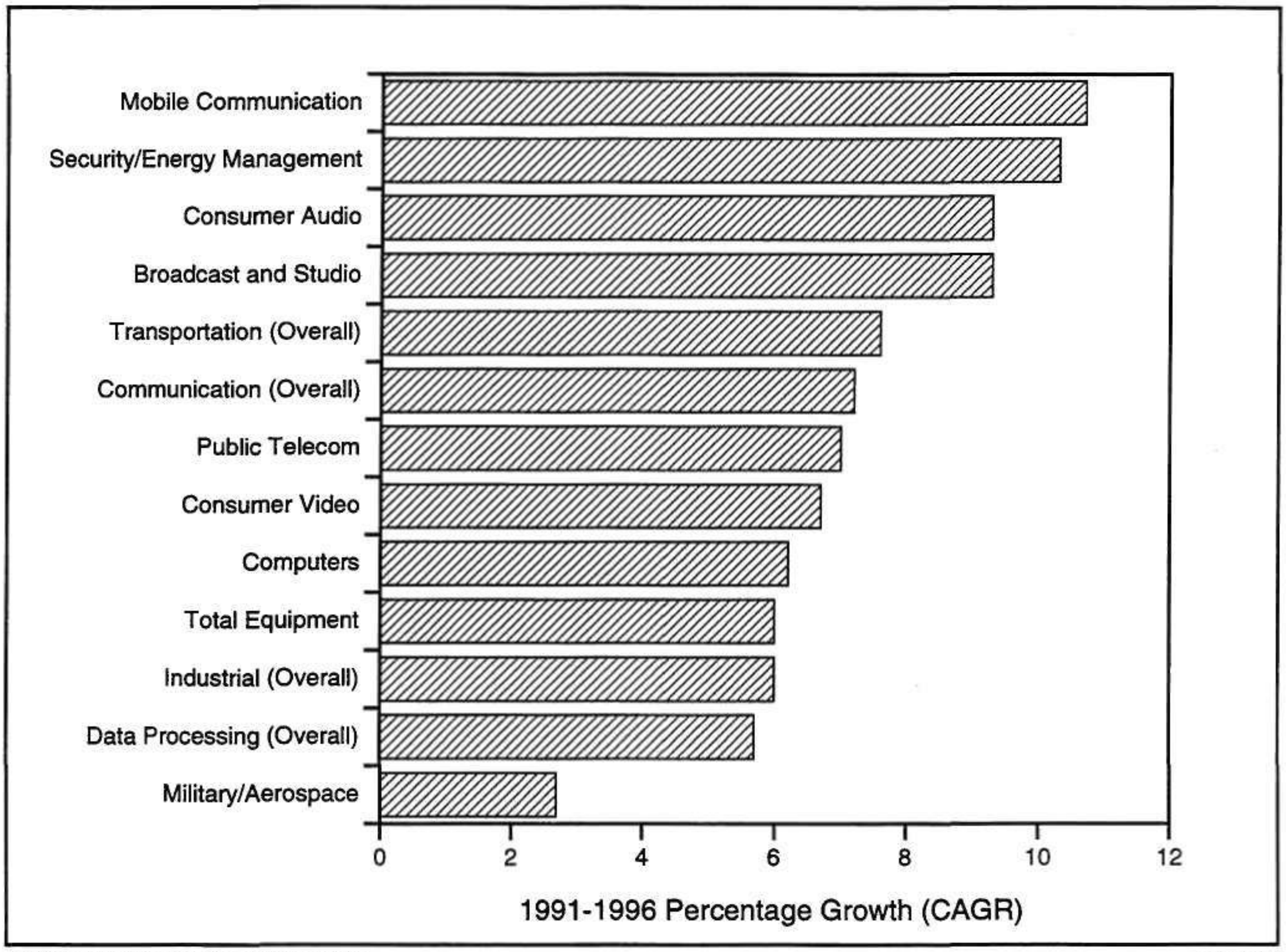
Figure 2
Worldwide Electronic Equipment Production Forecast (by Geographic Region)



Source: Dataquest (September 1992)

G2001507

Figure 3
Selected Electronic Equipment Market Rankings



Source: Dataquest (September 1992)

G2001508

$176 billion in 1991, Japanese electronic equipment production is expected to reach $212 billion in 1996. Key factors affecting Japan's production include the following:

- Continual movement of production once based in Japan to other parts of the world, mainly to address local content and joint-venture provisions
- The emergence of a strong workstation market and a solid position in multimedia-needed optical drives
- The rollout of ISDN and mobile communication networks as Japan upgrades its infrastructure
- Next big consumer products are personal information and communications devices (PICDs), next-generation audio (minidisk, among others), and karaoke.

Asia-Pacific/ROW: Indigenous Markets Complement Exports

Most Asia-Pacific/ROW economies continue double-digit or near-double-digit growth as indigenous demand complements their export orientation. Valued at $86 billion in 1991, Asia-Pacific/ROW electronic equipment production is expected to reach $156 billion in 1996. Key growth factors to note include the following:

- The emergence of more "tigers," such as Thailand, Malaysia, and Indonesia
- Continual investment by Japan, the United States, and European OEMs into plants and joint ventures as commoditization (that is, cost sensitivity) of desktop computers and peripherals continue

- Sizable infrastructure projects in public communication and factory automation
- Possible negative impact by North American trade agreement

Emerging Markets

Within each, and sometimes between each, of Dataquest's forecast categories there are numerous incubating hardware markets that are anywhere from two to five years away from significant volume. Some of those include the following:

- PICDs (Personal Information and Communication Devices)
- Pen-based computers
- Digital video/sound cards (multimedia)
- Personal workstations (for example, P-5 based)
- Solid-state storage/memory cards
- Sub-3.5-inch magnetic disk drives
- CD-ROM/XA, rewritable optical
- RAIDs (redundant arrays of inexpensive disks)
- Color laser printers
- Hand-held terminals
- Smart cards
- Intelligent point-of-sale systems
- Internetworking (bridges, routers, hubs, and gateways)
- N-ISDN terminals and networks (N = narrow band)
  - Group IV facsimile
  - Video telephones
  - Desktop video conferencing
- B-ISDN networks (B = broadband)
  - Asynchronous transfer mode (ATM) switches/muxes
  - SDH/SONET transmission equipment
- Personal communications networks (PCNs)
- Digital cellular/cordless phones
- Wireless data communications terminals
- Global positioning system (GPS)/navigation terminals
- HDTV (receivers, VCRs, laserdisks, camcorders, studio equipment)
- Advanced consumer audio (minidisk, compact cassette)
- Automotive air bags, antilock braking, transmission control
- Electric vehicle controls

Dataquest Perspective

We expect worldwide electronics markets to begin recovery this year, with 1993 being the year the various economies aid each other with positive feedback. The best long-term opportunities are in transportation and communication, with the latter being of much greater size. If military/aerospace were factored out of the numbers, the global growth rate would be 10 percent higher. Perhaps it is an overused recommendation, but local presence with technical talent able to influence product development is a good way to take advantage of some of the opportunities we have noted here.

By Gregory Sheppard

Turbocharged Modems: V.Fast Takes Off

V.Fast is the name for the new, as yet undefined, modem standard currently under review by CCITT Study Group XVII. It is receiving significant attention for two reasons: it promises a high level of performance; and one manufacturer, Motorola Codex, has released a family of products that allows data transmission speeds of up to 24 Kbps and carries the name 326XFAST, even though the V.Fast standard has not been fully defined.

TIA Helps to Solidify V.Fast

V.Fast recently emerged from the fog surrounding it and showed a glimpse of its final appearance after the recent Telecommunication Industry Association (TIA) meeting in Newport Beach, California. TIA recommended the following key features to CCITT:

- Transmission speeds up to 28.8 Kbps, synchronous, and up to 115.2 Kbps asynchronous, when using the V.42bis data compression algorithm

- Baud rates of 2400, 2743, 3000, 3200, and 3429 baud
- Line probing during call setup to optimize carrier and signaling frequencies to best utilize the available bandwidth on a given line
- Adaptive rate features that allow the transmission rate to change in response to varying line conditions, minimizing errors and enhancing throughput

The most important differences between V.Fast and previous modem standards—besides the higher transmission speeds—are the ability to optimize the signal modulation for given line conditions, the adaptive rate features, and more sophisticated precoding and signal space preshaping schemes to improve the signal-to-noise ratio on existing voice lines. Because of these features, V.Fast should be able to routinely deliver 19.2-Kbps transmission on lines currently capable of transmitting 14.4 Kbps using the V.32bis standard.

High-Speed Modems Precede the Standard: Putting the Cart before the Horse

The Motorola Codex product has incorporated many of the features likely to be part of the V.Fast standard, as well as several proprietary attributes. The family will support full duplex synchronous transmission rates of up to 24 Kbps and asynchronous rates of up to 115.2 Kbps with V.42bis data compression. 326XFAST also incorporates a line-probing capability, multidimensional Trellis coding, and signal space preshaping. The added features are of the type likely to be part of the V.Fast standard, but the specifics have not yet been discussed by the CCITT committee, putting Codex in the position of driving the standard rather than vice versa. Telebit has also introduced a high-speed modem, the Wordblazer V.32bis/TurboPEP, a higher-speed version of the V.32bis family capable of 23-Kbps speeds at half duplex, but only 14.4 Kbps at full duplex.

The 326XFAST family will be upgradable to be V.Fast-compatible by replacing a PROM chip, which will be provided at no charge if the customer performs the upgrade. U.S. Robotics also plans to release a V.32bis modem that the user will be able to upgrade to V.Fast compatibility through the field replacement of a daughterboard.

Market Analysis

Dataquest believes that, upon release of the standard, modems compatible with the V.Fast standard will rapidly become a commodity product, displacing the V.32 and V.32bis markets in much the same way those products displaced earlier generations. Driving the market for high-speed modems will be the following:

- Large file transfer applications, such as image files and large database files
- Backups to leased lines
- Remote server or LAN-LAN connections
- General sensitivity to connect-time charges

Table 1 indicates the historical and forecast revenue and unit shipments for modems in North America, beginning with the V.22bis standard. The marketplace has exhibited a voracious appetite for higher-transmission-rate modems, and Dataquest does not anticipate this changing. Dataquest predicts that V.Fast shipments will accelerate rapidly after introduction in 1994 and quickly displace V.32bis shipments. There is a potential upside to this forecast: Codex has introduced the 326XFAST product family at very aggressive pricing levels—$1,395 for the two-wire standalone version. Dataquest is forecasting the 1994 pricing at about $1,000. If the early pricing shows significant erosion below this point, the migration from V.32bis to V.Fast could occur even more rapidly.

Figure 1 shows the historical and projected revenue for the V.22bis, V.32, V.32bis, and V.Fast modems in North America. Dataquest believes that volume shipments of V.Fast modems will commence in the 1994 time frame and ramp relatively quickly, at about the same rate that V.32bis ramped at the expense of V.32.

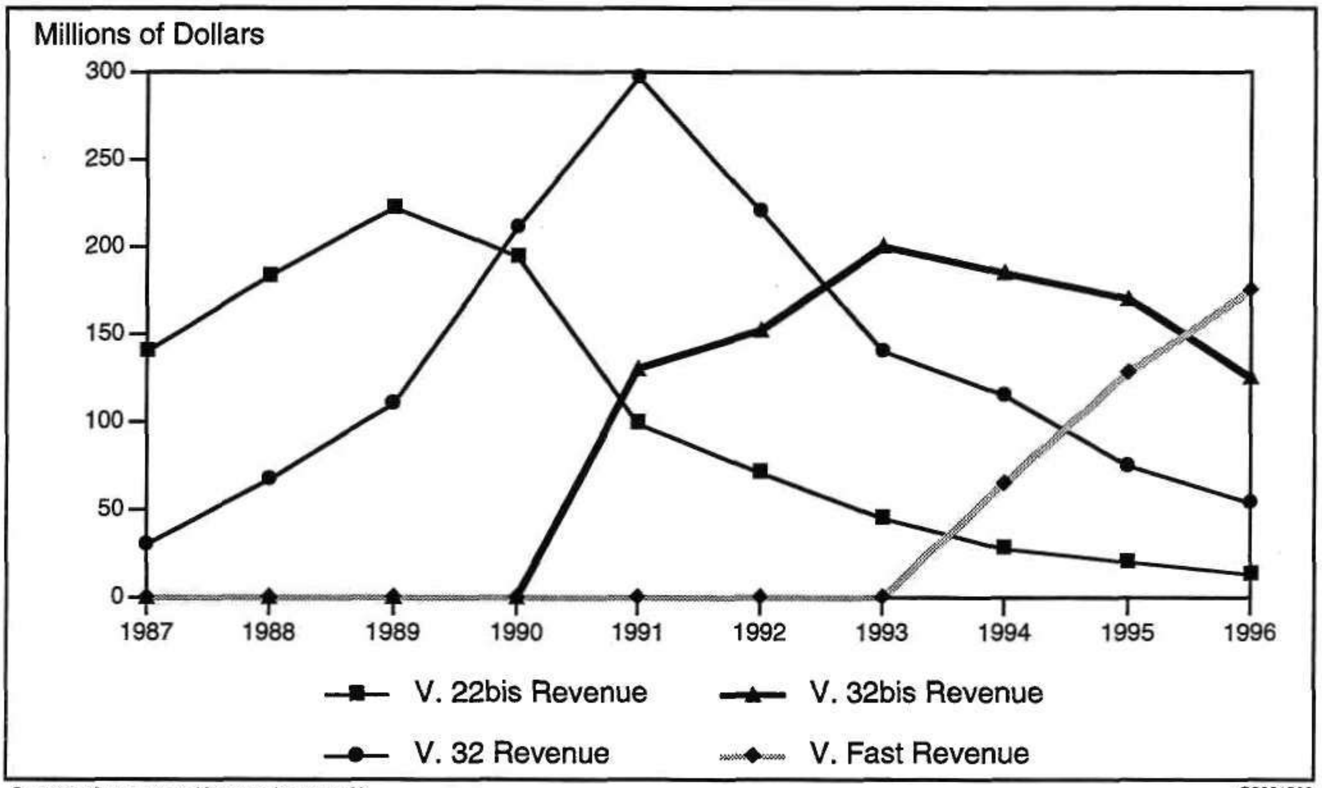
The emergence of a new high-speed modem standard will provide opportunities for mixed-signal chip set manufacturers to incorporate the DSP, microcontroller, and analog functions onto a chip set or a single chip. These products will help drive the migration of the modem and fax/modem functions from standalone boxes to add-in cards, and ultimately inclusion on the CPU motherboard, with concomitant price reductions.

Table 1
North American Modem Market History and Forecast, Selected Modem Standards

Calendar Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
V.22bis										
Units (K)	716.4	1,015.4	1,480.0	1,547.7	1,045.5	950.0	900.0	795.0	630.0	480.0
Revenue ($M)	139.7	182.8	222.0	193.5	99.3	71.3	45.0	27.8	19.5	13.4
V.32										
Units (K)	20.0	48.0	100.0	234.7	427.4	400.0	350.0	320.0	300.0	270.0
Revenue ($M)	30.0	66.6	110.0	211.2	297.0	220.0	140.0	115.2	75.0	54.0
V.32bis										
Units (K)	NA	NA	NA	NA	89.2	220.0	400.0	450.0	520.0	480.0
Revenue ($M)	NA	NA	NA	NA	80.3	151.8	200.0	184.5	170.0	125.0
V.Fast										
Units (K)	NA	NA	NA	NA	NA	NA	NA	64.6	196.2	350.0
Revenue ($M)	NA	NA	NA	NA	NA	NA	NA	64.6	127.5	175.0

NA = Not applicable
Source: Dataquest (September 1992)

Figure 1
North American Modem Market History and Forecast, Selected Modem Standards



Source: Dataquest (September 1992)
G2001509

Dataquest Perspective

As the quality of the public telephone system improves by gradual conversion of analog circuits and switches to digital, the maximum modem transmit speeds will increase commensurately. The addition of adaptive features that allow the modem to optimize the transmission conditions to the line capabilities also enhances the data transmission speed and throughput. Given the projected low cost for high-performance modems and the large existing voice line infrastructure, Dataquest believes that there is plenty of room left for the modem market, and it is unlikely to be displaced any time soon by ISDN, which is still largely unavailable and in many cases cost-prohibitive. With this scenario, the characterization of V.Fast as V.Last may be premature. Perhaps the more relevant question is, what will be V.Next?

By Charles Boucher

In Future Issues

An article on the following topic will be addressed in future issues of Semiconductor Application Markets *Dataquest Perspective:*

- Semiconductor opportunities in multimedia

Conference Announcement

Dataquest's 18th Annual Semiconductor Industry Conference

Each October, Dataquest brings together the top executives in the electronics industry for a forum on the latest issues facing this industry. This year's conference will focus on today's semiconductor marketing and technology issues, and preview tomorrow's major semiconductor applications that are *Fueling the Engines for Growth.*

Highlights of the conference are as follows:

- Special guest speaker: David Packard, Cofounder and Chairman of the Board of Hewlett-Packard.
- Eleven top industry executives sharing their insightful perspectives, real-world experiences, lessons, and bottom-line analyses.
- Two interactive panel discussions covering ASICs and strategic processor directions. Panels will be moderated by Dataquest and feature key industry leaders.
- Four breakout sessions presented by Dataquest senior analysts. The sessions will focus on manufacturing trends, semiconductor procurement issues, and two emerging applications areas: personal information and communications devices (PICDs), and multimedia.

In addition to the presentations and panel discussions, this year's agenda has been designed to allow social time for conferring with your peers on the critical issues and challenges facing the industry. You'll find the two days interesting, very informative, and, we hope, thoroughly enjoyable.

Seats are limited for this premier semiconductor event. To register for this conference, or to request a complete conference agenda, please call our toll free number, 1 (800) 457-8233, today!

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In This Issue...

Market Analysis

Optical Disk Drive Forecast Update

The March 1992 Semiconductor Application Markets *Dataquest Perspective* article entitled "Optical Storage: Is Multimedia the Driver?" presented Dataquest's optical disk drive (ODD) estimated consumption and forecast, courtesy of Dataquest's Computer Storage Group. The Computer Storage Group has issued an update (see Table 1), and the time has come to revisit that forecast.

CD-ROM unit shipments have been revised up for the calendar years 1991 through 1995. The most significant change is that the actual shipments for 1991—the base year for this discussion—were revised upward from 360,000 to 936,000 units. This revision has had the effect of lowering the compound annual growth rate (CAGR) from 1991 to 1995 from 72.3 percent to 35.2 percent. Forecast consumption for 1995 is up from 3.17 million to about 4.22 million units.

Cost Strategies Propel CD-ROM Market

In general the CD-ROM drive market is experiencing healthy growth spurred by the increased activity for multimedia applications. The use of CD-ROMs as a software distribution medium also is on the upswing. Some major software distribution houses are now selling CD-ROM drives at or close to cost in order to facilitate CD-ROM software sales. There are indications that this strategy is paying off.

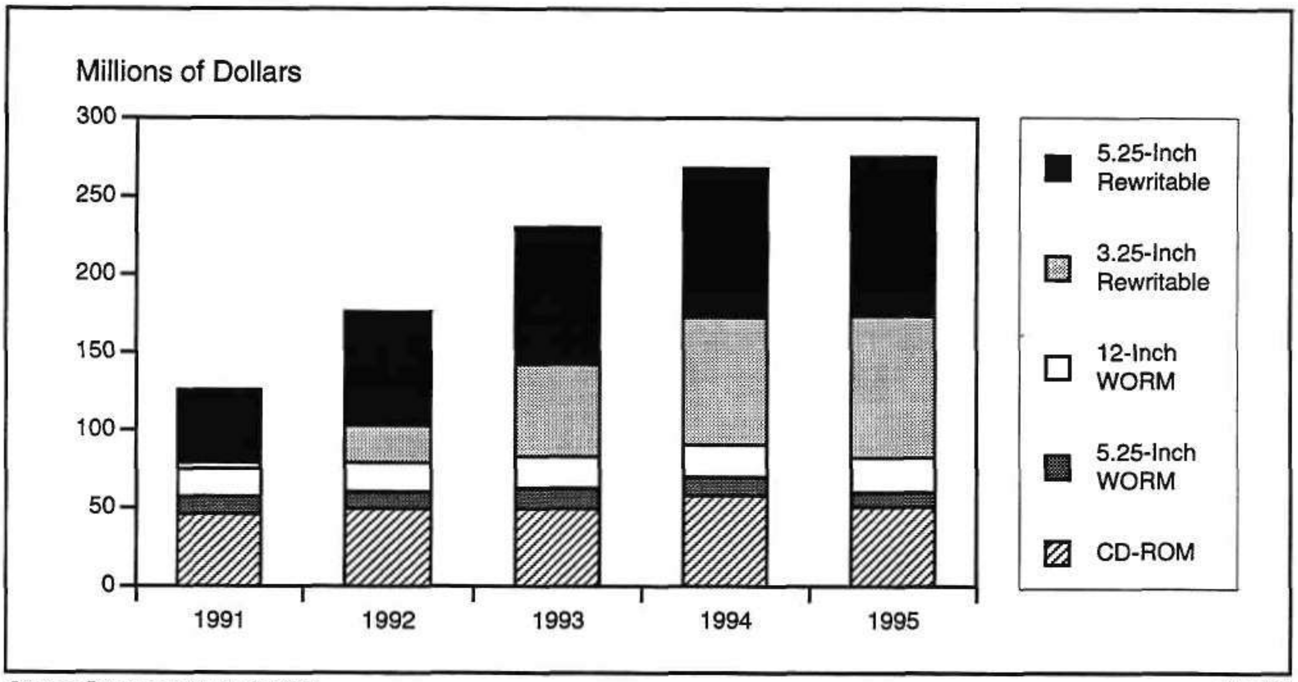
Software vendors have an ulterior motive for supporting CD-ROMs as a software distribution medium: It helps prevent software piracy because CD-ROMs cannot be easily copied in volume. Another benefit is, of course, lower shipping costs for software vendors. As the number of floppies needed to distribute today's software increases, so does the underlying cost, both in terms of the number of floppies needed as well as the shipping weight. The CD-ROM is

Table 1
Optical Disk Drive Estimated Worldwide Consumption (Thousands of Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
CD-ROM	936	1,498	2,246	3,617	4,228	35.2
5.25-Inch WORM	46.6	56	78	80.9	75	10.0
12-Inch WORM	11.5	13.8	17.5	21.2	24.8	16.6
3.25-Inch Rewritable	22	160	544	984	1,440	130.8
5.25-Inch Rewritable	121.2	249	390	558	780	45.1
Total	1,137.3	1,976.8	3,275.5	5,261.1	6,547.8	41.9

Source: Dataquest (July 1992)

Figure 1
Worldwide Semiconductor Total Available Market for Optical Disk Drives (Thousands of Dollars)



Source: Dataquest (August 1992) G2001038

seen as the obvious answer because the medium is inexpensive to manufacture and, from a storage standpoint, a single CD-ROM can replace 382 high-density (1.44MB) 3.5-inch floppies or 1,527 low-density (360K) 5.25-inch floppies.

Both the 5.25- and 12-inch WORM drives were revised slightly downward; the same is true for the 5.25-inch rewritable form factor. The 3.5-inch rewritable ODDs have been revised upward from 12,000 units in 1991 to 22,000. These drives still show the highest CAGR of all ODDs, with a 1991 to 1995 CAGR of 130.8 percent.

Table 2 shows the worldwide ODD forecast by drive type, drive factory ASP, and estimated semiconductor content for each drive type, along with the estimated total available market (TAM), for semiconductor devices used in ODDs.

Figure 1 shows the worldwide TAM for semiconductor devices by drive type, along with their relative contributions.

Table 2
Worldwide Optical Disk Drive Forecast

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
CD-ROM (K Units)	936	1,498	2,246	3,617	4,228	35.2
Factory ASP ($)	207	145	102	80	68	-24.3
Semiconductor Content ($)	49	33	22	16	12	-29.7
Semiconductor TAM ($K)	45,864	49,434	49,412	57,872	50,736	2.0
5.25-Inch WORM (K Units)	46.6	56	78	80.9	75	10.0
Factory ASP ($)	1,020	867	780	702	632	-11.3
Semiconductor Content ($)	244	199	171	147	126	-15.2
Semiconductor TAM ($K)	11,370.4	11,144	13,338	11,892.3	9,450	-3.6
12-Inch WORM (K Units)	11.5	13.8	17.5	21.2	24.8	16.6
Factory ASP ($)	6,480	5,832	5,249	4,724	4,488	-8.8
Semiconductor Content ($)	1,555	1,341	1,154	992	897	-12.9
Semiconductor TAM ($K)	17,882.5	18,505.8	20,195	21,030.4	22,245.6	4.5
3.25-Inch Rewritable (K Units)	22	160	544	984	1,440	130.8
Factory ASP ($)	780	642	499	399	319	-20.0
Semiconductor Content ($)	187	147	109	83	63	-23.8
Semiconductor TAM ($K)	4,114	23,520	59,296	81,672	90,720	85.6
5.25-Inch Rewritable (K Units)	121.2	249	390	558	780	45.1
Factory ASP ($)	1,600	1,280	1,024	819	655	-20.0
Semiconductor Content ($)	384	294	225	171	131	-23.6
Semiconductor TAM ($K)	46,540.8	73,206	87,750	95,418	102,180	17.0
Optical Disk Drive Semiconductor TAM ($K)	125,771.7	175,809.8	229,991.0	267,884.7	275,331.6	17.0

Source: Dataquest (August 1992)

Dataquest Perspective

As the revised ODD forecast indicates, CD-ROM shipments for the calendar year 1991 were above expectations. This very encouraging fact tends to support our earlier argument that multimedia is a strong driving force for this market segment; and with consumer interest riding high on multimedia applictions, CD-ROM drives appear to be heading down the high-volume/low-ASP road. Generally speaking this is good news for semiconductor vendors because it translates to high volumes for devices. The other bright spot is, of course, the 3.5-inch rewritable drives with substantially higher unit volume projections out to 1995. Because of a higher ASP as well as a higher semiconductor content, the 3.5-inch optical drive market represents the most significant opportunity within the ODD electronics market.

By Nicolas Samaras

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q: What is the status of the digital still (filmless) camera market?

A: The worldwide 35mm single lens reflex (SLR) market is about 5 million units annually and is projected to grow at a compound annual growth rate of 8 percent over the next four years. SLRs are the prime target of digital still cameras. Other markets are desktop publishing, education, and training, which would use digital cameras to capture images for multimedia usage. Filmless cameras now sell between $1,000 and $5,000, depending upon resolution and color or gray-scale capability.

Market growth will escalate and early adopters of moderate sophistication will be attracted if prices come down to the $500 range. Newspaper photographers who need to transmit their images are an example of an early adopter. This technology offers the promise of not having to pay for film processing and lower costs for color hard copies from color printers. And, the technology is instantaneous.

Professional photographers are turning to filmless or scanned images as a way of editing their work for print ads. Desktop filmless cameras are emerging on the scene to complement scanners from companies such as Logitech. This need is being driven by the move to more sophisticated image handling as part of the multimedia phenomenon. Japanese digital camera makers such as Canon, Nikon, Fuji, and Sony have indicated that the market for digital cameras will reach 1 million units by 1993. Film manufacturers such as Kodak and Fuji are investing heavily in filmless research and products just in case this technology attains broad acceptance and their business becomes jeopardized.

Inhibiting growth of filmless technology are perceived poor picture quality, infrastructure, and competing (existing) technology. The concern regarding quality relates to the use of existing camcorder CCD arrays at 400,000 pixels as the imaging array; plans are to soon double this to 800,000, and to 2 million when HDTV arrives. The cost versus quality factor will moderate broad acceptance. As for infrastructure, the local developing labs of the world need to be converted over to color hard-copy shops because consumers and businesses will not forego the photo album hard copy. As for competing technologies, there still exists the chemical film technology that has proven to have a lot of staying power. There is also Kodak's PhotoCD approach, where consumers can have a CD made of existing photographs. These CDs can then be played through a compact disk interactive system CD-I such as the one offered by Philips/Matshushita.

We believe that consumers and businesses will buy digital cameras, but only when the issues outlined here have been addressed. This translates into a delayed market emergence. Therefore, the million-unit mark will not be reached until 1995.

For semiconductor companies, specific opportunities exist to provide cost-optimized color CCD arrays (400K to 800K pixels), SRAM or flash memory cards (slow, 2/4MB, 20-pin), and data conversion, pixel manipulation, and JPEG compression functions.

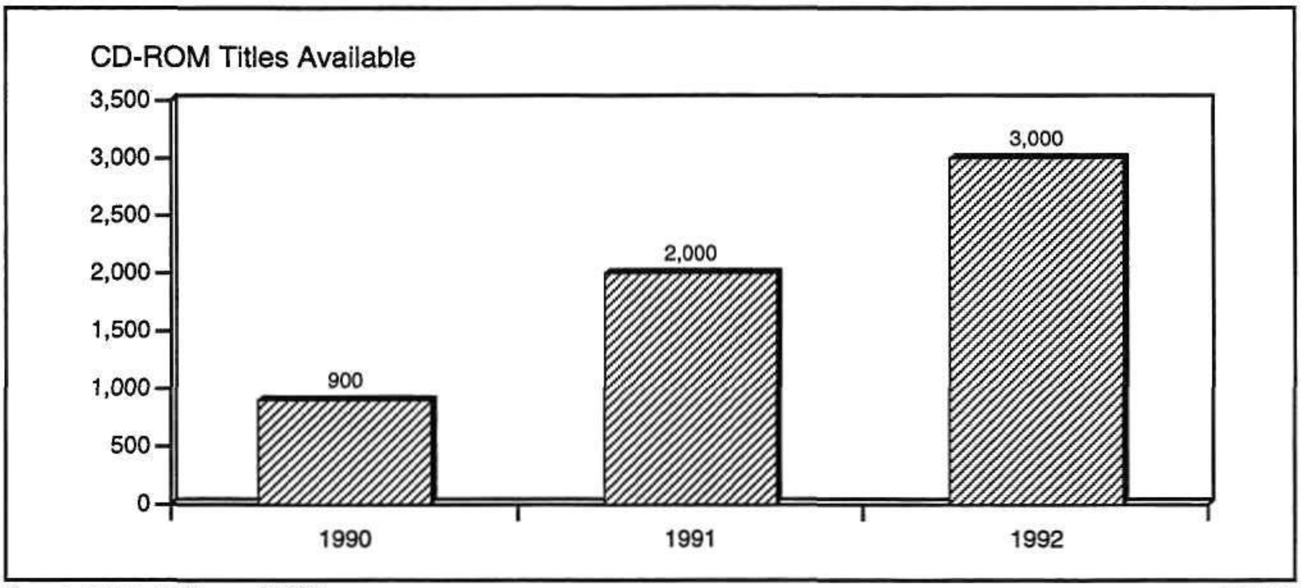
Gregory Sheppard

Q: How many CD-ROM titles are available, and in what general areas (for example, education, business)?

A: About 2,000 CD-ROM titles were available in 1991. This is expected to grow by 50 percent in 1992 (see Figure 1). Table 1 shows the CD-ROM title distribution for calendar year 1991.

Nicolas Samaras

Figure 1
CD-ROM Title Availability



Source: Dataquest (August 1992)

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Table 1
CD-ROM Title Distribution

Business	320	Military History	50
Medicine	160	Sports and Games	50
Science and Technology	130	Agriculture and Animal Husbandry	40
Library and Information Science	110	Parts Catalogs	40
Geography and Anthropology	100	Biology and Life Science	30
Statistics	100	Environment	30
Computer Software	95	Patents	30
Law	90	Social Science	30
Education	80	Auto Industry	20
Desktop Publishing	70	Multimedia	18
Newspaper and Books	70	Government Information	6
Language and Literature	60	Others	157
Telephone Listings	60		

Source: Dataquest (August 1992)

Q: Who are the major players in optical disk drives and what is their market share?

A: Table 2 shows the optical disk drive market's major vendors, along with their 1991 market share.

Nicolas Samaras

Q: Name the top 10 tape drive vendors that manufacture in the United States.

A: Table 3 lists the top 10 tape drive vendors with major manufacturing in the United States (1991). Their factory revenue figures, along with their market share, is provided as well.

Nicolas Samaras

Q: To which regions of the world were optical disk drives shipped in 1991 (by product category)?

A: Table 4 shows the actual shipment distribution. It is worth noting that the North American market consumed the majority of the optical disk drive output. The only exception is the 3.5-inch rewritable drives, where Japan actually was the No. 1 consumer.

Nicolas Samaras

(Note: Data from Dataquest's Computer Storage Group was used to answer some inquiries.)

Table 2
Major Players and Preliminary 1991 Market Share

CD-ROM	(%)	WORM 5.25-Inch	(%)	WORM 12-Inch	(%)	Rewritable 5.25-Inch	(%)	Rewritable 3.5-Inch	(%)
Sony	40	Panasonic	38	LMSI	32	Sony	48	Sony	45
Hitachi	19	Pioneer	18	Sony	30	Ricoh	19	Panasonic	23
NEC	11	Ricoh	18	Hitachi	20	Panasonic	13	Others	20
Toshiba	10	Others	25	Toshiba	10	Others	20		
Panasonic	6			Others	8				
LMSI	6								
Chinon	4								
Pioneer	2								
Others	2								

Source: Dataquest (August 1992)

Table 3
Top 10 Tape Drive Vendors Manufacturing in the United States (1991)

Company Name	Factory Revenue ($M)	Market Share (%)
IBM	240.0	11.7
StorageTek	225.0	11.0
Exabyte	209.7	10.3
Hewlett-Packard	137.6	6.7
Digital Equipment	89.7	4.4
Colorado Memory Systems	79.7	3.9
Laser Magnetic Storage	41.6	2.0
Shugart/Kennedy	35.2	1.7
Summit Memory Systems	18.5	0.9
Innovative Data Tech	13.3	0.7

Source: Dataquest (August 1992)

Table 4
Regional ODD Sales by Product Category (Percentage)

Product	North America	Japan	Europe	ROW
CD-ROM	80	7	10	3
5.25-Inch WORM	70	15	15	0
12-Inch WORM	53	13	23	11
3.5-Inch Rewritable	43	49	7	1
5.25-Inch Rewritable	54	29	16	1

Source: Dataquest (August 1992)

Greg Sheppard SAM-1038209 B: 1 N: 1
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On the topics in this issue ....Greg Sheppard, Director/Principal Analyst (408) 437-8261
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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9207 July 6, 1992

In This Issue...

Market Analysis

Data Compression: A Way to Double Bandwidth and Storage Capacity

While the world rushes to make networking faster and mass storage larger, the notion of compressing the involved data has until recently remained suppressed. Although lossless data compression has been around a while, its price-to-performance ratio has been high and standards underdeveloped. At last there has been a breakthrough on both counts, and lossless data compression in ICs will become a significant opportunity over the coming years.

Lossless Data Compression Defined

Lossless data compression has existed for many years in such forms as CCITT communications and disk drive endecs. In essence lossless data compression is a technique that encodes/decodes and reduces redundancies in data streams without changing or losing bits. This feature is required of all alphanumeric data streams (for example, an e-mail message). On the other hand, image and video data can suffer losses during compression/decompression unnoticeable by human eyes.

A very popular method for achieving compression is known as Lempel Ziv. This and similar techniques can be accomplished in both hardware and software, and can support compression ratios up to 8:1, although 3:1 and less is most economically practical today. There is a three-way trade-off among compression ratio, delay, or overhead time while the function is executing, and, of course, cost. For example, the cheapest way to do 2:1 compression is to steal CPU cycles and perform the function in software. We expect lossless data compression to migrate to the standard function state much like floating point and graphics functions did.

Market Outlook: Expanding Horizons

Figure 1 and Table 1 present Dataquest's demand projection for a hardware lossless data compression IC function. Although it will start modestly as software approaches are augmented by hardware, we expect the market to be an 8-million-unit opportunity by 1996.

Key applications for lossless data compression are noted in Table 2. The need spans computing platforms (file transfer and storage, among others) to WANs.

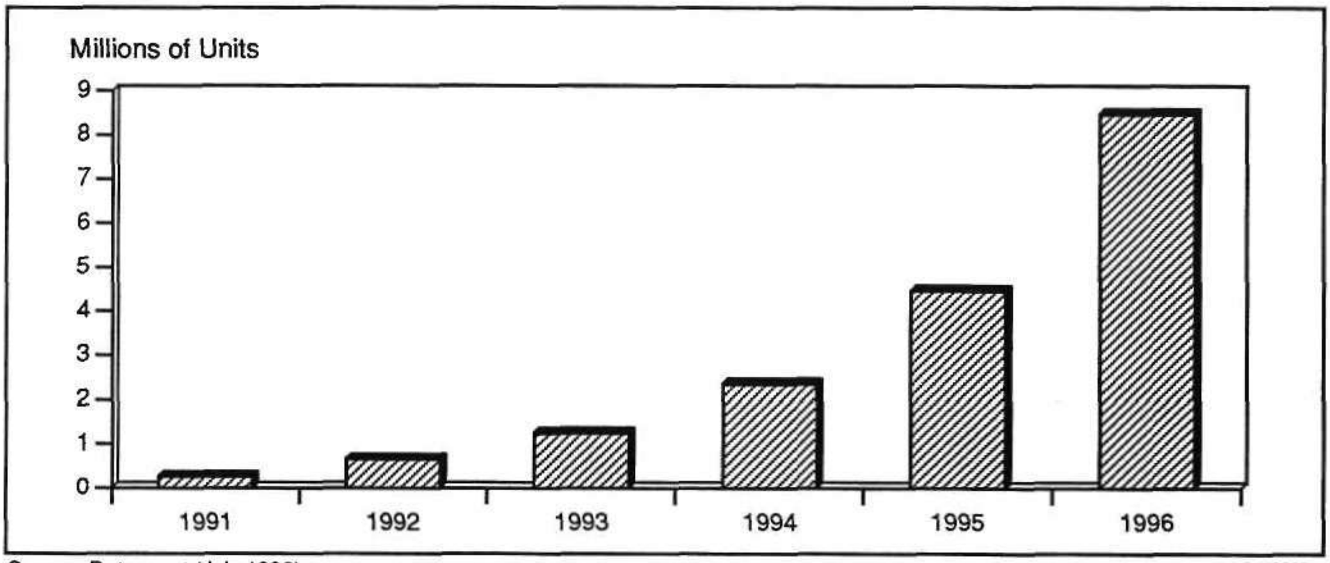
An Enabling Scenario

As with almost all multimillion-unit opportunities, economies of scale with a standard must emerge so that prices can come down and expand the market. Historically the most common way of doing this is through multisourcing; this most likely will be the case for lossless data compression. Because of the success Stac Electronics has had with its Stacker compression software and ICs, today there is a strong case for a defined standard. Stac is routinely at the top of the charts for the most popular PC upgrade product and has sold several hundred thousand units so far. Even though Stac is engaged in a lawsuit with competitor Integrated Information Technologies (IIT) concerning alleged infringement, an agreement may be worked out so that Stac, other suppliers, and the end user can all benefit from a common encoding/file format standard.

Functional Functions

The data compression function could be linked up with other functions such as network

Figure 1
Lossless Data Compression Accelerator Function, Worldwide Market Estimates (Millions of Units)



Source: Dataquest (July 1992)

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Table 1
Lossless Data Compression Accelerator Functions*, Worldwide Market Estimates

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Units (M)	0.26	0.65	1.24	2.35	4.46	8.47	100.7
ASP ($)	45	32	24	17	13	19	-26.0
Revenue ($M)	11.7	20.8	29.6	42.2	58.0	84.7	48.6

*Could be integrated into other functions in out years.
Source: Dataquest (July 1992)

Table 2
Applications and Needs for Lossless Data Compression

Application	Need
PCs and Workstations	Hard Disk Expansion, Networking
Tape Storage (DAT, etc.)	Capacity Expansion
LAN Cards (Ethernet/Token Ring)	Crowed Networks—Alternative to Pricey FDDI
Bridges/Routers/Hubs	Crowed Networks
Line Cards/TI-E1 Muxes	WAN Usage
Packet/Frame Transmission	WAN Usage
ISDN Terminal Adaptors	WAN Usage
PCMCIA Memory Card Interfaces	Enabler/Capacity
Wireless Data Communication	Reduced Transmission Time
Modem	Same as Wireless

Source: Dataquest (July 1992)

controllers or SCSI interfaces. Yet another direction is for the data compression algorithms to be executed on a general-purpose DSP processor so that it rests on the motherboard and multiplexes between other I/O functions such as V.32 modem transmission or Group III faxing. Performance degradation could be a factor in the DSP case if multitasking operating systems are used.

Players

Key IC players to date are Stac Electronics, IIT, InfoChips, and a relatively new company in Alberta, Canada called Compression Technologies. It is believed that the network controller IC companies are hard at work as well.

Dataquest Perspective

With the promise of modestly priced silicon and a stabilizing standard, a substantial opportunity exists for lossless data compression ICs. The applications are replete with economic justification, offering an aggressive demand. Now is the time to get in, but do be aware of legal issues as you proceed.

By Gregory Sheppard

Pen-Based Computing on the Brink of Viability

The following is an edited transcript of the Dataquest Pen Computing Telebriefing conducted by Dataquest analyst Andrew Seybold on March 5, 1992.

Andrew Seybold's Introduction

The analysts at Dataquest thought that it was time to update our pen-based computing outlook for a number of reasons—most related to delays of products in the industry that now appear to be on the verge of release. At the moment, many vendors are interested in investing heavily in pen-based computing. There is also a lot of end-user interest.

However, two pen-based operating systems—Go Corporation's PenPoint operating system and Microsoft Corporation's Windows For Pens—are both late to market. There is pent-up demand for pen-based computers, and a high level of interest in the market. You might say that the only people making money in pen-based computing today are the people holding seminars. Dataquest believes that is about to change, and that is why Dataquest decided to hold this telebriefing now.

To review Dataquest's forecasts, the 1991 figure for pen-based computers was 96,000 units worldwide. We have revised that number to 49,000, and we are re-evaluating our 1992 number. Dataquest had originally projected 353,000 units worldwide, and that number will be considerably lower because the operating systems are late to market.

The industry is poised for change, however. Go is about to enter its operating system into the marketplace. Windows For Pens is also about to make its entry. Geoworks has just announced its pen-based operating system. GRiD has been in the market successfully with its own operating system, and CIC and others are all joining the pack. So, let's take a look and see what is going to drive the market.

Pen-Based Market Has Unique Attributes

Dataquest believes that the pen-based market is like no other market we've seen in the computer industry, because it's going to be driven primarily by the end-user community. The companies that are going to be successful in the market are those that establish relationships with and listen to the end-user community and are fast to market with a product that meets the end user's needs.

The pen-based computer market also is unique because, for the first time in the history of the PC industry or any computer industry that we are aware of, the hardware, operating systems, and applications are all coming together at the same point in time.

At present few vendors are shipping hardware: GRiD Systems, Momenta, and several others. Phoenix Technology has introduced a reference design board and will sell a reference design with a CAD tape to anybody interested in producing hardware. It is complete with dual-boot BIOS for either Go or Windows For Pens. That will attract a number of smaller vendors into the market because it will reduce the time and costs involved in getting products to market. There are few applications at this point, but there are lots of promises.

What we find in the corporate environment is that end-user organizations are being pretty realistic. They are using 1992 and 1993 primarily as pilot project years, and using these pilot programs to gain valuable experience that they can relay back to the vendors.

Applications Will Take Center Stage

Applications are what really push the market. At the Technologic Partners Pen-Based Conference two weeks ago, Slate Corporation demonstrated its spreadsheet and, perhaps more important, introduced its personal information management system. This particular application was designed by Dan Bricklin of VisiCalc fame. If nothing else, Slate pulled off a coup because it introduced a product in conjunction with Daytimers. And most of you have probably carried a Daytimer at one time or another.

The interesting thing about this particular application is that it involves no handwriting recognition at all, and therefore is an extremely important product. It permits end users to use a pen-based hardware platform in the same way they would use their own day books.

The other entrant in the personal information management field is a company called PenSoft Corporation. PenSoft has taken a different approach. It is offering a relational database day book system, where users can actually map people, contacts, and companies. It is a very, very intriguing product.

The reason I mentioned these two products is because Dataquest believes that this type of application will drive the horizontal pen-based market (not the vertical markets). And it is important that we follow this software as it becomes available.

Market Interest in Pen-Based Computing

There are some interesting figures regarding the interest in pen-based computing within the Fortune 500 MIS community. We have found that more than 50 percent of those companies plan to either purchase evaluation units in 1992 or early 1993, with 15 percent of the companies planning to purchase major numbers of units (500 or more) in that time frame. That's tremendous potential, but again, these corporations are being very realistic about what they expect this year and next year in terms of hardware and operating systems.

The comments we have been getting from the MIS community are that they are to date still somewhat disappointed with the hardware, with the clarity of the screen, with the battery life, and with the size, weight, and form factors of the products. They do realize, however, that as technology moves forward all of that is going to get better, so they are willing to go ahead and look at the technology as it currently stands.

They are also very realistic about the importance that handwriting recognition plays in what they are planning to do. They realize that, at this point in time, handwriting recognition is not very good on anybody's operating system and it only plays a small part in overall pen-based computing.

Most of the MIS people that we've discussed this with are more interested in forms completion and vertical market applications than they are in horizontal applications. They are aware that notes can be stored as a graphic and retrieved, and they know that handwriting recognition will get better. They have also had enough experience to know that numbers recognition, which is a key to forms completion, is a lot more robust at this point than handwriting recognition. They are aware that deferred recognition can be used very effectively. And the medical community realizes that nobody in the world is ever going to come out with a system that recognizes doctors' handwriting.

End Users Play a Critical Role

The thrust of the end-user community is that they want to form partnerships with the vendors. In doing so, end users want to set realistic goals and expectations—they want to crawl before they can walk. They want to work very closely with hardware and software vendors on platforms, and they are acutely interested in connectivity and data transfer issues. Typically, corporations are setting up review groups that include MIS department, vendor, and end-user representatives. A new trend is that the review groups are listening to the end-user community for pen-based computing much more than for any other form of computing to date.

The key to success is this market—at least in the vertical market—is that vendors are going to have to establish relationships with the end-user community, something that they've never entered into in the past. And the vendors are going to have to listen very closely to the end-user community.

Connectivity for Pen-Based Systems

As with other types of computing, software is a key to success. One major concern is connecting pen-based devices to host and PC computers, and moving data easily and quickly—without the connectivity struggle that now happens between laptops and PCs. Unfortunately, a number of vendors in the PC industry are treating the connectivity issue as a single, common issue. Dataquest would like to strongly suggest that the connectivity issue is two separate issues.

First is the issue of transport layer—which is radio frequency (RF), infrared, wired, modem-controlled through phone lines, or cellular. Second is the software or information layer on top of the transport layer. These layers need to be addressed separately.

Currently there are lot of things going on in the RF world, which means that there will be no standards for a many years in RF communication. However, there are lots of different opportunities in this area.

The software or information layer that actually moves on top of the transport hardware layer is a key to success for a pen-based product, and recently there have been several entrants. Traveling Software and Slate have teamed up to create a series of deferred data transmission and file translation products that will make data transfer much easier than it has been in the past.

Pen Computing Conferences

Two conferences on pen-based computing have been held recently. The one that was the most interesting (to me) was the Pen Computer Users Conference held in Baltimore on January 15. It was extraordinary because there were 25 vendors and 350 pen computer users. (Although "pen computer users" is at present a misnomer, there were 350 people from corporations who want to become pen computer users.)

The Pen Computer Users Conference was a very well attended conference, and a place where the vendors that attended gained a lot of insight from the end-user community. It was also a conference where end users gained the understanding that pen computing is not a mecca.

There has been a tendency among some vendors in the pen computer industry to oversell the capabilities of pen-based computing. And the MIS and the end-user communities that attended this conference understood that there are limitations with the technology, and will accept working with these limitations over a period of two or three years. What they said to the vendors was, "We don't expect it to be magic, so don't promise us more than you can deliver." That was, I believe, the main message that came out of that conference.

The other pen-based computing conference, the Technologic Partners Conference held in February in San Jose, California, was also well attended, but with a different crowd. It was essentially vendors talking to vendors about what is happening in the industry.

There was a lot of excitement about connectivity—especially RF connectivity—and about some of the applications that were shown, including Slate's product and PenSoft's product. There were a lot of vendors that were showing special utilities for Windows For Pens.

Everybody is poised at the beginning. It is kind of like we are all at the starting gate right now waiting for the flag—and the flag is Go PenPoint and Windows For Pens. And both are coming very quickly.

Questions from Briefing Attendees

Q: Who are the suppliers of hardware and software in this industry, and are they U.S. or foreign?

At this point, the vendors that are shipping hardware in the United States—with one exception—are U.S.-based. NCR, Momenta, and GRiD are U.S. companies shipping hardware. Samsung (a Korean manufacturer) also has a product that I believe is currently shipping in the United States. The software vendors are, to my knowledge, entirely U.S.-based.

Q: What percentage of corporate users are looking at vertical market applications within their corporation, such as the UPS or truck drivers or dock inventory-type applications, versus a horizontal application, like daytimers, for corporate executives and sales forces?

The pilot programs that are under way are all in specific vertical markets—which are basically for route-type salesmen, inventory control, truck dock loading and unloading procedures—the day-to-day forms completion type of application. It is not that they haven't expressed a desire to move this computing platform into the executive office. In fact, that's from where the requests to start pilot programs are generally coming. However, because of the limitations of the software and connectivity, most have chosen to start with the vertical applications and over time move into the horizontal applications and the executive office.

Q: You mentioned some problems with the displays . . . what are these problems? Do they have to do with the interface or is it more of a lifetime issue?

The problems I was talking about with the display are strictly visibility issues. There are two types of pen computer users that we are talking about. There is the user who is computer literate and is used to looking at displays and portables. But most of the pilot programs are involving users who have never before used a computer, and are used to using pen and paper. They are disappointed that the screen clarity and brightness is not good enough for the varied lighting conditions that they are involved with in the course of a day's operations.

Q: You discussed deferred software. What does that mean?

Deferred software on pen-based computers are applications for documents (like correspondence, faxes, or calendar information) to be transmitted from the pen-based machine to another PC, or through an e-mail network, or through a fax network.

When a user is finished working on a specific document, the document is moved with the traveling, or deferred, software. For example, the software moves the document to an out basket on the pen-based computer. When the pen-based computer is docked or connected to a PC, the PC automatically looks for the out basket, grabs the contents of it, and distributes the contents to the proper place: to e-mail, fax, word processor, or wherever else it is meant to go. It works the same way for incoming documents. Once connected to a PC, if there are messages waiting for the user, the messages will be transferred and placed in the proper file for that end user.

Q: What are the most promising ways of transmitting this information? What do you think is going to be the most popular?

The most popular way of transmitting the information is going to depend on where the products are used. For example, if they are used in a corporate environment confined to one building or within a hospital, the preferred method for the next couple of years is probably going to be infrared.

Because of the wide bandwidth, the ease of use, the RF connectivity, the cellular, and the point-to-point RF, there is not going to be a standard that comes about that allows people to map this consistently. Everyone's solution to wireless is going to be different, and therefore disjointed for some period of years.

Q: We all understand that the lateral migration of the pen computer is from notebook size to palmtop size. However, when you're dealing with a pen, there has got to be a certain size limit for the screen to be legible and to be able to write on it. What do you believe is the minimum size of a writing surface and a display surface?

The whole issue of minimum size of a display surface and a writing surface is going to depend on the resolution of those surfaces. For now, the 5 x 7-inch size seems to be as low the industry is willing to go for good resolution. We expect that over time for vertical markets and specific products the screen size will come down. But the typical screen sizes that we expect to see over the next two to three years range from the full 8.5 x 11-inch to the 5 x 7-inch with several intermediate sizes, but the size will not dip below the 5 x 7-inch display.

Q: In the next several years, what do you think will be the most popular sizes?

In the vertical market, the 8.5 x 11-inch tablet. The tablets will come down in size and weight and the display will get better, so there will be the 8.5 x 11-inch clipboard form factor, and a 5 x 7-inch display for a day book.

Q: How about the weight issue and the battery life issue? If you have a large size, apparently the weight is heavier, and the battery life is going to be shorter.

There are several opposing factors concerning size and weight. The end user who has to carry around a pen-based computer all day is going to be extremely sensitive to the weight, and also the battery life. This is especially true for applications where somebody has an 8-hour or 10-hour shift.

I think there are several things that will happen over time. As the technology gets better, we will have better battery life, better screen displays, and lighter-weight computers. But as connectivity gets to be better and better, the amount of electronics and the amount of storage required in a tablet is going to become less. This will result in increased battery life and decreased weight.

Connectivity, the inclusion of a hard disk, and the need for a lot of memory will affect the battery life and the weight of a computer, in addition to any advancements in technology.

Q: As far as the processor is concerned, do you think the 386SX-level type of products are going to dominate, and if so, is there a market for the 8086 or 286?

The products coming to market that are going to operate with Pen-Based Windows or Go's PenPoint are going to have to have a 386 or above processor. There is a very viable market in 8086- or 8088-based specific products. For example, Hewlett-Packard is marketing its HP95LX as a business solution. It is not a computer at all to most users, but rather a financial modeling system that also happens to be a computer. The 8086 or 8088 will be optimal for some vertical applications, such as inventory control and ticket-writing for law enforcement agencies. That type of product will have a fairly good life over the next few years, because this is a very specific vertical market where the operating system is much less of an issue than for more generic or horizontally designed machines.

Q: When you were discussing the current hardware limitations, one thing you didn't mention was processor performance. Do you think that in the future we're going to have higher requirements for processor performance?

Yes, absolutely. The Go PenPoint operating system and Microsoft's Pen-Based Windows I believe operate in the 386 environment. That is the marginal operating environment; there will be a demand for more speed. If you've spent time with Go or with Windows in a 386 environment, you know that changing pages moving data is a fairly slow process, even with a 386-based processor. And handwriting recognition is not nearly as robust as it could be, given more processing speed. I would expect that some of the alternative hardware platforms over a period of time will not stay with the Intel architecture, but instead move to a RISC-based platform to get more processing speed.

Q: You mentioned that the updated 1992 forecast will be considerably reduced from the original forecast of 353,000 units worldwide. What type of a reduction are you looking at?

We are re-evaluating the drop right now, but it is likely to be 30 to 50 percent, and probably more in the order of a 50 percent reduction.

Q: When do you see it ramping up, or do you see it ramping up to a level you have forecast through the 1995 time frame?

We think it is going to ramp to the levels that we have forecast in the 1995 time frame, but our forecast was based on time-to-market after the Go PenPoint operating system and Pen-Based Windows hit the market. At this point our belief is that the real ramp in product will start six to nine months after the operating systems have been on the market and applications have become available for the product. We are pushing our projections out by a year and a half at this point.

Q: You made a comment when you spoke about the Pen Computer Users Conference that currently users have very low expectations. Is that being factored into this one-and-a-half-year lag in your forecast ramp?

Yes it is. The corporate buys are going to lag because there will be many more pilot programs than large purchases; companies have to try out the hardware, the software, and address connectivity issues; and companies have to measure productivity for end users and understand the return on investment. It is a long process for the large sell. It is also going to be longer before the individual end user feels a compelling need to walk into a computer store and buy a pen-based computer for horizontal applications instead of a keyboard-based machine.

Q: Are you looking at a 350,000-unit level by 1994?

Yes.

Q: You talked about Pen Find and Windows For Pens, but what is the feeling about CIC Pen DOS? Also, are you looking at pen-based operating systems for low-end machines?

For the 8088-based machines and up, the CIC Pen DOS and the Geoworks products both did extremely well in that market. I think there is a good opportunity for both companies, but again, that is more of a vertical market than it is a horizontal market. I'm excited about the fact that we do have companies like CIC and Geoworks that are not abandoning the low-end vertical market. I see basically four or five different operating systems coexisting very nicely in this environment.

Q: I understand that for CIC the connection is 386-based code. Are they working on an 8086- or 286-based version of the code?

For 8086- or 8088-based products, I believe that handwriting recognition will not play a significant role in that arena. They are strictly vertical markets—forms completion or graphics capture—and handwriting will not be an issue in that marketplace.

Q: What are the storage requirements necessary for the various applications that you mentioned for pen-based computing? Also, could you speak about hard disk drives and memory cards, and whether you believe memory cards will be accepted on pen-based systems?

The issue of storage is key to pen-based computing. At this point, the disk drive form factor of 2.5 inches offers up to 120MB of storage. Over a period of a year or so, that will go up dramatically. By the end of 1992, we will see a 1.8-inch form factor of 60 to 80MB hard disks.

The price per megabyte on the memory cards is still relatively high. The price per megabyte on a JEIDA or PCMCIA standard card is in the neighborhood of $150. The Sundisk 8MB card that was announced at the conference two weeks ago is being offered at $50 per megabyte (which is still very, very high when compared to hard disk storage).

The bottom line is all of the applications require a lot of storage because of the intensive use of and need to store graphics. The winners are going to be the vendors that can provide the most storage for the least price in the smallest form factor. That sounds kind of trite, but it is key. The good news is that the memory card prices are going to come down dramatically over the next two or three years. Also, there are going to be exciting advances in the hard drive technology. The choices available to vendors will be increasing in a number of ways, resulting in lower prices over the next three to four years.

Q: What do you feel is the minimum storage requirement today for these systems?

The minimum storage requirement depends on the application. A vertical market product—one that is strictly forms completion—can exist in the market today with 4 or 8MB of RAM and no hard disk or solid-state storage of any kind. A generic, horizontal application computer is probably going to require 4 to 8MB of RAM and 60 to 80MB of hard disk storage.

Q: For the wireless links, what are the present requirements for data rates, and what will they be in the near future?

The data rate is going to be dependent on the transport layer. The Traveling Software product that I mentioned, for example, currently uses wired connection and the data rate is extraordinarily high: 100,000 bps and above. Wireless data rates typically are running 9,600 or 19,200 which is acceptable, but not really adequate. As we get into spectrum and artist situations, data rates of 50,000 bps will be standard and acceptable.

Q: You mentioned that 15 percent of the corporate sample will buy major numbers of pen-based units. What is a major number?

Major purchases are 500 units or above.

Q: What about markets overseas? Is this going to be a situation where most of the sales will be in the United States?

The overseas market is a real question at this point. The Japanese market is further advanced than the U.S. market because kanji is easier to recognize, and there are more specific applications. I believe the market will start in the United States, grow in the United States, and then it will move to Europe on a slower basis than we experienced with PCs, until companies invest the time and effort into localizing for the European market.

Q: How do you think the new PCMCIA standard will play in pen computing?

I believe that the PCMCIA 2.0 standard, with execute-in-place and hardware-versus-software capability, is a very important standard for the entire mobile computing industry. I expect this standard to become the bus of the portable computing environment, and it will be used by many vendors to personalize equipment for various vertical markets. It is very important for hardware companies to recognize PCMCIA and to build equipment that is compatible with version 2.0, and the Intel exCHANG specification.

Q: Where do you see the need for color displays?

I think the industry has to fix the problems with the monochrome displays first. But I also believe that end-user demand will be there when the vendor community can provide very good high-contrast color displays without a major differential in price and battery operation.

Q: When will that happen?

In the 1994/1995 time frame.

Q: You referred to two display form factors for pen-based computers: 8.5 x 11-inch and 5 x 7-inch. What is the reasonable price point of these two form factors?

When we talk about price, we need to talk about the type of machine. For a 5 x 7-inch day book-type machine, the price has got to be under $1,000. For a vertical market application, an 8.5 x 11-inch thin form factor tablet should be in the $1,000 to $1,500 price range. The generic machine—the full blown horizontal computer—is currently at a $4,000 price point. That is going to have to come down dramatically—to the $2,000 to $2,500 price range.

Q: What do you see as the pen-based or pen-enhanced computers share of standard desktop purchases? As much as laptops and notebooks?

If the connectivity issues are solved—the connectivity between any portable computing environment and a network in a corporation is done very well—you are going to start seeing all types of portables taking away from desktop sales. But I don't believe that is going to happen in the immediate future. There are other issues involved. Issues of security, of data integrity, of loss and theft of product, and the fact that the price point of desktop machines is currently very low. It is going to be a fairly long time—I would guess two to three years or more—before there is a major erosion of desktop machines because of pen-based computing.

Q: In Japan, Sony introduced pen-based computers almost two years ago. How are they doing now, and is there anything you have learned from Sony's experience of marketing in Japan?

I do not personally have any information on the sales of this Sony system in Japan. That is something that we can provide to you, but I'll have to get it from our Japanese office. However, the Japanese market in portable computing has been extremely different from the market in the United States. The end-user communities are different and the uses for the computers are different. We have found, and I believe this is true for pen-based computing, very little correlation between what is going on in the Japanese market and what the potential is in the U.S. market.

Q: Could you categorize the types of changes that need to be made to today's operating systems to accommodate pen-based computing? For example, you mentioned a version of Windows for pen computers. What types of things had to happen to Windows to make it accommodate pen-based computing?

Vendors need to build applications specifically for a pen computer rather than for a generic computer that—oh, by the way—uses a pen. The difference between the Go operating system and Windows For Pens is all of the software for the Go operating environment is written to use a pen from the very beginning, while the start of Windows For Pens software will be keyboard-type applications that are written—oh, by the way—to recognize a pen. There is an entire market of users out there, the largest market that the computer industry has ever seen, that has never before used a computer. Vendors that are going to be successful will provide applications that are not based on traditional existing computer metaphors.

Q: Could you describe what a pen-based operating system looks like? What are some of the characteristics that you would find in such an operating system?

The end user should never see a pen-based operating system, and the pen is the only mechanism that should be used. It should be extremely intuitive, and it should be built from the ground up to understand that applications are not standalone, that they all interact with each other, and that data used in one application may be required in another application and may be referenced in still another application. If I could design an operating system (which I have no intention of doing), it would have a relational database-type underpinning, underneath all applications.

Q: What are the needs for ruggedness by corporate users and consumers? Can users drop them, kick them, and throw them? And what type of price premium are corporate users willing to pay for the most rugged machine?

It is going to depend specifically on applications. Our belief is that there will be several degrees of ruggedness. The generic user will expect the same type of ruggedness available today in a Sharp Wizard or a Casio Boss or a notebook computer. However, there are a lot of vertical markets that are going to require much more ruggedly built equipment. Hospitals, for example, and truck drivers, and users like them. Corporations that I've talked to realize they are going to have to pay a price premium for ruggedness.

To characterize how much that's going to be is difficult. I'll take a stab and say expect probably a 20 percent hit in the price of a product for additional ruggedness—and understand that under some conditions no product can be rugged enough—because of the screen. It is also reasonable to expect a higher rate of down time and repair with this type of product than with existing products.

Q: Is the expectation that these computers will never break, or is it expected that these computers can be inexpensively and easily replaced, or field-serviced?

The expectation is that the computers will break, because they are used on a day-to-day basis. But the expectation also is that their down time will be minimal, because the systems will be either field-repairable or modular—and corporations don't want to buy a lot of spares. The understanding is that some down time is required, but, for example, in a hospital environment, the expectation is to run on a 10 percent spare basis.

Q: What is the viability of the combination of pen input with keyboard input in one product? How will this type of product cut into purely pen or purely keyboard computer sales?

The Momenta product is probably the best present-day example of a combination of pen-based and keyboard-based product. Personally, I have mixed feelings about this type of product. It is going to appeal more to a computer-literate person who wants to move from a desktop environment to a portable environment. There also may be some executive-type users who will find that it is a nice choice, and a nice choice for somebody who is going to spend a fair amount of time doing data entry (using the keyboard for data entry and the pen for manipulation). My belief is that this combination system is not the mainstream product that we are going to see in the market. That is a product that certainly will sell a large number of units, but it will not be the most sought-after type of pen-based computer.

Q: Do you believe that a premium can be charged for something like that?

In today's marketplace, considering the competition, a premium over a notebook, yes; a premium over a pen-based machine, no.

Q: How important do you think pen input will become to traditional desktop usage—to do things like document publishing, to be able to mark up a document, etc.?

I think it is extremely important and an area that nobody has spent enough time concentrating on. Not only for document production, but for an executive office, I have envisioned several products that replace a standard work unit. I'd still use a keyboard with a desktop computer and a VGA or super VGA screen, yet I would also have a pen-based screen in front of me so that I can manipulate my day book on my desktop, and still refer to the screen.

Inquiry Summary

Semiconductor Application Markets

Inquiry Highlights

Q: What are the implications of Hewlett-Packard's introduction of the 1.3-inch hard disk drive?

A: This could be bad news for the 2.5-inch and 1.8-inch hard disk drives (HDDs), as the smaller form factor is more desirable. One can argue that notebook computers have adequate power and space for a 2.5-inch or 1.8-inch drive. The same is not true, however, for hand-held PCs such as the HP 95LX. Here the 1.3-inch drive is the only viable HDD choice. If the 1.3-inch drive can be manufactured in volume, our earlier predictions of an expanded rigid disk drive market 2 to 10 times its current size may come true (see "Rigid Disk Drives: A Case for Integration," in the Semiconductor Application Markets *Dataquest Perspective*, Vol 1., No. 2 by Nicolas Samaras).

The following pertinent information is taken from a Blast-O-Fax written by Dataquest's Computer Storage group on June 8, 1992.

Hewlett-Packard's Disk Mechanism Division in Boise, Idaho today announced the industry's first 1.3-inch-diameter (34mm) rigid disk drive. The Kittyhawk Personal Storage Module (PSM) offers 21.4MB in a miniaturized package only 10.5mm x 36mm x 50.8mm. The two-platter drive uses glass media from Nippon Sheet Glass Company and 50 percent thin film nanosliders.

AT&T Microelectronics Division was contracted to codevelop a set of highly integrated chips for the drives. Using only 7 ICs instead of the normal 20 in 2.5-inch drives, the drive's dimensions are dictated by the size of the printed circuit board. The heads are estimated to be flying at 3 microinches over the surface of the glass media. The average seek time is less than 18ms; an embedded servo is used for positioning the rotary voice coil actuator. The spindle spins at 5,400 rpm. The areal density of the drive is 111 Mb/sq. in., with a bit density of 51,000 bpi and a track density of 2,400 tpi. Data are recorded in six zones. The drive platform is expected to grow to 200MB by 1995.

The most interesting feature of the drive is not openly discussed by HP representatives. The Kittyhawk is designed with a feature much like the collision sensors for airbags on automobiles. The drive detects an impending impact and causes the electronics to put the drive into a protection mode, averting data loss. The drive is rated at 100G operating shock. The nonoperating shock specification is 225G. The drives are produced with either a PCMCIA card interface or an IDE connection.

Applications for the drives are believed to include subnotebook, palmtop, and pen-based computers. HP also believes that they will find their way into data collection devices, imaging peripherals, HDTV, interactive TV, and advanced game machines. The evaluation units are available for $450 and the volume OEM pricing has been set at $12/MB, with a goal of $10/MB in 1993. The products are to be mass produced by Citizen Watch Company Ltd. in Japan, using micromechanical assembly techniques. Very high yields are anticipated and production volumes are believed to be planned at tens of millions within 24 months. HP indicates that U.S. and Japanese buyers are equally interested.

Dataquest Perspective

The Kittyhawk was a well-leaked surprise, but its feature set was certainly worth waiting for. The drives herald a new generation of storage products, and a new industry is born. No longer must we think of higher capacity as the goal for future developments. At $10/MB for a 5MB drive, it will be possible to provide any industry with a $50 disk drive! Although 5MB is not a desirable capacity for a Windows-based personal computer, a video game or an automobile phone directory will fit nicely. Mass production, high yields, device integration, and low-cost heads and glass media are essential to the success of this new industry. It sounds as though HP is pretty far along with the technology and is in a position to dictate the future. Usually the innovators are small, underfinanced start-ups that are squashed after they pioneer a product. Now we will see if a major corporation can survive the inevitable attempts to kill the messenger.

By Phil Devin

Q: How will the introduction of the 1.3-inch hard disk drives affect acceptance of solid-state disks and memory cards?

A: It is perhaps too early to tell. Solid-state storage can and most likely will share the stage with hard disk drives. Even though semiconductor memory is still more expensive than magnetic media storage, solid-state disks (SSDs) are a better fit for applications that require very low power, or "instant-on" operation. Lower-capacity memory cards can be viewed as a form of "solid-state floppy" that also satisfy the role of an information exchange medium, and as a result are not threatened by the 1.3-inch drive. From a cost standpoint the 1. 3-inch drive is half that of the equivalent flash memory SSD. It is also interesting to note that the 1.3-inch drive from HP is offered with the PCMCIA interface as one of the two options, a fact that lends credibility to the argument that memory cards and SSDs are here to stay.

By Nicolas Samaras

In Future Issues

The following topics will be addressed in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Forecast update
- Emerging markets overview

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9206 June 8, 1992

In This Issue...

Market Analysis

Video Phones: It Takes Two to Tango

It has been a long time since the 1964 World's Fair when AT&T demonstrated its first video phone. As is well known in the annals of MBA case studies, the video phone was not a commercial success. It was too expensive to make and use, standards were undeveloped, and consumers were not sure if they wanted to comb their hair every time the phone rang. A lot has happened since then to address the first two points; on the last point we can only hope that vanity has stopped building bonfires in the 1990s and that semiconductor companies will have a real opportunity.

A Market Scenario

As the title of this article implies, it takes at least two video phones to have an audio/video conversation. A video phone can be either a desktop standalone unit with a CCD camera and LCD display or an add-in card for a PC/workstation with a CCD camera and display accomplished through a window on the monitor. Furthermore, it takes two video phones operating with the same signaling, protocol, and compression standards, available in mass quantities from multiple suppliers at well-known price points to stimulate broad acceptance. Therein lies our assumptions regarding a forecast of the North American market for video phones and the semiconductors they consume. Table 1 and Figure 1 present a scenario based on the following assumptions:

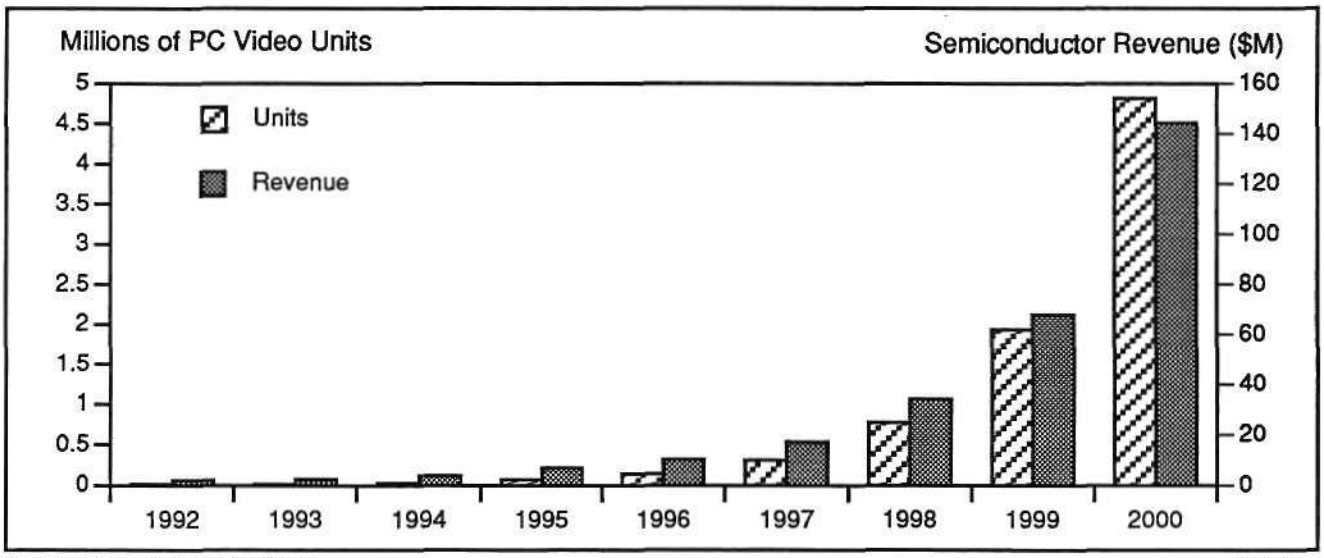
- That CCITT standards for video telephony are finalized and interoperability among different implementations is assured. Notable is adoption or migration to the H.261 standard for video coding and compression (aka Px64). Other CCITT standards include G.711 (64 Kbps audio) and G.722 (48, 56, and 64 Kbps ADPCM audio), G.728 (16 Kbps audio), H.221 (framing), H.230 (control signals), H.242 (setup/disconnect), and H.320 (narrow bandwidth systems).

Table 1
North America Video Telephone/Attachment* Market Estimate

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1992-1996	CAGR (%) 1996-2000
Video Phones/ Attachments											
Revenue ($M)	85.0	95.2	97.9	122.4	153.0	275.4	550.8	969.4	1,236.0	16	69
ASP ($K)	1.70	1.36	1.09	0.82	0.61	0.46	0.37	0.29	0.25	-23	-20
Units (M)	0.05	0.07	0.09	0.15	0.25	0.60	1.50	3.30	4.95	50	111
Semiconductor Market											
$ Content/Unit	204	163	131	98	73	55	44	35	30	-23	-20
Total Revenue ($M)	10.2	11.4	11.8	14.7	18.4	33.0	66.1	116.3	148.3	16	69

*Attachment = Px64-compatible attachment or add-in card for PC or workstation
Source: Dataquest (June 1992)

Figure 1
North America Video Phone Opportunity



Source: Dataquest (June 1992)

G2000234

- Picture quality that is acceptable to the user. The AT&T VideoPhone 2500 features a 128 x 112-color-pixel capability with up to 15 frames per second. This is probably on the low end of user acceptability but future versions with QCIF (176 x 144 pixels) and CIF (352 x 288 pixels) should meet consumer/office needs. Further rollout of ISDN (2B+D) lines in the late 1990's will acclerate low-cost, high-resolution versions.

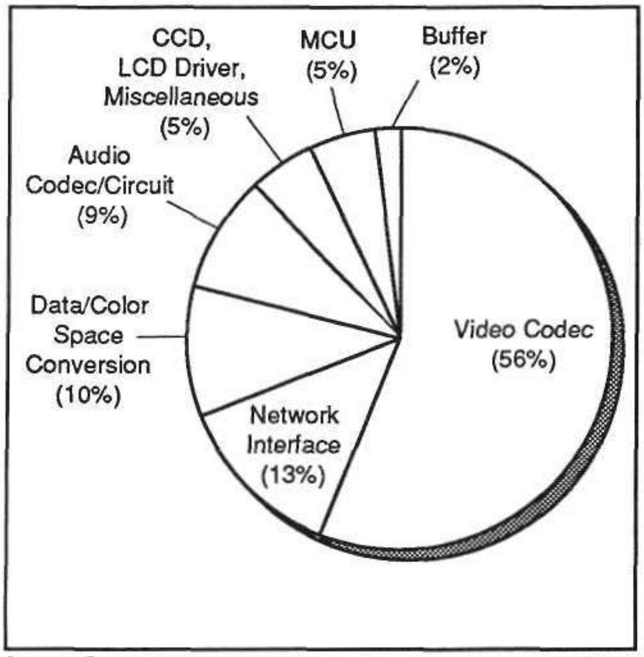
- Broad supply sources will develop with economy-driven price declines to affordable levels. Lack of travel during the Gulf War did a lot to heighten awareness of video conferencing, which is video phones' big brother. Likewise, availability of H.261 compression chip sets from AT&T, IIT, LSI Logic, SGS-Thomson, and others are truly enabling OEM plug-and-play offerings. AT&T, Hitachi, British Telecom (GEC Marconi), IBM, Siemens, Northern Telecom, NTT, and Mitsubishi have or are developing offerings. Expect almost every company that makes telephones and video PC/workstation add-in cards to be at some state of bringing product to market. Picture Tel and Compression Labs will continue to be principal technology contributors.

- There will be a substantial warming toward using video communication in the home and office. Using airline revenue as a market to steal from, video calls could displace a substantial percentage of business and personal trips. Early adopters should be businesses with geographically dispersed and middle/upper middle income families with small children (the same market that bought camcorders to send tapes to grandmother). The market should develop like the fax market did (need two to communicate), which gestated for about five years before the knee of the growth curve was attained.

Semiconductor Opportunities

Figure 2 breaks out the semiconductor opportunity presented by video phones manufactured for use in the North American market. We project the overall video phone semiconductor market to reach $15 million by 1995 and $148 million by 2000. We expect annual shipments of more than 100,000 video phone units by 1995. We expect video phones to become a common household item by the late 1990s as prices drop below $300. Our analysts in Europe project a similar growth scenario there, with a market size comparable to that in North America. With its strong ISDN infrastructure, Japan could ramp up to speed quickly with a market half the size of that in North America.

Figure 2
Video Phone Semiconductor Market Breakdown (North America)



Source: Dataquest (June 1992) G2000235

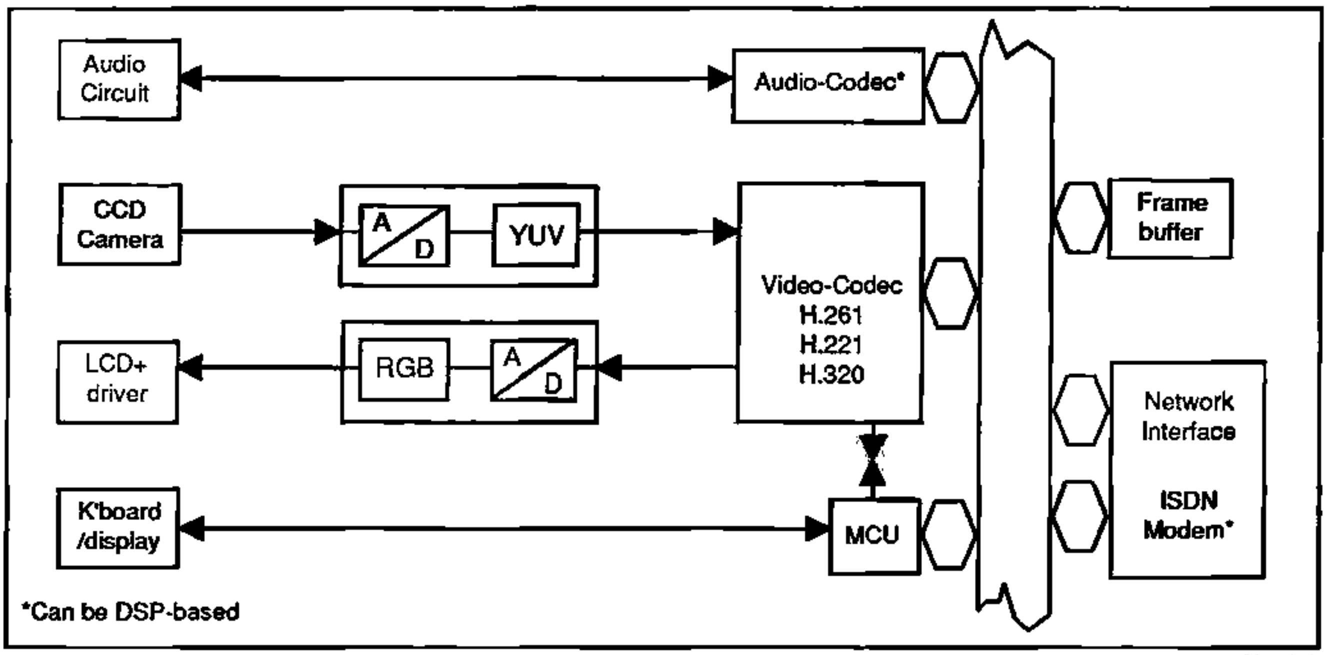
Major opportunities exist in providing the H.261, H.221, and H.320 functions, data, and color space conversion (RGB:YUV); audio codecs (ADPCM) and conversion; and network interface functions such as modems (19.2-Kbps mixed-video and audio) and eventually ISDN functions including S interfaces (2B+D). This application will also be a modest user of DRAM (1/8MB) and perhaps flash memory for presets and other uses. Figure 3 shows a generic video phone block diagram. Echo cancellation, higher data rates for better resolution, and certainly integrated and mixed-signal versions of the various functional blocks (for example, combined audio codec and video codec) will provide a value-added differentiator. PC or workstation attachments and cards could eventually be merged with other video and audio functions inside these platforms. When that happens, the audio and video processors will need to handle multiple standards.

Dataquest Perspective

We believe that video phones will become a real opportunity, but perhaps not ramping up as quickly as vested interests would like to believe. The overriding justification we use as a model is based on fax machine penetration through the 1970s and 1980s. It appears that all the right pieces are in place for the market to emerge: standards, enabling technology (compression ICs), and the promise of economies of scale with dropping prices. Once again, as in other markets, much of the value and opportunity is in the ASSP/DSP functions whose partitioning will need to be mixed and matched by the OEMs. The relationships are forming now.

By Gregory Sheppard

Figure 3
Video Phone Block Diagram



Source: Dataquest (June 1992)

G2000236

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q: What is a smart card?

A: A smart card, often called an IC card, is an information-carrying device that shares form factor with the typical credit card. Information is stored in a microchip that is embedded into the plastic card, which measures 3.375 x 2.125 x 0.030 inches (see Figure 1).

Smart cards use a set of six contacts (optionally eight) to derive power and communicate with a card reader. Information is stored in some form of nonvolatile memory. Early on, EPROM was used; currently EEPROM is used for this function, and flash may be substituted. Nonvolatile memory storage capacities range from a few hundred bits to 64Kb.

The microchip embedded in the smart card is a standalone single-chip microcomputer containing ROM, RAM, EEPROM, or EPROM. This is the preferred device for financial transaction cards, as it affords the most security and flexibility, albeit at a higher cost. Alternatively, an IC with hardwired logic and a small amount of EEPROM or EPROM may be used. This configuration is common for prepaid telephone cards, metro/bus tickets, and vending machine applications.

Q: Who invented smart cards?

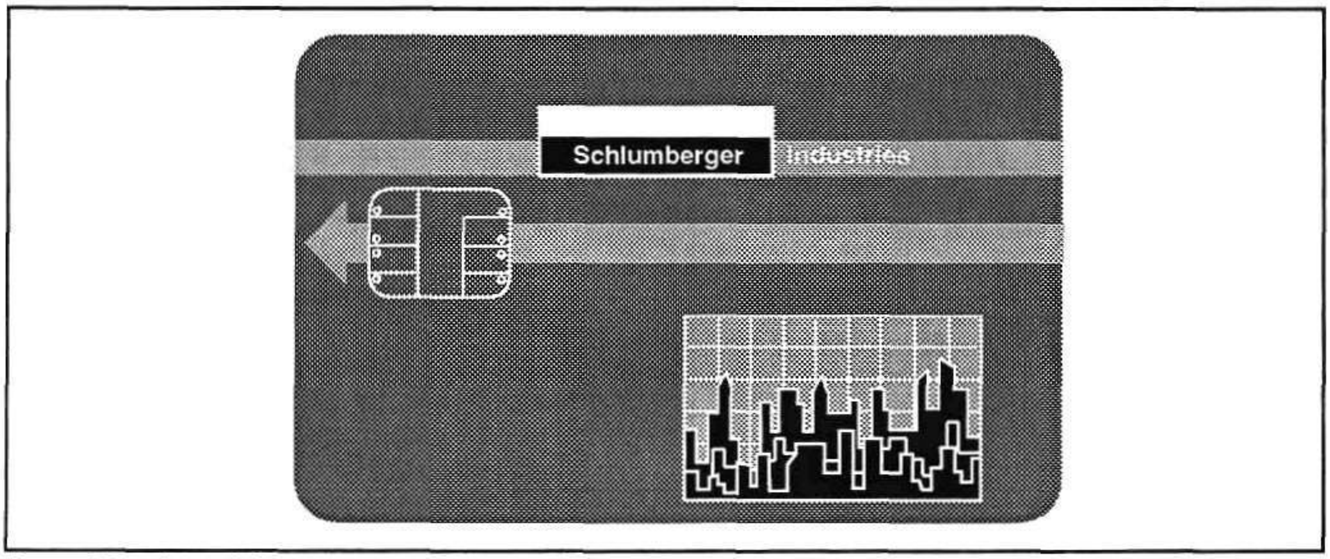
A: Roland Moreno, a French journalist, has been credited with the invention of smart cards. He was granted a patent (France, Europe, United States, and Japan) in 1972 and subsequently formed Innovatron, a company whose purpose was to provide licenses to corporations involved in smart card manufacturing. Dr. Kunitaka Arimura of Japan worked on a similar device that was able to communicate with a card reader using radio frequency. He was granted a patent in March 1970 limited to Japan. Dr. Arimura is credited with the invention of the contactless smart card.

Q: What is the difference between magnetic stripe cards and smart cards?

A: A smart card shares the form factor with the common credit card found in everybody's wallet. The typical credit card contains both visual information (embossed characters that include name and expiration date) and binary data stored in a magnetic stripe on the back of the card. The magnetic stripe actually contains three tracks where data can be stored. However, storage is very limited; track one can store 79 alphanumeric characters, track two 40 numeric characters, and track three 107 numeric for a total of 226 (see Figure 2).

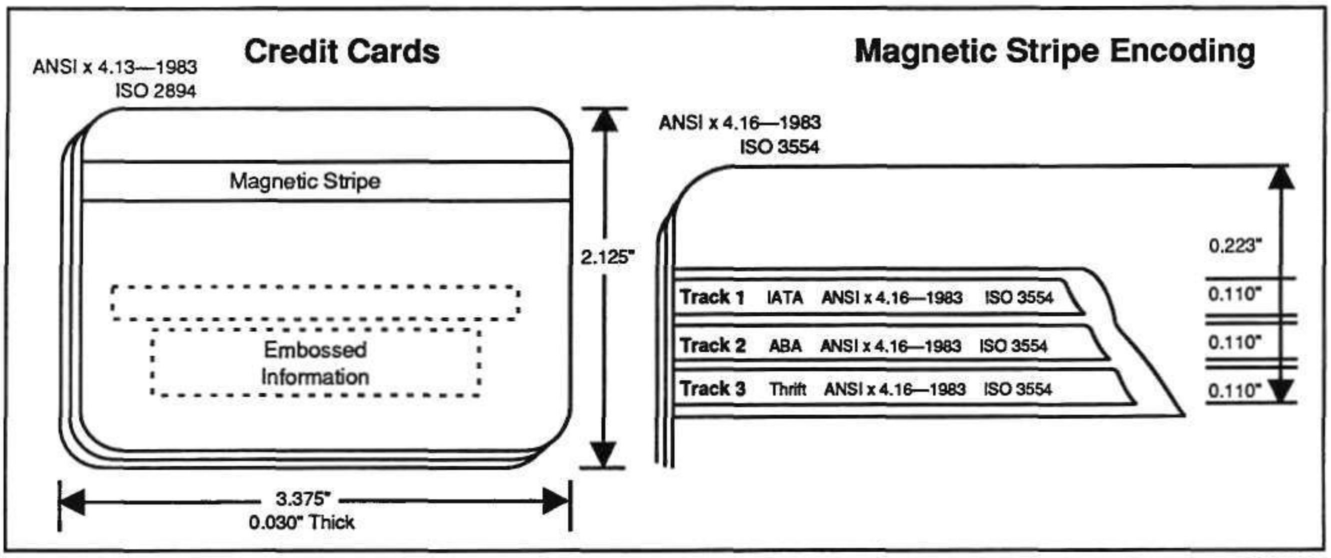
The smart card, on the other hand, contains a microchip embedded in the upper left corner (or the newer middle left position). In essence it is the chip that gives the card the ability to store a fair amount of binary data and provides the intelligence. The typical smart card microchip represents a special kind of a microcomputer, with on-board ROM, RAM,

Figure 1
Smart Card



Source: Schlumberger Industries G2000237

Figure 2
Magnetic Stripe Card



Source: Mag-Tek G2000238

EPROM or EEPROM, and an 8-bit CPU. Unlike the general-purpose microcomputer, smart card microcomputers most often have a total of five pins: Vcc, GND, RESET, I/O, and CLOCK. The primary reason for limiting the number of IC pads is security; all communications are serial in nature, using an asynchronous protocol at 9,600 baud. Additional security is provided as the on-board CPU supervises all communication and, unless the CPU is operational, no access to the stored data is provided to the outside world. It is this software-hardware interlock that provides high security in smart cards. Additional levels of protection/security are provided by the operating system, which include passwords and personal identification numbers (PINs). The card's operating system is stored in the ROM when the chip is manufactured. The RAM is used as a scratch pad for temporary storage. Actual data such as the cardholder's name and account number are stored in the EEPROM area. Current-generation smart cards use EEPROM for data storage; older cards as well as smart cards used for telephone applications use EPROM for this function.

Q: What are some smart card applications?

A: The following are smart card applications:

- Telephone cards. This application consumes most smart cards to date.
- Financial transaction cards (FTC). This application was envisioned as the natural evolution/migration path for credit cards that now use magnetic stripes to store the account ID and some other limited amount of data. For a variety of reasons FTCs (either credit or debit cards) have not been a runaway success story. However, their use is increasing in France, and to a lesser extent in other parts of Europe. Japan is expected to follow the European lead. The process most likely will take much longer in the United States.
- Pay TV cards. This is a promising up-and-coming application. In France the Canal PLUS S.A. uses smart cards, and in the United Kingdom Sky Broadcasting Ltd. (Sky TV) uses a similar scheme. This is perhaps the most promising future application in the United States.
- Toll road cards. Italy has experimented with this system using AT&T contactless smart cards. Besides Italy, similar systems are under consideration in other countries. In the United States trials are under way in Texas toll roads.
- Financial transactions. Smart cards could one day replace current-generation magnetic stripe credit cards. A single smart card can substitute for a number of magnetic stripe cards because the smart card offers far greater nonvolatile memory capacity (typically EEPROM). Different accounts can coexist within the same card. Each account can be protected by a password or PIN, thus ensuring confidentiality.
- Cellular phone cards. In Europe the new pan-European cellular phone network will use smart cards for billing purposes. Here the benefit to the consumer is that a call can be made anywhere in Europe with simplified automated billing.
- Tokens. Tokens similar to smart cards but not limited to that form factor are used in vending machines in Europe and Japan.

Q: Which country uses the most smart cards?

A: France, the country that is credited with inventing smart cards, uses them the most. The majority of smart cards are prepaid telephone cards (Telecarte) with a fixed amount of telephone time units burned in or programmed into the card's EPROM during manufacturing. Telecartes are discarded after all units have been used. The Telecarte is a simple smart card that uses EPROM technology to store the "time units," which are decremented during a telephone call. In other respects, it is very similar to more sophisticated smart cards and uses a serial interface to communicate with the pay phone. To use it, the user inserts the card into a pay phone (mechanism similar to those of ATM machines), where the smart card makes electrical contact with the pay phone connector. The pay phone supplies the power and the clock signal for the card, and initiates the authentication process. Once the card is deemed valid and has a balance of "time units," the transaction can proceed with the caller dialing the number in a normal fashion. When connection is established, units stored in the card are decremented according to the applicable rate. If a zero balance is reached the user is given the opportunity to swap that card with a new one, or the call is disconnected. The French Telecom has realized a substantial benefit as vandalism and coin theft has been substantially reduced if not eliminated. In addition, often cards are not fully used, thus allowing for a monetary gain from the "floating" currency. Additional revenue is realized from advertising sales as most smart cards are imprinted with ads. The cost of such a card is about $1, excluding the telephone "unit" cost. In 1991 about 70 million Telecartes were sold in France.

Q: Name other countries that use smart cards.

A: In Germany the telephone card is the most widespread application to date. Other European countries include Italy, Spain, the Netherlands, and Norway. In the United Kingdom, smart cards are used in satellite TV applications (SKY TV), where the card contains the descrambling algorithm. The viewer needs to insert the card in a box similar to a cable box to descramble the TV signal. Here use of a smart card allows the TV program provider to quickly switch to a new algorithm should the existing one be compromised, a process far less expensive than having to replace actual hardware (the cable TV box, for example). A smart card is periodically mailed to the subscribers to ensure that the TV signal provider stays ahead of any "hackers." This is a real-time process that allows the "cable" company to disconnect anyone not paying the bill. Other countries include Japan, with both banking and transportation applications, as well as Singapore and the United States.

Q: Why haven't we seen widespread use for smart cards in the United States?

A: One reason is that the United States has a good telephone network that allows users to call from anywhere without coins. The telephone credit card system used (one's telephone number plus a four-digit extension) is simple but by no means fraud-free. Vandalism, however, and coin theft appear to be less of a problem in the United States, or are not enough to warrant changing the infrastructure (that is, the public phones), which can be an expensive proposition. Smart cards have not replaced credit cards, as financial institutions prefer to recover the losses from fraud by means of an annual card fee rather than change the existing infrastructure, ATM magnetic stripe cards, with new ATM smart cards. Estimates for losses by companies such as MasterCard and Visa range from $600 million to more than $1 billion annually. Nonetheless trials are under way on a number of fronts. Smart cards have been used to store medical information/data, social security and or drivers license numbers, in the military to replace the dog tag, and as a means for delivering Medicaid/Medicare and social security payments.

Q: What are the advantages/disadvantages of smart cards over magnetic stripe cards?

A: Smart cards are extremely difficult to counterfeit. Magnetic stripe cards on the other hand, can be duplicated easily.

Q: Name the top 10 semiconductor vendors of smart card microcomputers.

A: The top 10 semiconductor vendors are Motorola, SGS-Thomson, Hitachi, Texas Instruments, Oki, Siemens, AT&T, Toshiba, Catalyst, and Philips.

Q: Name the top 3 smart card vendors.

A: The top 3 smart card vendors are GemPlus (France), Groupe Bull (France), and Schlumberger (France).

Q: What are smart card sales in Europe?

A: Figure 3 shows Dataquest's sales estimates for smart cards sales in Europe.

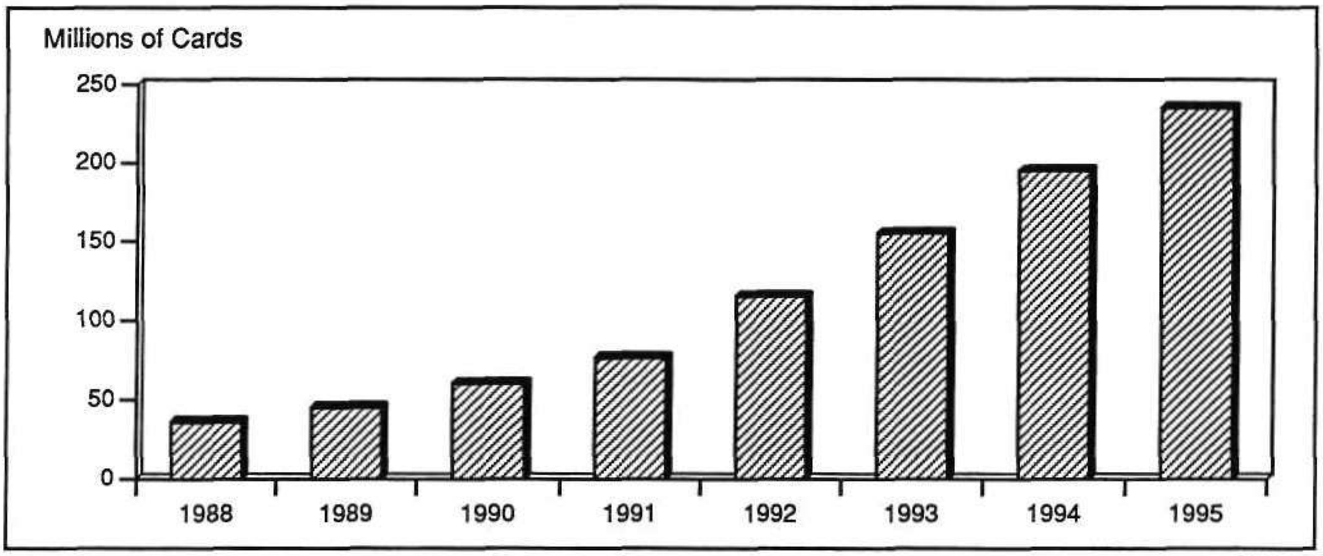
By Nicolas Samaras

In Future Issues

The following topic will be addressed in a future issue of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Emerging opportunities

Figure 3
European Smart Card Sales (Millions of Cards)



Source: Dataquest (June 1992)

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9205 May 11, 1992

In This Issue...

Market Analysis

Digital Cellular and PCN Market: An Upwardly Mobile Opportunity

Two exciting semiconductor applications are emerging in the U.S. market concerning mobile/cellular communication: the conversion of the U.S. cellular market to digital-based and the emergence of the personal communications network (PCN), a go-anywhere cordless phone. Also known as personal communications systems (PCSs), PCNs extend the cordless phone's mobility using a microcell structure of a few kilometers in diameter, broadcasting in the 1.8- to 2.0-GHz range.

This article abstracts information from Dataquest's *Personal and Wireless Communications* report.

Semiconductor Technology for Digital Cellular/PCN Applications

Historically, telecommunications applications have lagged behind data processing applications in their use of VLSI system-on-a-chip architectures. The complex mixed-signal nature of telecom applications (RF, microwave, analog I/O and amplification, and digital switching) has traditionally implied relatively low levels of integration and performance. However, with the recent trend toward datacomm and telecom network standards, deregulation, and network infrastructure digitization, a gradual segmentation of telecom semiconductor applications is occurring.

High-performance CMOS technology is being universally embraced for data compression, digital signal processing, and switching applications. Mixed-signal ASICs and application-specific standard products (ASSPs) incorporating telecom core cells are being implemented in CMOS as well as BiCMOS technology. BiCMOS technology is eventually expected to play an important role in digital cellular and PCN applications because of its unique ability to cost-effectively integrate and interface high performance with RF/IF front-ends with the high-density, low-power integration capabilities of CMOS for baseband compression, coding, and digital signal processing operations. GaAs up/down conversion circuitry will also complement BiCMOS in certain applications where power or battery energy budgets are strained.

Telecom semiconductor companies are using ASICs (gate arrays and standard cells) in combination with programmable logic device building blocks such as complex PLDs and field-programmable gate arrays (FPGAs) in order to hasten time-to-market for the first-generation digital cellular and PCN telephone design. Dataquest expects future PCN chip sets to be optimized as ASSPs using telecom-standard cells and DSP cores. PLD ICs such as complex PLDs and FPGAs will be used to offer customized value-added programmable features. Submicron high-performance CMOS and BiCMOS technology will enable lower chip counts per design, smaller form factors, lower cost, lower power dissipation, and better performance in future digital cellular and PCN chip sets.

Dataquest believes that, by the year 2000, one- and two-chip tightly integrated BiCMOS/bipolar/GaAs PCN IC solutions will offer high-performance, low-cost PCN telephones. These PCN chips will be based on 0.5-micron million-gate embedded gate arrays with optimized telecom macro cells, DSP cores, microcontrollers, filters, codecs, cache RAM, and ROM.

Semiconductor Market Forecast for U.S. Cellular Telephone Applications

Table 1 and Figure 1 show Dataquest's forecast for the U.S. cellular infrastructure and telephone market between 1991 and 2000. The total U.S. semiconductor market for cellular applications is projected to grow from $210 million in 1991 to $401 million by the year 2000. The market is forecast to peak at $436 million in 1995, after which the market growth will flatten because of the encroachment of the PCN semiconductor market. Infrastructure-related cellular semiconductors account for about 25 percent of the $210 million 1991 U.S. market, falling to 12 percent of the $401 million U.S. market by the year 2000.

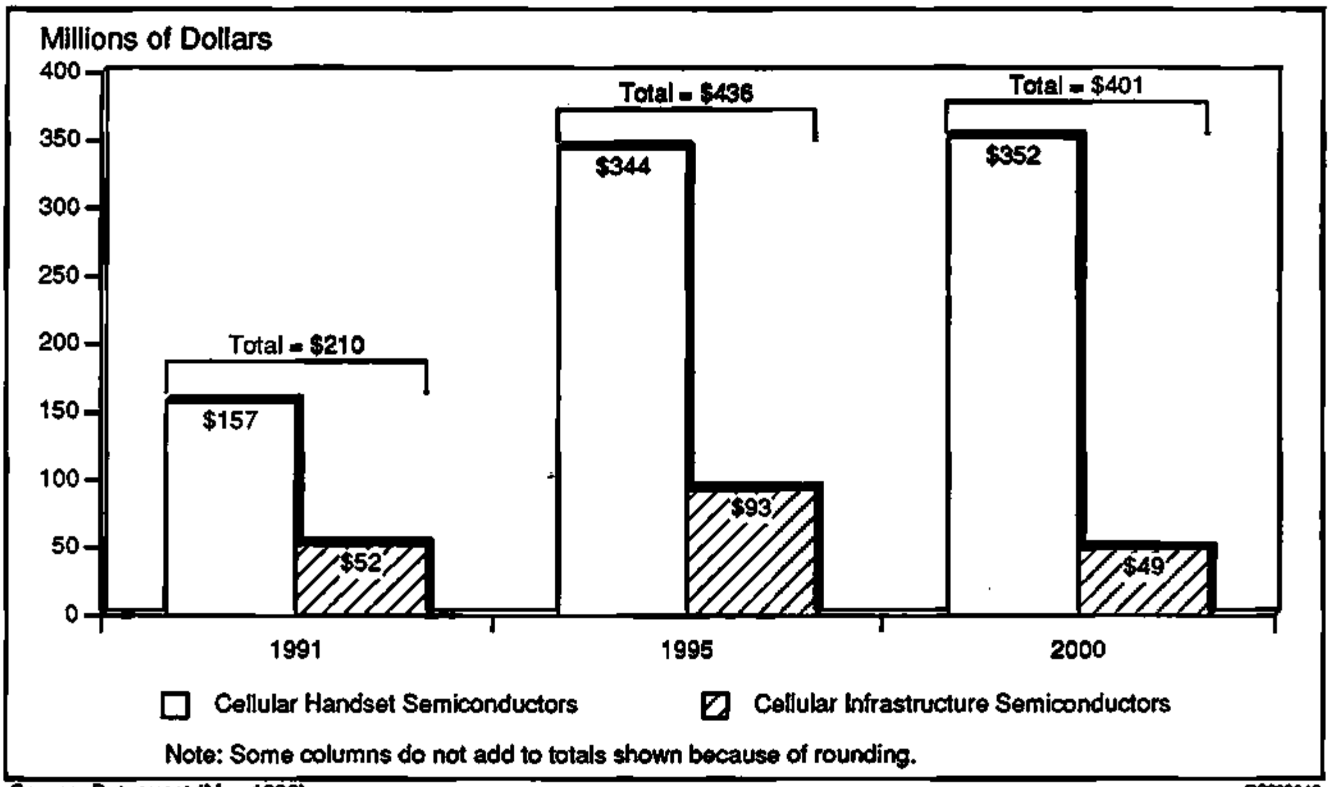
Dataquest forecasts that the average semiconductor content of cellular telephones will decrease at a compound annual growth rate (CAGR) of 4 percent from $55 per telephone in 1991 to $45 per telephone by the year 2000. The transition from the analog AMPS system to dual-mode digital-TDMA/analog AMPS telephones will result in a higher semiconductor content temporarily in the 1992 to 1993 time frame. However, technology advances attributed to submicron-level chip integration, ASSP market evolution, and increased competition will drive the semiconductor content of cellular telephones downward after 1994 in order to accommodate aggressively lower telephone end-user prices.

Table 1
U.S. Cellular Equipment Market Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1991-2000
Cellular Infrastructure	1,045	1,082	1,210	1,578	1,850	1,280	1,270	1,200	1,110	9,80	-0.7
Telephones	1,849	2,305	2,689	3,217	3,253	3,082	2,724	2,660	2,930	2,855	4.9
Telephones (K Units)	2,860	3,490	4,180	5,460	6,220	5,820	6,100	6,550	7,900	7,800	11.8
Telephones (ASP $)	647	660	643	589	523	530	447	406	371	366	-6.1
Semiconductor $ Content/ Telephone Unit	55	65	60	58	55	53	51	49	47	45	-4
Telephone Semiconductor Market	157	227	251	314	344	309	311	320	371	352	-4
Infrastructure Semiconductor Market	52	54	61	79	93	64	64	60	56	49	-0.7
Total Cellular Semiconductor Market	210	281	311	393	436	373	374	380	427	401	7.5

Source: Dataquest (May 1992)

Figure 1
U.S. Cellular Semiconductor Market Forecast



Source: Dataquest (May 1992)
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Semiconductor Market Forecast for U.S. PCN Applications

Table 2 and Figure 2 show Dataquest's forecast for the U.S. PCN infrastructure and telephone market between 1991 and 2000. The total U.S. semiconductor market for PCN applications is projected to grow at a healthy CAGR of 77 percent from $6 million in 1994 to $172 million by the year 2000. Infrastructure-related PCN semiconductors will account for about 50 percent of the 1994 U.S. market of $6 million, rising to 58 percent of the $172 million U.S. PCN semiconductor market by the year 2000. The PCN goal of ubiquitous coverage and low-cost hand terminals will skew the growth of the U.S. PCN semiconductor market toward infrastructure applications through the year 2000, while keeping the terminal semiconductor content and cost low enough to achieve market ramp-up and end-user acceptance.

Dataquest forecasts that the average semiconductor content of a PCN telephone hand terminal will decrease rapidly at a CAGR of 21 percent from $100 per telephone in 1994 to $25 per telephone by the year 2000. Technology advances attributed to submicron-level chip integration, ASSP market evolution, and increased competition will be the key factors driving down the cost of PCN telephones.

Table 3 and Figure 3 show the breakdown of the U.S. cellular and PCN semiconductor market by device type between 1991 and the year 2000. Pure analog and mixed-signal devices such as RF functions and codecs comprise about 50 percent of 1991-generation analog AMPS cellular telephones. AMPS-based telephones use relatively low-horsepower microcomponents such as 8-bit microcontrollers and low-density ASICs such as 5K gate arrays and some PLDs to implement random logic.

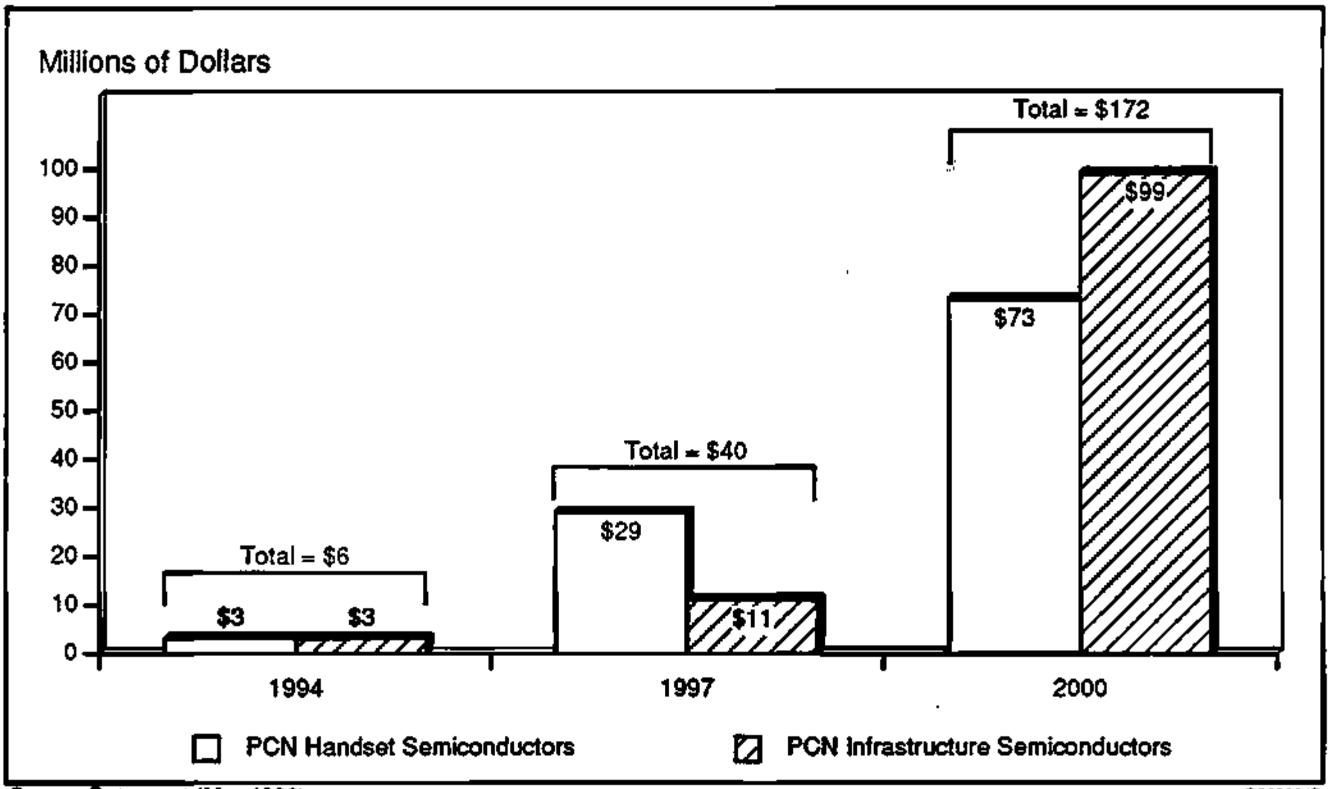
However, by the year 2000, about 40 percent of a digital cellular/PCN telephone's semiconductor content will be composed of highly integrated 16/32-bit microprocessors and digital/mixed-signal ASSPs. The pure analog and primitive mixed-signal building blocks will shrink to 25 percent of the total U.S. cellular/PCN semiconductor market. The hardwired ASIC gate array/standard cell portion of the market will shrink to 5 percent of the market

Table 2
U.S. PCN Equipment Market Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1991-2000
Infrastructure	0	0	0	42	139	80	183	368	755	1,652	84.4
Telephones	0	0	0	30	54	77	210	225	352	522	61.0
Telephones (K Units)	0	0	0	30	90	170	600	750	1,600	2,900	114.3
Telephones (ASP $)				1,000	600	450	350	300	220	180	-24.9
SC $ Content/Telephone Unit				100	67	60	48	40	30	25	-20.6
Telephone Semiconductor Market				3	6	10	29	30	48	73	70.1
Infrastructure Semiconductor Market				3	8	5	11	22	45	99	84.4
Total PCN Semiconductor Market				6	14	15	40	52	93	172	77.3

Source: Dataquest (May 1992)

Figure 2
U.S. PCN Semiconductor Market Forecast



Source: Dataquest (May 1992) G2000647

as standard functionality gets soaked up by the microprocessor/ASSP blocks. Dataquest, however, believes that the need for value-added programmable customization will increase the PLD semiconductor market from 10 percent of the 1991 market to 15 percent of the market by the year 2000.

Digital Cellular/PCN Design Impact on Semiconductor Market

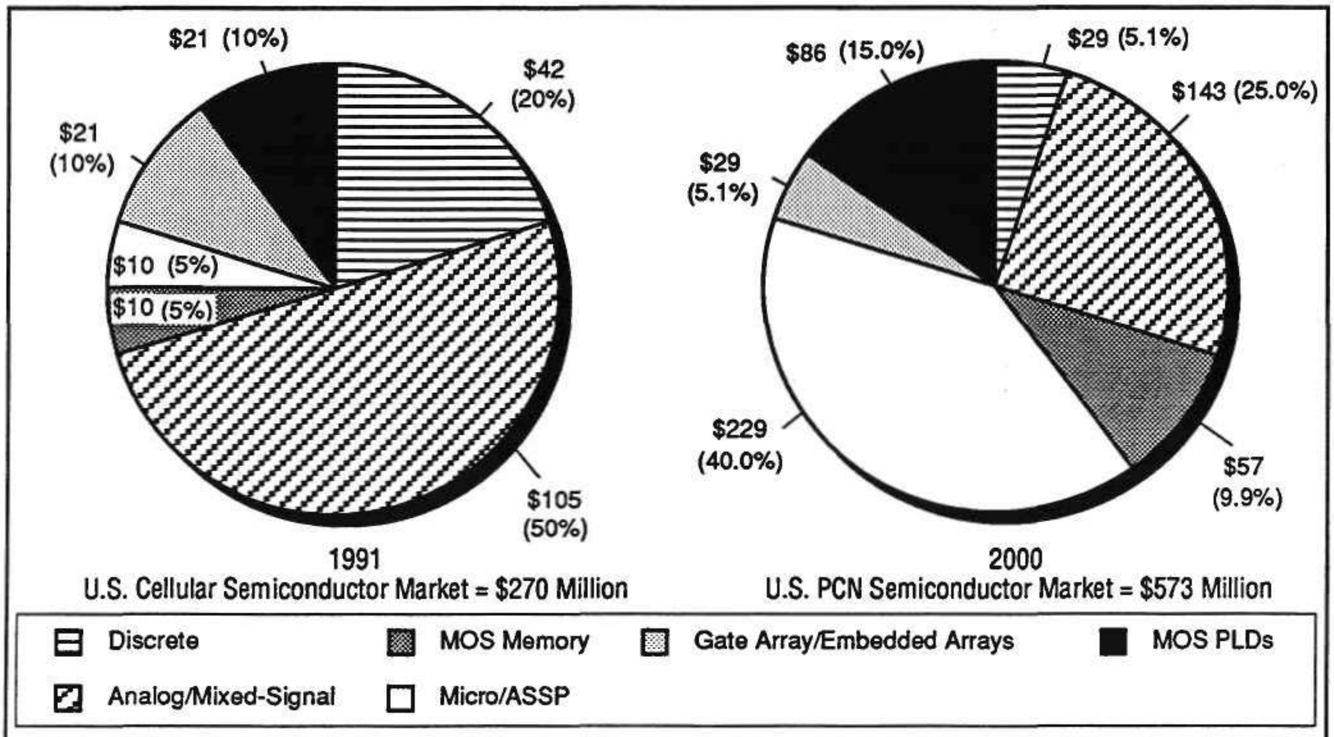
Figure 4 shows the basic building blocks of a conventional AMPS-based analog cellular telephone in 1991. The system is heavily dominated by analog/mixed-signal building

Table 3
U.S. Cellular and PCN Semiconductor Market Forecast by Device Type (Millions of Dollars)

Year	1991	1995	2000	CAGR (%) 1991-2000
Discrete*	42	45	29	-4.2
Analog/Mixed-Signal*	105	180	143	3.5
MOS Memory	10	32	57	20.8
MOS and BiCMOS Micro/ASSP	10	108	229	40.9
MOS and BiCMOS Gate Arrays/Embedded Arrays	21	32	29	3.5
MOS PLDs	21	54	86	17.0
Total	210	450	573	11.8

*GaAs will be an increasing percentage.
Source: Dataquest (May 1992)

Figure 3
Combined U.S. Cellular and PCN Semiconductor Market



Notes: GaAs will be an increasing percentage. Segments may not add up to 100 percent because of rounding.

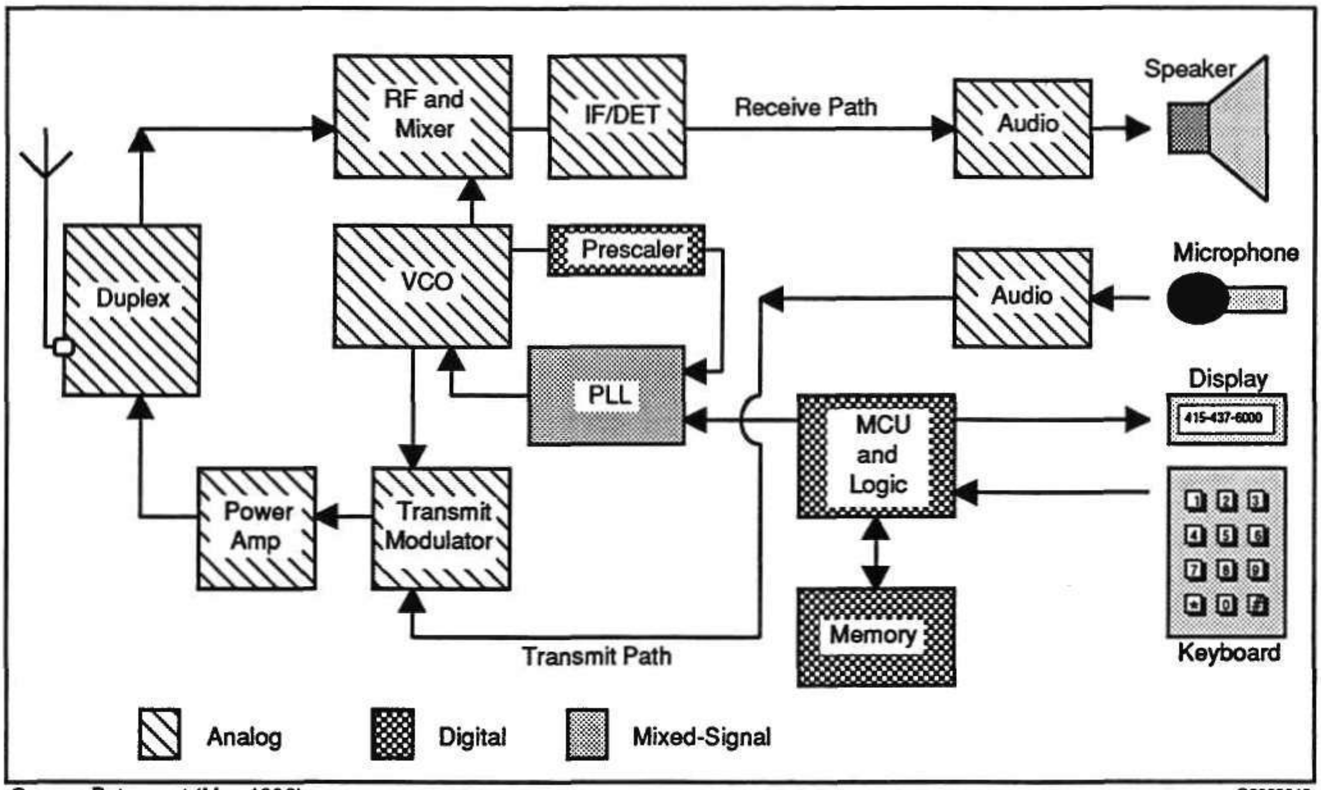
Source: Dataquest (May 1992)

G2000648

blocks to implement functions such as power amplification, frequency synthesis, and modulation. A relatively simple 8-bit microcontroller is used for control and execution.

Figure 5 shows a simplified schematic of a digital cellular/PCN telephone system. In this case, elaborate speech codecs and baseband codecs are needed to implement the digital coding of the TDMA (for cellular) and CDMA (for PCN) algorithms. A high-performance 16/32-bit CMOS microprocessor (RISC-like streamlined architecture) controls the compute-intensive baseband codec, equalization, and CDMA/TDMA modulation functions, which use high-performance 16/32-bit DSP engines. The RF front end is based on high-frequency bipolar or

Figure 4
Simplified Analog Cellular Telephone



Source: Dataquest (May 1992) G2000649

GaAs ICs. It is conceivable that the progress toward ULSI-level sub-0.5 micron IC integration can yield a single-chip integrated BiCMOS PCN/digital cellular solution that combines the high-frequency, high-gain RF front end with the computationally intensive baseband section.

The building blocks for a PCN handset, although similar in concept to a digital cellular handset, will be somewhat simpler and less costly in implementation. The elimination of hard cellular handoffs, high-speed mobility and noise-filtering, frequency hoppings, and high transmit power requirements will render the IC implementation of a PCN handset somewhat easier, compared to a digital cellular handset.

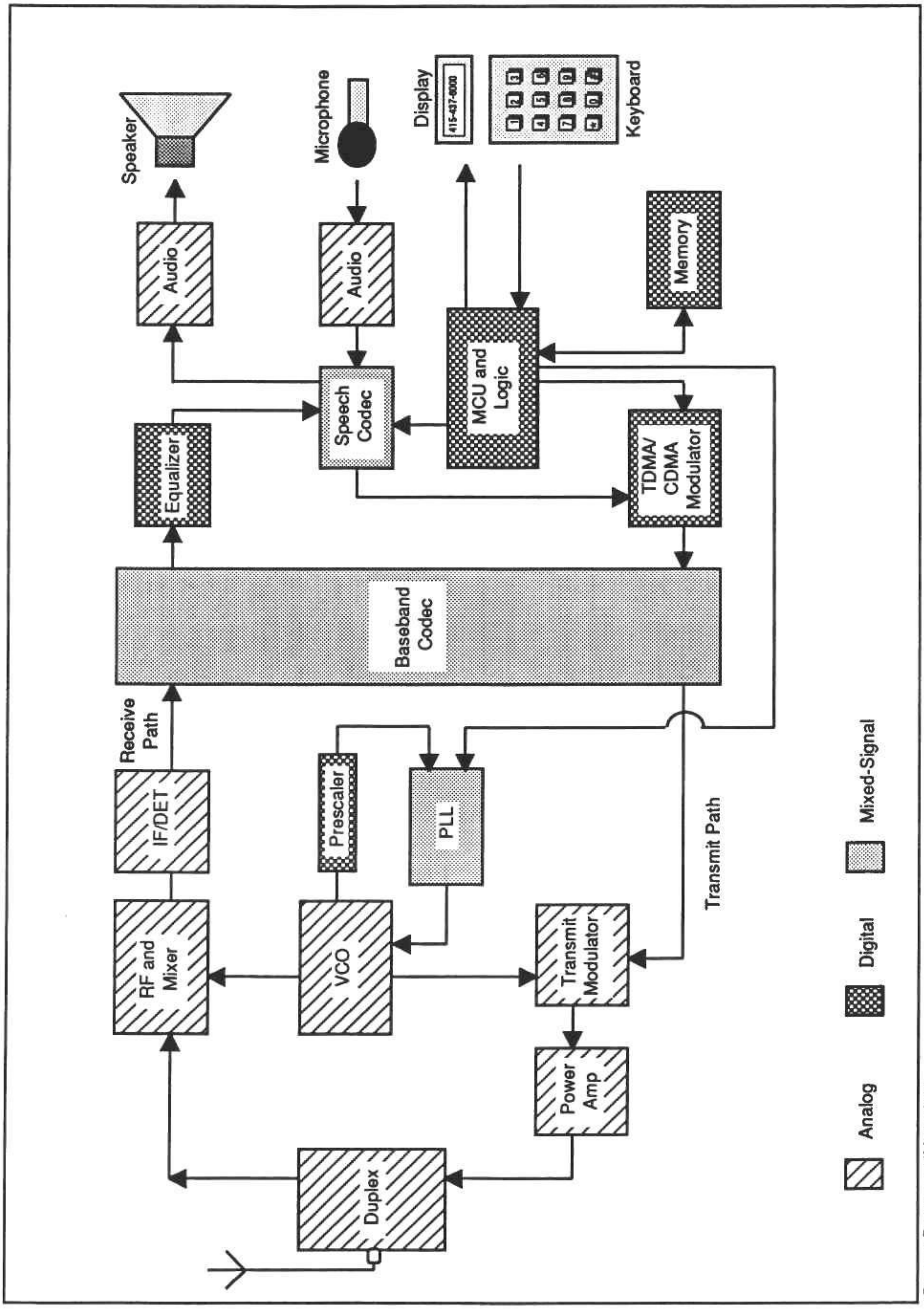
As for memory functions, mask programmable ROM and EE/flash will be needed for control code and user data (such as phone numbers), respectively. The nonvolatile memory requirement can range from 64Kb to 132Kb, some or all of which can be absorbed by the microcomponents. Because of the need for a DSP scratch pad/buffer, upward of 64Kb of slow SRAM can be required as well. There may be a future need for a memory card (prepaid debit card) interface, but markets such as Europe are the better near-term opportunity for that functionality.

Dataquest Perspective

A mixture of pure-play merchant semiconductor vendors and mixed captive/merchant vendors aims to capture significant portions of the U.S. cellular/PCN semiconductor market. Companies such as AT&T Microelectronics, Motorola, Mitsubishi, Matsushita, Sony, Fujitsu, Siemens, Oki, NEC, and Ericsson hope to parlay their systems knowledge expertise into IC component market dominance. Such companies aim to achieve multiple returns on their core technology at both the OEM telephone handset level as well as the IC component level. Vigorous competition in the merchant digital cellular/PCN semiconductor market will ensure production economies of scale, efficient cost structures, and market-driven performance specifications for their semiconductor building blocks.

In contrast, pure-play semiconductor companies such as GEC Plessey, National Semiconductor, Texas Instruments, Harris, Philips, Samsung, and SGS-Thomson are expected to leverage their core

Figure 5
Simplified Digital Cellular/PCN Handset



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Source: Dataquest (May 1992)

competencies and manufacturing muscle into key roles as merchant building block suppliers of high-performance, cost-effective digital cellular/PCN chip sets. Dataquest also expects a new wave of fabless application-specific semiconductor companies with experience in mixed-signal wireless telecommunication to emerge in order to target this emerging market. The availability of high-performance mixed-signal foundry processes and merchant CAD tools will be a significant entry barrier challenge for fabless semiconductor companies in this arena.

By Krishna Shankar
Gregory Sheppard

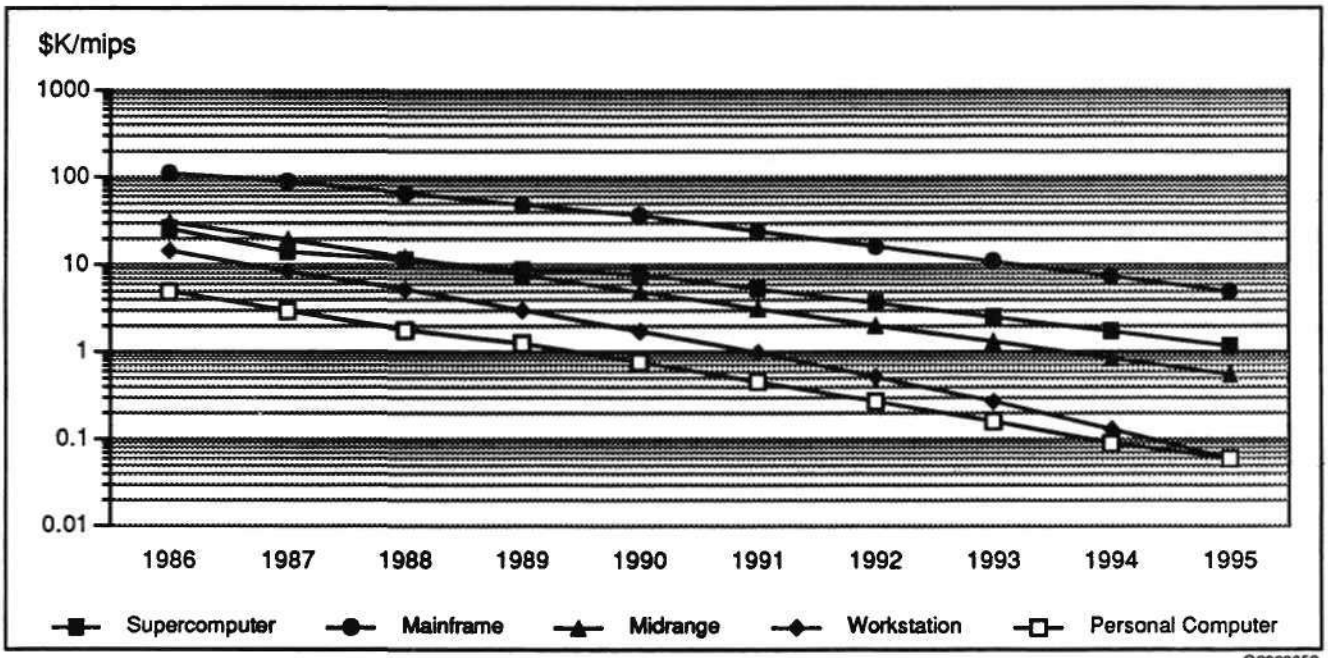
Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q: What does Dataquest project for the price of computing power across the various computer system types?

A: Figure 1 shows Dataquest's forecast for worldwide computer systems growth in mips units shipped and for worldwide computer systems price per mips.

Figure 1
Worldwide Computer Systems Price per mips



Source: Dataquest (May 1992)

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9204 April 13, 1992

In This Issue...

Inquiry Summary

Dataquest's Semiconductor Application Markets inquiry summary is designed to inform clients of commonly asked questions and Dataquest's respective answers. No confidential information provided by our clients is included in this material. The information contained in this publication is believed to be reliable, but it cannot be guaranteed to be correct or complete.

Q: What is the forecast for the worldwide plain paper copier market?

Q: What is the disposition of the color copier market?

Q: What is the size of the PC graphics chip set market?

Q: What is Dataquest's 1991 market share ranking for PC suppliers?

Market Analysis

Laser Printers: Evolution Darwin Would Be Proud Of

Next-generation laser printers will come very close to having the computing power of many of the PCs they support. This factor and the continued expansion of their use worldwide make laser printers an ongoing attractive market for semiconductors.

Differentiation and Value

Not unlike the computer OEMs, laser printer manufacturers are continually searching for ways to add value and differentiate their products. The following paragraphs describe some value-adding trends that can be expected over the next few years.

Higher Resolution Struggle

The fiercest battlegrounds for product differentiation are in print quality, gray-scaling/halftones, and the elimination of aliasing (stair-step effect on curves). This will become particularly important as multimedia desktop systems evolve to handle and print images. The future will yield an array of complementary techniques that modulate the laser diode's intensity and duration for more precise resolution, something usually done after the page bit map has been created. The most common resolution today is 300 × 300 dots per inch (dpi), but a variety of technologies that expand the effective resolution to 600 × 600 dpi and beyond have emerged. True addressable 600 × 600 dpi technology in midrange printers will emerge over the next two years.

Hewlett-Packard's Resolution Enhancement Technology (RET) actually retains the 300 × 300 dpi matrix but achieves effective 600 × 600 dpi by moving a scaled-down laser beam around within a standard "dot." One criticism of this technology is that the smoothing algorithm employed can distort some complex figures or images. QMS Inc. has come out with a true 600 × 600-dpi technology called MultiRes, where all the dots are separately addressable on what is normally a 300-dpi system. Users can select either 300 dpi or 600 dpi from the control panel or via company-provided host software. QMS's approach does not require any distortion-prone dot smoothing. DP-Tek has also introduced a fully addressable resolution enhancement approach called TrueRes, which can double the vertical and horizontal dot resolutions of 300-, 400-, and 600-dpi printers. DP-Tek also licenses its technology to other OEMs and board companies.

Destiny Technology is another merchant supplier of a resolution enhancing technique called Edge Enhancement Technology (EET). It offers a RET-like ASSP that NEC's Silentwriter 95 has incorporated. Table 1 lists companies with notable resolution enhancement techniques.

In general, resolution enhancement features are being incorporated into CMOS ASICs and ASSPs. Each technique handles the laser beam differently and is tailored to a particular printer engine (for example, Canon NX or SX).

Battle for Rasterization

Just when it appeared that laser printers were heading for supercomputer status, the following question was posed: Why not take advantage of some of the host CPU cycles for some of the laser printer functions? In fact, several available software packages can perform much of the image rasterization function on the computer system and send to the printer a prerasterized bit stream. This capability addresses the so-called what-you-see-is-what-you-get (WYSIWYG) trend where display and printer information look the same. It also addresses the trend toward graphical user interfaces such as Windows, where bit-mapped graphics are needed most of the time. The leading examples of host-based rasterization software packages are Adobe's Type Manager, Microsoft's TrueImage, and Sun Microsystems' NeWSprint.

A potential impact of host-based rasterization would be the need for a less intelligent printer controller. Therefore, it is conceivable that a market could develop for modestly priced 8/16-bit MPU-based laser printers that do not perform rasterization. Although this scenario is arguable, we believe that host-generated raster streams will bog down the system more often than not unless a multitasking OS is present and/or the system MPU's speed is 33 MHz or greater. Graphics and image printing also would further slow host-based rasterization.

Interpreting Interpreters

Seven years after Adobe's PostScript Level 1 was introduced, the company recently released PostScript Level 2. Some key features of this update include decompression of the bit stream from the computer (if driver-based compression is used), color management, forms caching, and more efficient and dynamic memory management. Several PostScript-like

Table 1
Companies Offering Resolution Enhancement for Laser Printers

Company	Offering
Apple	FinePrint/PhotoGrade
Lexmark	Print Quality Enhancement Technology (PQET)
HP	Resolution Enhancement Technology (RET)
Destiny	Edge Enhancement Technology (EET)*
QMS	MultiRes
DP-Tek	TrueRes*
LaserMaster	TurboRes
NewGen	Image Enhancement Technology

*Licensor or ASSP provider
Source: Dataquest (April 1992)

interpreters exist from companies such as Phoenix Technologies, Destiny, and Peerless. Likewise, HP's PCL 5 technology is now cloned by several companies.

As PostScript/PCL 5-compatible printers become more prevalent, they are retaining the ability to emulate bit-mapped printers. Several emulations usually are supported for prior generations of printers and plotters. A key trend is toward automatic emulation recognition where the printers automatically recognize the language and provide the necessary personality to the host.

Opportunities

Table 2 shows what could be the evolutionary path of laser printers at two of the most popular price points. Laser printer models appear to have an average market life cycle of three years. Currently, entry-level laser printers (PCL 4) are priced substantially less than $800, run at 4 pages per minute (ppm), are based on a 68000 processor, come standard with 0.5MB of main page storage, and feature bit-mapped fonts. By 1994 , entry-level users could upgrade to a 6-ppm, PostScript/PCL system available for less than $1,200. It is also possible that 20-ppm PostScript/PCL printers will be available for less than $3,000.

Shipments of color laser printers to date have been limited because of high price tags. We believe that the price of color versions will come down rapidly to near $10,000 as new engines and integrated controllers roll out in the next two years. With color, opportunities exist for compression schemes such as JPEG to reduce the high bandwidth and memory requirements of color.

Figure 1 identifies the future functions and opportunities within a laser printer controller.

MPU

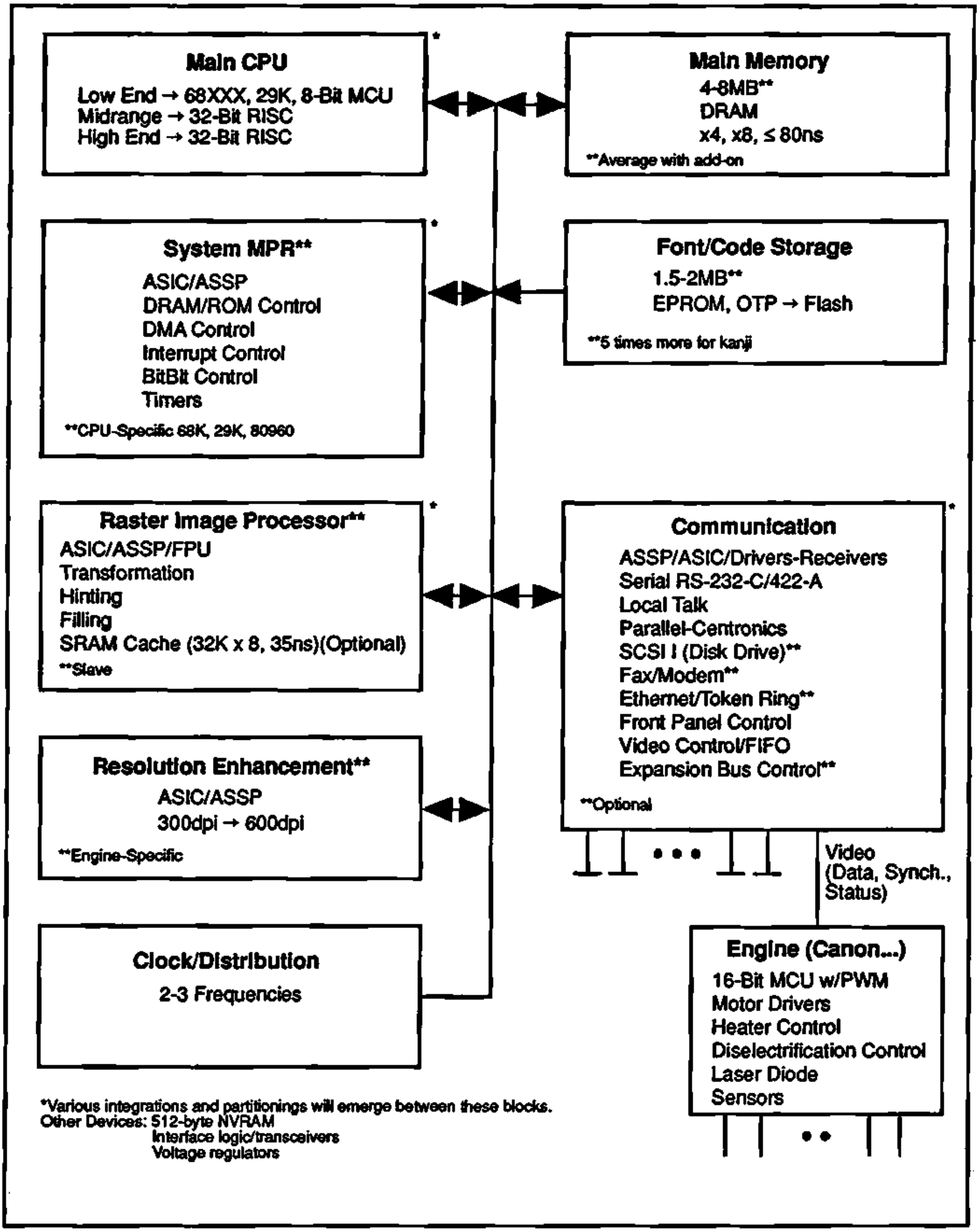
The 68000 should remain the single most dominant MPU type for low-end printers (less than $1,200) through the mid-1990s. By 1994, 6-ppm, $1,000 PostScript/PCL 5 printers powered by 16-MHz 68000 MPUs with resolution enhancement should prove to be in great demand; 68020 and 29K-based printers also will become more prevalent in the 8- to 12-ppm range. Midrange printers (12- to 20-ppm) will continue to see a shift to 32-bit RISC MPUs as performance needs go up and MPU prices come down. AMD's 29K family has probably been the most successful RISC MPU to date in the midrange, with Intel's 80960 gaining ground rapidly through some expected design win announcements. AMD's 29200 "printer on a chip," which combines the vital MPR functions, engine interface, and host communication, promises a PCL 5 controller in six chips.

Table 2
Laser Printer Evolution by Price Range

	1992	1994-1995
$800 to $1,200	4-6 ppm	4-10 ppm
	68000—16 MHz or slower	Mostly 68XXX; some RISC to 20 MHz
	2MB DRAM with add-on	4MB DRAM with add-on
	Bit-mapped fonts	PostScript II/PCL 5—16 fonts
	300 × 300 dpi/Some resolution enhancement	300 × 300 dpi/Resolution enhancement
	Semiconductor content of $75-$135	Semiconductor content of $85-$145*
$2,000-5,000	6-17 ppm	10-20 ppm
	680XX, 29XXX, XL, NS to 20 MHz	Mostly RISC (80960, 29K) to 33 MHz
	4MB DRAM with add-on	8MB DRAM with add-on
	PostScript II/PCL 5—35 fonts	PostScript II/PCL 5—35 fonts
	300 × 300 dpi/Resolution enhancement	300 × 300 dpi/Resolution enhancement
	Semiconductor content of $265-$275	Semiconductor content of $265-$275

*Less intelligent (host rasterized) versions will run half of this amount.
Source: Dataquest (April 1992)

Figure 1
Laser Printer Controller Evolution (Circa 1994)



Source: Dataquest (April 1992)

G2000096

As host-based rasterization emerges, a need will develop for less intelligent controllers with only an 8- or 16-bit MCU needed for housekeeping functions.

Memory

Factory-installed and add-on DRAM for main memory will continue to run about 40 percent of the semiconductor bill of materials. Our research indicates that the typical user will double the size of the factory-installed SIMM-based DRAM. Currently, 4M DRAMs are being adopted within printers in either x4 or x8 configurations, with 80ns access times becoming common. The need for DRAMs could increase substantially as fully addressable 600-dpi resolution and 32-bit color (4 primary colors at 8 bits each) emerges later in the decade. Downloadable soft fonts could drive DRAM requirements up as well, but this feature remains out of the mainstream. With the advent of PostScript Level 2 from Adobe, embedded data compression could possibly reduce the memory needed. Once again, this would come at the expense of stealing host CPU cycles.

Nonvolatile storage for PostScript/PCL 5 interpreter code, bit-mapped fonts, and scalable outline fonts (Type 1, TrueType, Intellifont, kanji) will continue to migrate down into the low-end printers, stimulating growth for various ROM versions. A printer equipped to run PostScript (or compatible)/PCL 5 and various emulations of other printer standards can require as much as 3MB. Kanji capability could consume 5 to 10 times that amount. Most of the printers we have analyzed use UV EPROMs for flexibility. We expect flash memory to become an opportunity when price parity is reached.

Other occasionally used memory includes 32K × 8, 35ns SRAMs for caching during the rasterization process, and E^2 or NVRAM (serial, 512 B) for user preferences and booting.

ASICs/ASSPs/Chip Sets

MPU Support MPR

MPU-support MPRs provide traditional support functions such as those found in PC chip sets. In addition to functions such as DRAM and interrupt control, the block transfer BitBlt function is also required. As elsewhere, these functions can be swept up by an ASIC or implemented as an ASSP for supporting various CPUs.

Raster Image Processor

Raster image processors (RIPs) off-load the main MPU by handling the generation of the rasterized image from outline fonts. This IC handles transformation (scaling) hinting (fine adjustments), and filling (shading) and can operate up to 7,500 characters per second. This function can often be achieved with a standard MPU coprocessor or proprietary ASIC. However, opportunities exist for creating merchant ICs that handle Type 1, TrueType, Intellifont, kanji, and other character sets. Adobe with VLSI Technology, as well as Destiny Technology, offer tailored RIP merchant chips. The Adobe/VLSI chip is designed to work with ATM and for accelerating kanji character handling, the latter being a price/performance challenge limiting the acceptance of laser printers in Japan.

Resolution Enhancement Processor

Resolution enhancement processors control the modulation and movement of a laser beam within a dot to give apparent resolution doubling to 600 × 600 dpi (or greater). As noted earlier, this stimulates price/performance greatly as users get better printouts without speed degradation. Most printer manufacturers treat this as a differentiator and thus attempt to control the technology by using proprietary ASICs. This has changed recently because Destiny Technology has released its merchant D9001 Edge Enhancement Technology (EET) chip for resolution enhancement (CMOS, 68-pin PLCC, $10 in high volumes). Starting with the NEC Silentwriter 95—which we analyzed—there should be several further introductions at about $1,500 with PostScript 2/PCL 5 capability using Destiny's chip.

Communication

In communication, as in other platform trends we have analyzed, the amount of change in laser printer interfaces is not surprising. In addition to the standard serial/parallel/Local Talk interfaces, we can expect midrange versions to either incorporate or make more add-on card provisions for LAN connections, SCSI I interfaces, and fax/modem capability. The LAN connection applies to network server applications where the printer controller might be called to run the popular network operating systems. The SCSI I interface would be needed for adding a disk drive for soft font downloading, and for high-speed spooling where the other interfaces are too slow. Fax/modem capability is already being seen as optional in HP's offerings, for example, as fax users take advantage of the printer engine.

For some processor-specific applications, merchant chip vendors are introducing ICs that integrate the host communication, expansion bus interface, front panel controls/display, and video (printer engine) interface. Both VLSI Technology and Destiny Technology offer merchant, integrated printer communications controllers that save several square inches of board space.

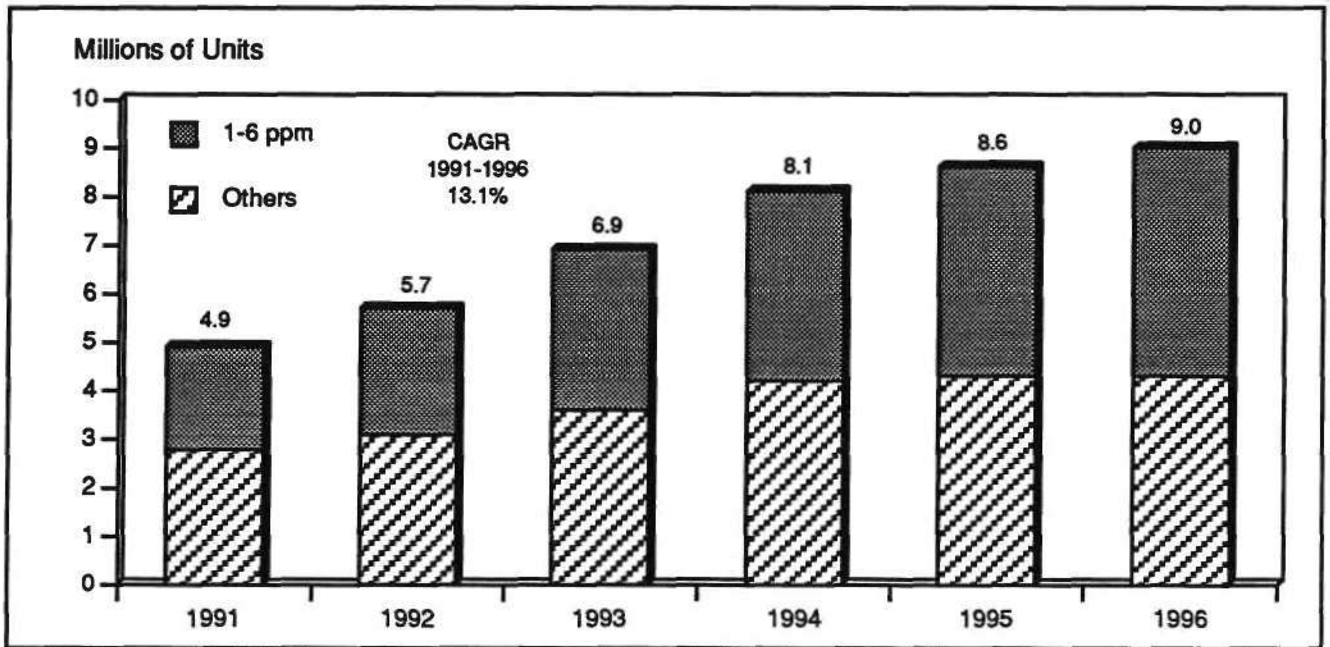
Forecast: Maturing Market, but Opportunities Are Plentiful

Figure 2 shows the worldwide market forecast in units for laser printers (including other imaging techniques such as LEDs). In spite of a maturing North American market for laser printers, Europe and Asia/Japan will continue propelling the world market at a 13.1 percent rate through 1996, reaching about 9 million units. The entry of price- and performance-effective kanji and other complicated character set printers will help expand the Asia/Japan market. Good growth prospects exist in the 1- to 6-ppm area as they break the $1,000 price barrier and attract new users. The 16-ppm-and-greater categories will continue serving growing print server requirements for networks.

There are more than two dozen laser printer OEMs today, but HP, Apple, IBM, Canon, and Panasonic have an estimated 70 percent of the market among them. There also is a growing trend for printer OEMs to become integrators using outside controller boards. Controller players include Adaptec, Bezier, Doctor Design, HDE, Peerless, and Xante. Although there are at least a dozen now, Canon, TEC, and IBM are the dominant engine manufacturers.

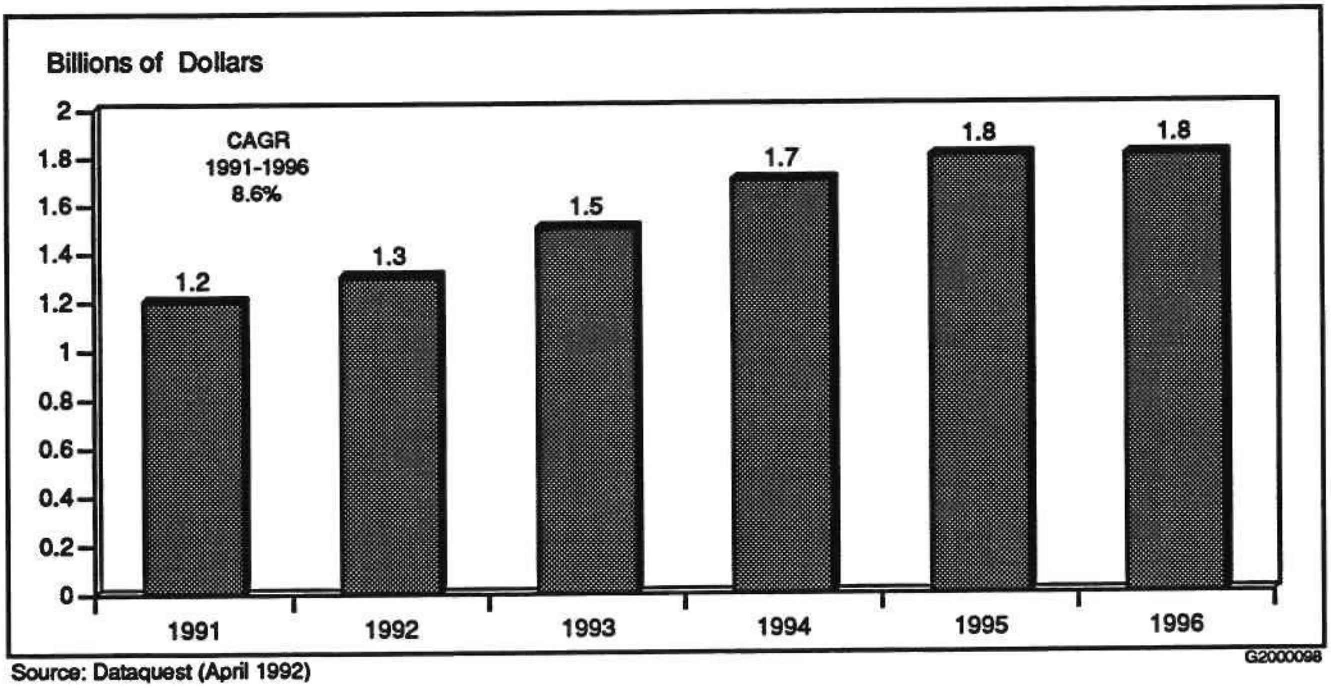
Figure 3 and Table 3 show the semiconductor opportunity offered by laser printers. Averaging $233 today per printer (with average add-on memory), the semiconductor market for laser printers is expected to have an 8.6 percent CAGR through 1996, where it reaches $1.8 billion. The semiconductor content is expected to decline somewhat as the market mix shifts more toward lower-functionality printers.

Figure 2
Worldwide Page (Laser) Printer Market



Source: Dataquest (April 1992)
G2000097

Figure 3
Worldwide Page (Laser) Printer Semiconductor Market



Source: Dataquest (April 1992)

Table 3
Laser Printer Semiconductor Content in Dollars (Generalized)

	1992	1994
Less than $1,200 Printer		
DRAM (2MB)	60	(4MB) 48
Nonvolatile (1MB)	28	(2MB) 40
MPU	10	15
ASIC/ASSP	20	25
Communication	5	1
Interface/Analog	4	3
Discrete/Opto	4	4
Total ($)	75-135	85-145
$2,000-$5,000		
DRAM (4MB)	120	(8MB) 128
Nonvolatile (2.5MB)	70	(4MB) 80
MPU	32	22
ASIC/ASSP	35	28
Communication	5	1
Interface/Analog	4	3
Discrete/Opto	4	4
Total ($)	265-275	265-275

Note: A SCSI I interface would add $8-12 in semiconductor content and an Ethernet connection $26-34. SRAM based cache (32K x 8) could add $6-24 and an NVRAM $1.50.
Source: Dataquest (April 1992)

DRAM is expected to account for an average of 40 percent of the semiconductor bill of materials, while nonvolatile memory will average about 25 percent. The embedded microprocessors will average 10 percent, whereas the value-added playground of ASICs and ASSPs will average about 15 percent. Communications ICs, interface logic, voltage regulators, motor drivers, sensors, and the laser diode account for the rest.

Dataquest Perspective

In our last analysis of laser printer technology we forecast the need for higher-performance MPUs, and ASSP chip sets to replace the variety of ASICs found on the controller. There is clearly a trend toward using more 32-bit CISC and RISC MPUs and doubling DRAM and ROM requirements. During 1992, a new class of laser printers vendors using barrier-lowering ASSPs are entering the market with very competitive offerings on a price/performance basis. ASICs will most likely remain a value-adding tool for market leaders such as HP, Apple, and IBM, while ASSPs will principally remain the tool of the market followers.

Our analysis of this market and its hardware designs reveals that detailed applications knowledge is as vital as ever with laser printers. Detailed knowledge of the target controller MPU and engine is now complemented by serving the OEM's need to differentiate products on price/performance. The laser printer market is only in its adolescent stage and therefore should continue to be a margin-laden opportunity for semiconductor vendors for years to come.

By Gregory Sheppard

Nomadic Computing and Semiconductor Opportunities for Hand-Held PCs

Portable PC terminology is confusing. Definitions change with time as technology races to fit a Cray supercomputer in a shirt pocket! In this article, Dataquest provides basic definitions and then discusses trends and semiconductor opportunities in the portable PC industry.

Definitions

A notebook PC is a desktop PC shrunk to the approximate size of 8.5 × 11 × 1.5 inches; it weighs 4 to 7 pounds.

A companion PC is basically a smaller notebook PC that typically measures 10 × 6 × 1 inches and weighs less than 3 pounds. It may use a floppy and a hard disk or silicon disk for mass storage.

A hand-held is a desktop PC shrunk to at least a size of 8.5 × 4 × 1 inches (more often 6 × 4 × 1 inches) and weighs less than 1.5 pounds. Because of size and power constraints, hand-held PCs do not use a hard disk for mass storage. Instead they rely on PCMCIA-type memory cards to fulfill this function. The memory card here performs dual functions: that of a removable mass storage device (hard disk) and of a floppy that allows for information exchange. The term palmtop is often used to indicate a similar class of machines. For our discussion we will focus on machines that support a standard operating system (OS) such as DOS.

A personal organizer is a small portable device (6 × 3 × 1 inches or smaller) typically running a proprietary OS and a small set of personal information management (PIM) utilities such as appointment calendars and phone books. Personal organizers do not run general-purpose software. They can, however, communicate with PCs for data transfers.

Why Do We Need Hand-Held PCs?

Even though portable PCs are getting smaller and lighter by the day, they are still cumbersome for many applications and users. It is true that notebook PCs have brought the computing power of the desktop to an 8 × 10 × 1-inch form factor weighing just under 5 pounds. But even though they fit in briefcases, they are still limited in a number of ways.

Portable PCs depend on expensive nonstandard rechargeable batteries that allow for just 2 to 4 hours of operation, which creates a problem: It is nice that such powerful full-fledged PCs can be taken on the road, but they tend to become temporarily useless once they run out of power. Of course they can be brought back to life when an AC outlet is found, but then, this is not much consolation inside an airplane! Another problem is the AC adaptor, which is not lightweight and takes up space. At 4 to 5 pounds (adaptor excluded), notebook PCs are still heavy for most users, who would prefer something much lighter if given a choice. More importantly these PCs are not socially accepted in meetings, while paper-based daytimers and organizers are. Portable PCs also are not very rugged, the weak points being the hard disk and to a lesser degree the LCD display. Finally, there is the cost issue: Notebook PCs still cost $1,500 to $4,000, excluding software.

Enter the hand-held PC, which is much smaller, much lighter, runs on off-the-shelf batteries (often standard AA) for up to 100 hours, fits in a shirt or vest pocket, costs a third the price of a notebook, runs most (if not all) PC application software, and easily connects with desktops.

Because the hand-held PCs run off-the-shelf software, they become almost as useful as the desktops. The key word here is almost. Some choices had to be made to downsize a desktop to a hand-held. There is no space or power to use a hard disk, which means that some alternate form of mass storage is needed. The only viable—and in the short-term, expensive—alternatives were solid-state disks and/or memory cards. The solid-state disk based on flash memory is the hard disk replacement; the memory card is the floppy.

Solid-state storage is a blessing in disguise. Because it is more expensive than the equivalent hard disk drive (HDD), it mandates that only the necessary software be built-in or carried along. This fact, limiting as it may at first glance seem, forces examination of the utility of the software carried along. Only absolutely necessary software is embedded in hand-held PCs because semiconductor mass storage is not cheap. On a per-megabyte basis a hard disk drive costs $3 to $4, whereas a flash memory disk/card may cost $50 to $75. By year's end it is expected that the cost disparity between hard disks and solid-state storage (flash) will be reduced to 5:1 as memory cards reach $25 per megabyte.

A point often missed in cost-per-megabyte discussions is that just 3MB of hard disk storage cannot be bought for $9! Even if the cost issue is ignored, hard disks cannot be used in hand-held PCs because they consume too much power and their size, even at the 1.8-inch form factor, is a problem. This may not hold true if and when low-power 1-inch HDDs become available. At that size most problems inhibiting their use in hand-helds should disappear. A 1-inch hard disk would be reasonably rugged and power nimble. For now, however, solid-state is the only alternative.

Hand-held PCs are not meant to replace the office PC; instead, they are expected to act as adjunct computers.

To the extent that hand-held PCs can effectively be used as take-along computers, their compatibility with the user's desktop PC is essential. However the ability to run all the software as the user's desktop is a questionable quality. The hand-held is more of an outgrowth from the organizer camp as opposed to the downsizing of the notebook PC. Attributes other than full compatibility are more important. For example, are the PIMs adequate and well designed? Is the hand-held small and easy to carry along and use? Is the keyboard useful for a reasonably small amount of typing? Are the batteries easy to find and do they last 50 to 100 hours? Is the display quality acceptable? How easy is it for the average user to connect the hand-held to a desktop and upload/download data? Is connectivity expensive? Successful hand-held implementations should have plenty of yes answers for this set of questions.

Who Uses Hand-Held PCs?

Beyond the on-the-go professional that needs something light for the road, a multitude of people use and will use these devices in a variety of environments. Weight, portability, and battery life are key features that make hand-held PCs attractive in industrial/commercial tasks on the factory floor to collect data, in shipping and receiving, for inventory and other tasks. Thus assuming that hand-helds deliver on the challenges at hand (ease of use, long battery life, and seamless connectivity), they stand to clearly dominate parts of mobile computing. Figure 1 shows a representative level of integration in today's hand-held PCs.

The trend in hand-helds is toward using a highly integrated MPU such as the NEC LH72001, the C&T F8680, the VADEM VG-230, or the Motorola LSC80018. The memory card port can be controlled in a number of ways. A memory card controller may be used if space and cost permit. Alternately, glue logic or even the MCU may be used for direct but less efficient control. This function will ultimately migrate to the MPU.

Table 1 shows hand-held unit projections based on Dataquest's Personal Computers group's forecast, which does not include personal organizers. Hand-held PC unit shipments are expected to grow at a compound annual growth rate (CAGR) of about 84 percent from 1992 to 1996. Both average selling prices and hand-held semiconductor content are expected to come down following reasonably well-defined learning curves. The total available market for semiconductor vendors is projected to grow at a healthy rate of 67.2 percent over the same period. It should be noted that the semiconductor TAM figures do not include the substantial semiconductor memory (flash, ROM, and RAM) opportunities arising from memory card sales.

Figure 2 shows projected hand-held PC market share for 1992 and 1996.

Hand-Held PC Players

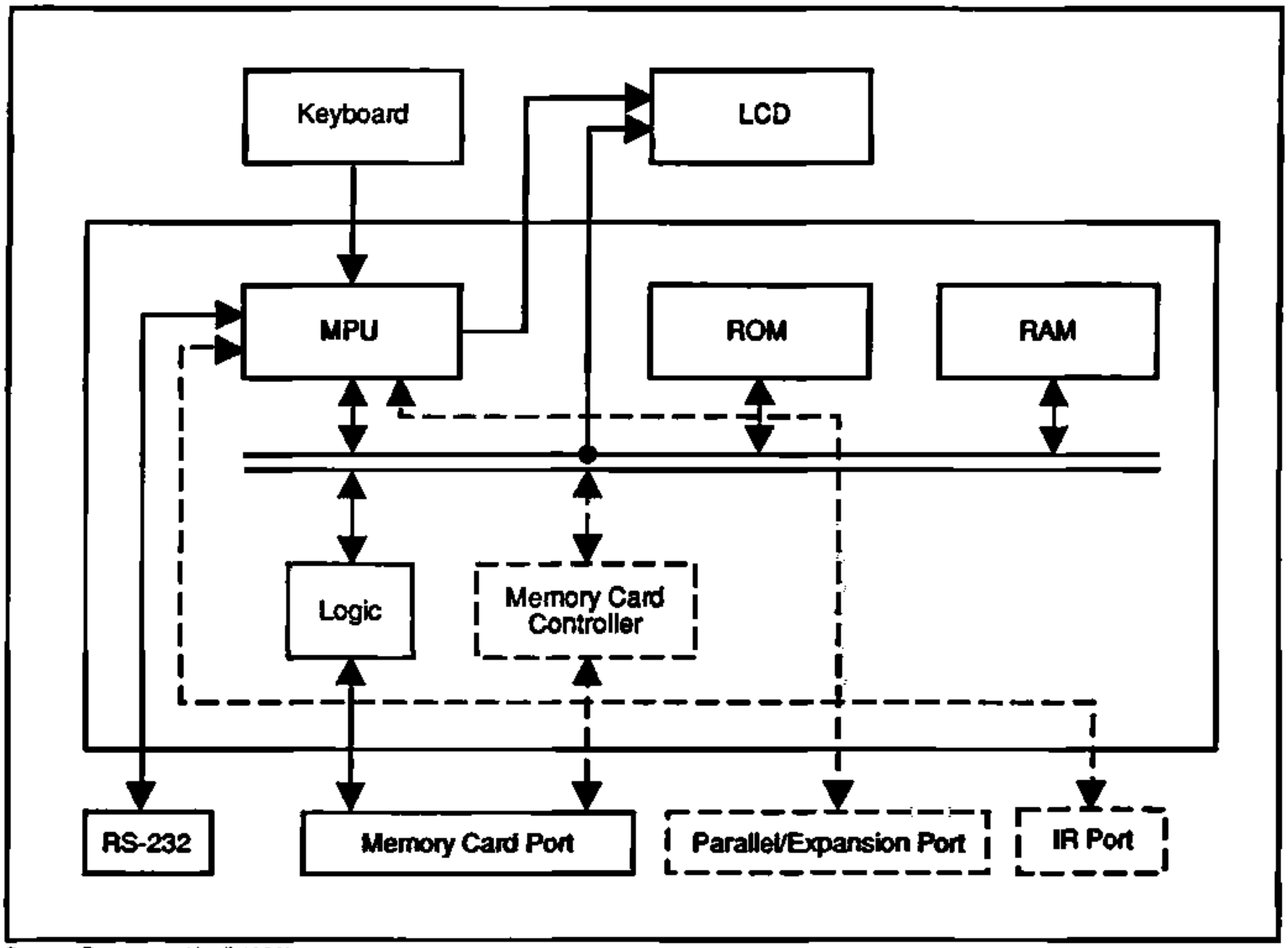
Players in the hand-held PC market, along with their status, are as follows:

- HP—In its second generation of product, HP 95LX 1MB.
- Poqet—In its second generation of product, Poqet PC.
- Sharp—About to enter the hand-held PC market with its PC-3000. Has participated in

the organizer market with its Wizard product line.

- Casio—So far has offered a series of organizers (B.O.S.S. product line).
- Atari—Offers the Atari Portfolio. Sold close to 100,000 units in 1991.
- Sony—At present offers a line of hand-held PCs for the Japanese market that run a proprietary OS and accept pen input.
- PSION—Has offered a product that is similar to HP's 95LX but is based on a proprietary OS.

Figure 1
Hand-Held PC—Block Diagram



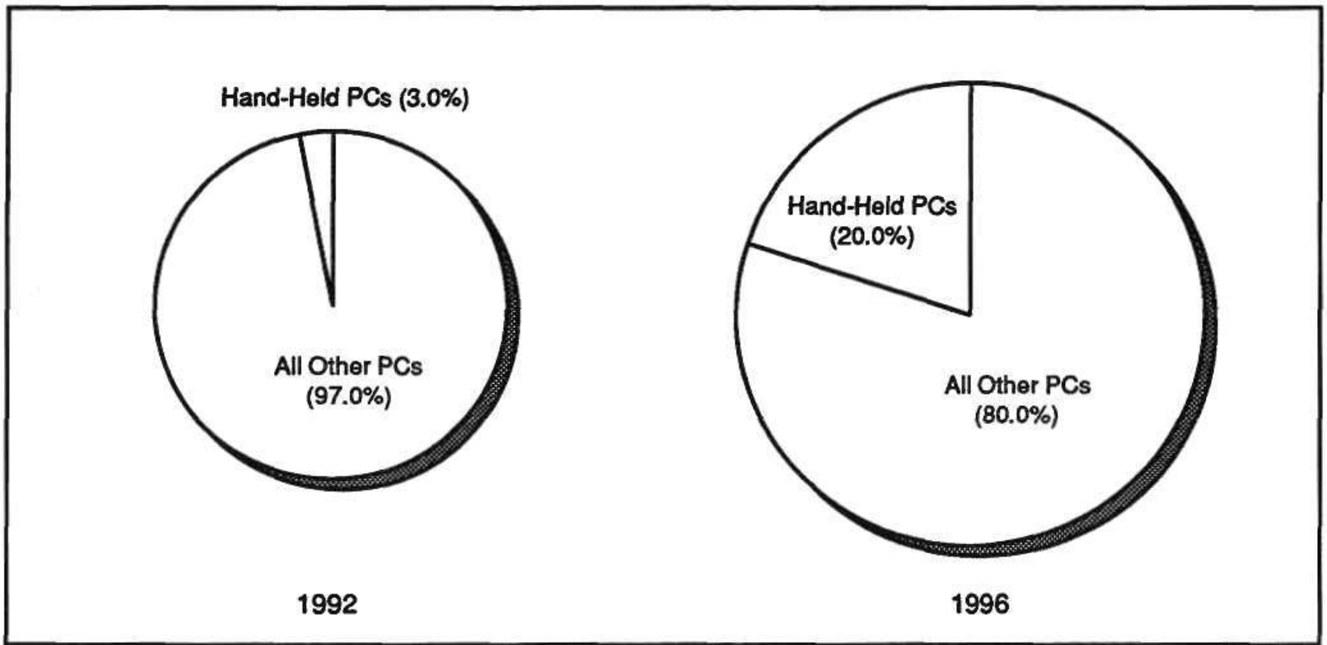
Source: Dataquest (April 1992) G2000099

Table 1
Estimated Total Available Market, Worldwide Hand-Held PCs

	1992	1996	CAGR (%) 1992-1996
Units (K)	801	9,215	84.2
ASP ($)	330	280	-4.0
Semiconductor Content ($)	56	38	-9.2
Semiconductor TAM ($M)	44.8	350.2	67.2

Source: Dataquest (April 1992)

Figure 2
Worldwide Hand-Held PC Market Forecast



Source: Dataquest (April 1992) G2000100

Semiconductor Opportunities and Trends

Opportunities and trends for semiconductors are described in the following paragraphs.

MPU

Because both space and power come at a premium, MPUs that integrate most if not all the functions needed to build a hand-held PC are now appearing to fill the gap. Figures 3, 4, and 5 are typical implementations. As high integration is achieved, board space and cost will be freed for other functions such as speech and handwriting recognition, and IR and RF communications capabilities. MPU speeds will increase, primarily driven by handwriting recognition, algorithmic demands, data compression speech processing, and communications needs.

Main Memory

Today 1MB of SRAM/PSRAM (pseudo RAM) is typically used. PSRAM is preferred for cost reasons. Two 4MB, 3/5V devices do the job. If the execute-in-place (XIP) function is successfully implemented, then main memory may increase marginally to 2MB. Flash will be used in the future because of nonvolatility and low power consumption; most likely it will replace at least a part or all SRAM/PSRAM.

ROM

The 1MB typically used today most likely will be replaced by flash in the near future. In this area hand-held PCs store their operating system (for example, DOS) and programs such as Lotus 1-2-3 and PIMs. The problem with ROM is that it cannot be changed and thus the hand-held PC may be rendered obsolete in a short period. Flash memory is far more appropriate for this function. The expected memory size is 2MB to 4MB in the near term, increasing to 10MB by the end of the decade.

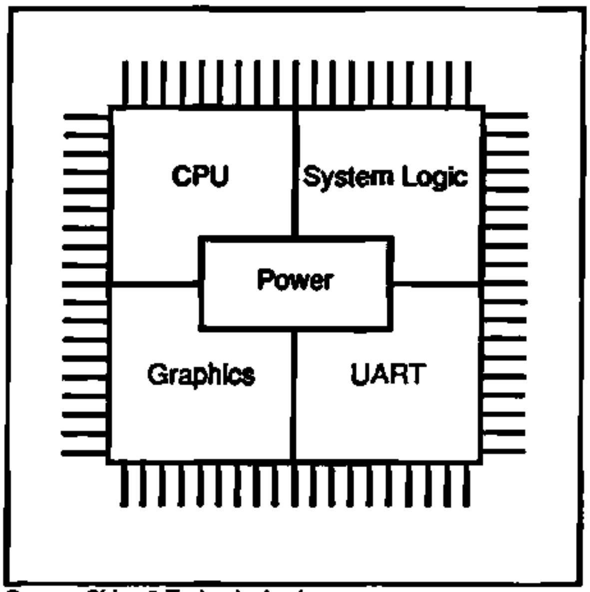
Mass Storage

Solid-state disks using flash memory with capacities on the order of 2MB to 5MB should be used in the near term; 10MB to 40MB should be used by 1995. Small densities should not be underestimated; by using software compression their size could be more than doubled, thus decreasing their apparent cost.

Data Compression

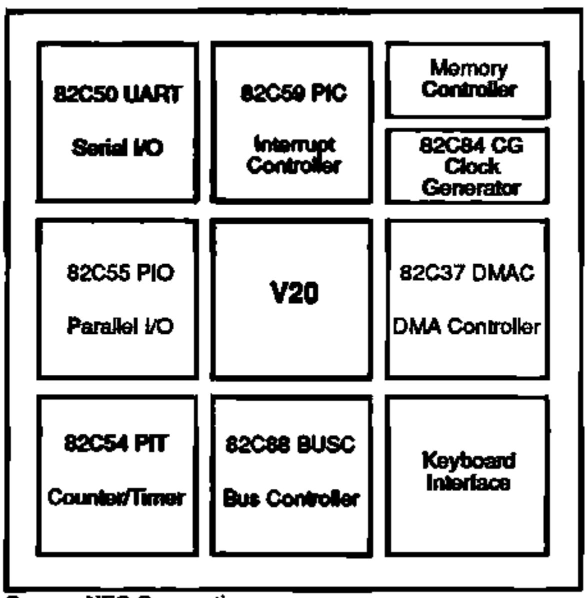
This function begs for eventual implementation in silicon, perhaps as part of a chip set at first, eventually to be integrated in the core MPU. Data compression is needed to offset the high cost of silicon-based memory used for mass storage.

Figure 3
Block Diagram of the Chips and Technologies F8680 (PC/CHIP)



Source: Chips & Technologies Inc. G2000101

Figure 4
Block Diagram of the NEC LH72001



Source: NEC Corporation G2000102

Other Storage

Hand-held PCs will incorporate one or two PCMCIA-type ports supporting XIP. Flash and SRAM memory cards will be used as secondary storage devices. ROM memory cards will carry application software. Programming flash memory cards will become easy with the introduction of single-supply 5V devices now, and 3V in the future.

Connectivity

Connectivity is a key issue with devices such as hand-helds that tend to depend on the uploading and downloading of data to and from a desktop PC. Beyond the RS-232 type connections, infrared such as the one used by HP seems to be a very good alternative. An infrared connection with the desktop may simplify the chore of transferring data and programs between a desktop and the hand-held. In the long run, with PCMCIA ports finding their way into desktops and notebooks, the memory card will be used to transfer data between hand-held and desktop PCs.

Communication

The HP 95LX hand-held can mate with the NewsStream receiver from Motorola. It allows the user to receive e-mail over national, regional, or local paging services. Most products offer built-in terminal emulation software that allows the hand-held to be tied up to a network such as CompuServe by using a modem. Modem and or wired/wireless fax capabilities may be integrated into hand-held PCs in the near future.

Who Makes Microprocessors for Hand-Held PCs?

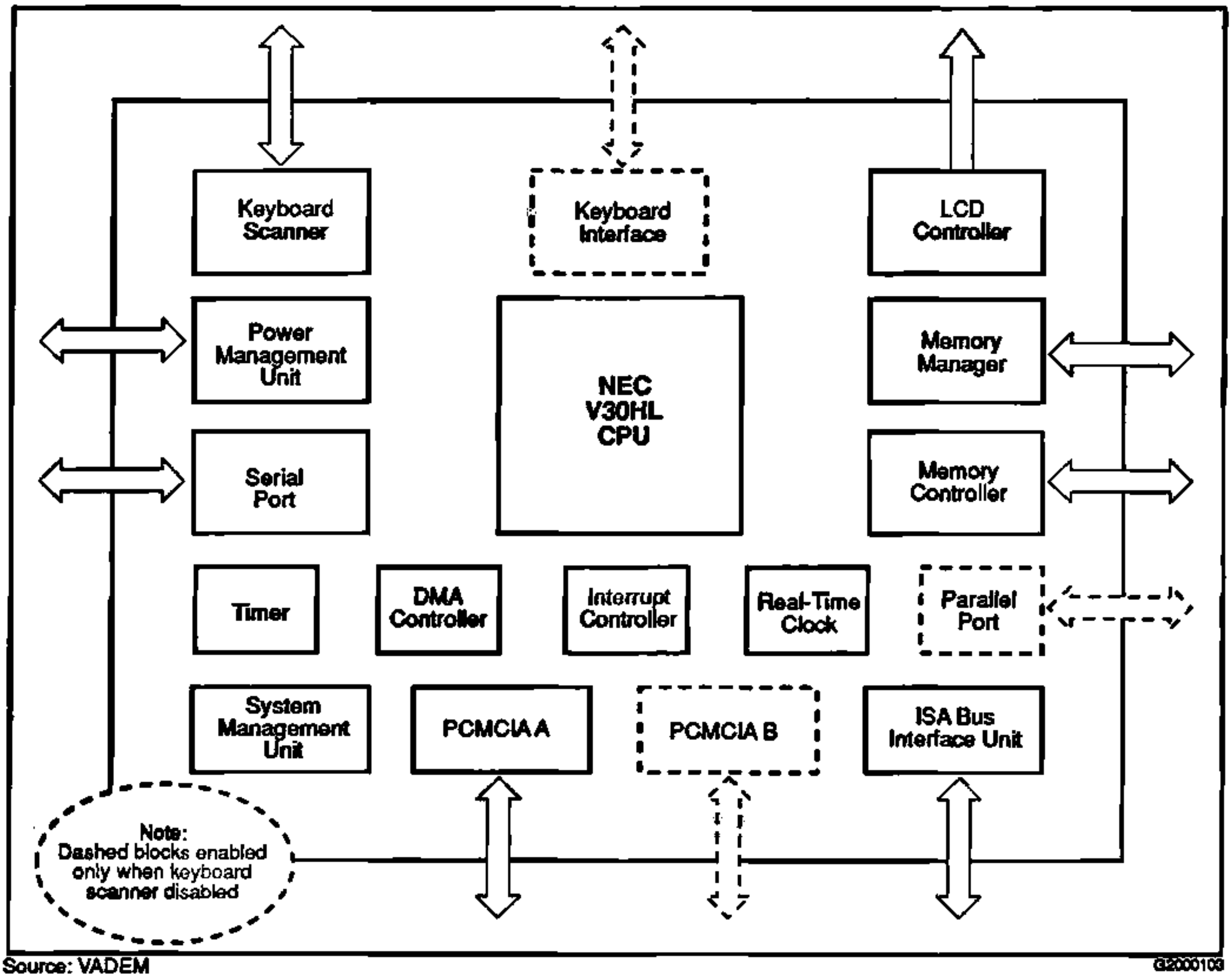
The NEC V20 MPU is used by the HP95LX, the Poqet, and the Sharp Wizard series of products. It is by and large the microprocessor most commonly used in these IBM-compatible PCs.

A number of newcomer single-chip MPUs are poised to challenge this MPU. C&T introduced a single-chip highly integrated MPU, the F8680 (PC/CHIP), which also includes power management logic, a CGA-compatible LCD controller, a serial port, and IBM XT-compatible bus logic.

Newcomer VADEM will shortly introduce the VG-230, a device that incorporates the V30 MPU, a power management unit, serial port, timer, DMA and interrupt controllers, real-time clock, memory controller and manager, graphics LCD controller, and keyboard scanner.

Motorola is about to offer a highly integrated MCU, the LSC80018, to a small consortium of

Figure 5
Block Diagram of the VADEM VG-230



Source: VADEM G2000103

companies with the common goal of promoting a hand-held variant called PocSec for the Pocket Secretary. The LSC80018 features an 8-bit MCU that incorporates a graphics LCD controller, a real-time clock, an SPI, SCI, 3.5K of ROM, 448 bytes of RAM, and an 8MB MMU.

IC Peripherals for Hand-Held PCs

Table 2 lists memory card controller ICs, and Table 3 compares three hand-held computers. The Poqet has been around the longest. HP has been very well received, with sales on the order of 100,000 units for 1991. The Sharp PC-3000 is about to enter the market.

Dataquest Perspective

The need for portability must be balanced with the usefulness of a hand-held PC, which, depending on implementation, may be portable but not useful. A nagging problem in today's hand-held PCs is the human interface. A small hand-held with a tiny keyboard can fit in a pocket. Unfortunately, even the smallest amount of typing using such a keyboard becomes a chore. That makes the hand-held effectively an organizer that can be connected to a desktop PC.

On the other hand, if the minimum useful size keyboard (such as the Poqet/Sharp PC-3000) is used, the hand-held cannot fit in a pocket and its usefulness is again reduced. The solution

Table 2
Memory Card Controller ICs

Intel	82365SL	Memory card controller	160-pin QFP
VLSI	VL82C107	Includes memory card Control function	128-pin QFP
Fujitsu	MB86301	Memory card controller	120-pin PQFP

Source: Dataquest (April 1992)

Table 3
Hand-Held PC Features

	HP95L × 1MB	Sharp PC-3000	Poqet
Size (Inches)	6.3 × 3.4 × 1.0	8.8 × 4.4 × 1.0	8.8 × 4.3 × 1.0
Weight	11 oz	1.23 lbs.	1.2 lbs
CPU/Speed	V20H at 5.37 MHz	80C88 at 10 MHz	80C88 at 7 MHz
System Memory	1MB SRAM 1MB ROM	1MB SRAM 1MB ROM	640KB SRAM 768KB ROM
Keyboard	60 + 10 FN + 10 Apps	77 + 12 FN	77 + 10 FN
Display Column/Emulation	40x16—MDA	80x25—CGA/MDA	80x25—CGA/MDA
Display Resolution	240 × 128	640 × 200	640 × 200
Batteries/Type	Two/AA	Three/AA	Two/AA
Memory Card Slot	1 PCMCIA-1.0	2 PCMCIA-1.0	2 PCMCIA-1.0
O/S	MS-DOS 3.22	MS-DOS 3.3	MS-DOS 3.3
Other Ports	3 wire RS-232 Intra-Red	RS-232C Parallel I/O	RS-232C I/O bus (XT comp)
Opt. Peripherals	NewsStream Receiver	1.44MB 3.5" Floppy	1.44MB 3.5" Floppy
Built-In Software	Lotus 1-2-3 Ver 2.2 Scheduler Address/Phone Book Memo Editor HP Financial Calc DataComm Filer Clock/Stopwatch ToDo list	Lotus compatible Scheduler Address/Phone Book Memo Editor Calculator LapLink File Manager Clock ToDo list	Scheduler Address/Phone Book Memo Editor Calculator File Manager Clock ToDo List

Source: Dataquest (April 1992)

may be a hybrid product such as the HP 95LX where the keyboard keys are enlarged to a size closer to those in the Poqet/Sharp PC-3000 (QWERTY without separate numeric keypad) and where the pen input is allowed to supplement the keyboard. Both Sharp and Sony have demonstrated products that incorporate such a pen-based input device. Even though these are not hand-held PCs that run DOS, they are a step in the right direction. Making such devices PC-compatible is rather simple.

The key to success for hand-helds may be semiconductor devices that allow for a good machine-human interface, which may be handwriting on the LCD screen, voice recognition, or a combination of both, and provide seamless connectivity. If hand-helds succeed in being easy to use, then their unit volume potential will exceed our expectations.

By Nicolas Samaras

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q: What is the forecast for the worldwide plain paper copier market?

A: The worldwide copier market, on a unit basis, is predicted to grow at compound annual growth rate of 4.6 percent through 1995, with Europe becoming the largest market and Rest of World (mainly Pacific Rim) the fastest-growing market (see Table 1). Canon, Xerox, Sharp, Mita, and Konica in rank order are the largest suppliers to North America.

Table 1
Worldwide Copier Placements (Thousands of Units)

	1990	1995	CAGR (%) 1990-1995
North America	1,322	1,433	1.6
Europe	1,291	1,693	5.6
Japan	731	904	4.3
Rest of World	545	840	9.0
Total	3,889	4,870	4.6

Source: Dataquest (April 1992)

Q: What is the disposition of the color copier market?

A: Just about all the major copier manufacturers have entered the market or are about to. The 1995 world color copier market is projected to be 90,000 units. Canon and Savin are the largest players in North America.

Q: What is the size of the PC graphics chip set market?

A: Dataquest estimates the worldwide merchant market to be 19.8 million units at an ASP of $20.50. More than 95 percent of the market is for VGA applications.

Q: What is Dataquest's 1991 market share ranking for PC suppliers?

A: Table 2 shows our rankings.

In Future Issues

The following topics will be addressed in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in personal communication
- Inquiry summary

Table 2
Top PC Companies Worldwide—Preliminary Estimates

			K Units			Market Share		
1991 Rank	1990 Rank	Vendor	1990	1991	Percent Growth	1990 (%)	1991 (%)	Percent Change
1	1	IBM	2,842	2,684	-5.6	11.8	10.7	-1.1
2	2	Apple	1,788	2.261	26.4	7.5	9.0	1.6
3	3	Commodore	1,695	2,100	23.9	7.1	8.4	1.3
4	4	NEC	1,343	1,412	5.2	5.6	5.6	0
5	5	Compaq	939	998	6.3	3.9	4.0	0.1
6	10	Packard Bell	575	683	18.9	2.4	2.7	0.3
7	8	Tandy	634	676	6.6	2.6	2.7	0.1
8	7	Atari	734	590	-19.6	3.1	2.4	-0.7
9	6	Toshiba	882	552	-37.4	3.7	2.2	-1.5
10	12	Zenith	440	469	6.6	1.8	1.9	0.1
11	11	Olivetti	454	467	2.8	1.9	1.9	0
12	14	AST	274	399	45.5	1.1	1.6	0.5
		Total	23,993	25,019	4.3			

Source: Dataquest (April 1992)

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9203 March 23, 1992

In This Issue...

Market Analysis

Optical Storage: Is Multimedia the Driver?

The optical disk drive (ODD) is a rotating mass storage device. One familiar form of an optical storage device is the compact disc (CD) player. The CD stores audio information (analog signals) in a digital format by means of a process known as analog-to-digital conversion. The process is reversed during playback and the original audio information is reconstructed by means of a digital-to-analog conversion.

The CD player, which uses a laser to pick up the information stored on the CD, was developed by NV Philips to replace record players. By most standards the CD technology has been extremely successful and has essentially eliminated records and record players. That success helped the development of ODDs that work in the digital domain, that is, those that store and retrieve only digital information. As a result the ODD found its way into computer mass storage. However, it should be noted that ODDs do not compete directly with hard disks as the primary mass storage devices for computers because of a number of limitations.

Terminology

Terminology used in the optical storage industry is as follows:

- Compact Disc-Interactive (CD-I): A CD format (developed by NV Philips and Sony Corporation) that provides audio, digital data, still graphics, and limited video.
- Compact Disc Read-Only Memory (CD-ROM). A 4.75-inch laser-encoded optical memory storage medium (developed by NV Philips and Sony Corporation) with the same constant linear velocity (CLV) spiral format as compact audio disks and some videodisks. CD-ROMs can hold about 550MB of data.

- Compact Disc Read-Only Memory extended architecture (CD-ROM XA). An extension of the CD-ROM standard billed as a hybrid of CD-ROM and CD-I, and promoted by Sony and Microsoft. The extension adds adaptive differential pulse code modulation audio to permit the interleaving of sound and video data to animation and sound synchronization. It is an essential component of Microsoft's plan for multimedia computers.

Types of ODDs

There are three basic types of ODDs: the CD-ROM, which is an outgrowth of the CD; the write-once/read-many (WORM) drive; and the magneto-optical (MO) drive.

Optical drives are increasingly driven by multimedia and consumer applications.

The MO is the only type that behaves similarly to a hard disk drive in that it allows the user to rewrite data. The WORM allows the recording of data once, and as a result can be regarded as an archival device. The CD-ROM is the least flexible in that, as with the CD, information is permanently stored (recorded) during manufacturing onto a disk and cannot be altered.

CD-ROM

The CD-ROM is the most common type of ODD and can store an impressive amount of data—550MB—in a single inexpensive and removable disk. As a result it is used as an archival medium to store text and/or images. It is also used for software distribution (especially operating system and application programs for workstations), and has been embraced by multimedia systems such as DVI from Intel Corporation and CD-I. DVI supports interactive full motion video and audio using add-in boards in personal computers. On the other hand, NV Philips-supported CD-I is a standalone system aimed at home entertainment.

The development of multimedia, with its educational and training uses, may further propel sales of CD-ROMs.

A new and potentially very promising application is that of Photo CD, a joint development effort between The Eastman Kodak Company and NV Philips, in which images from photographic film professionally recorded onto a CD-ROM can be played back on any CD-ROM XA drive. The pictures can then be viewed using any TV connected to the CD-ROM XA drive. The images are stored in a compressed form so that a single disk can hold up to 100 images that retain the original film resolution. Each compressed picture from a 35mm negative can be stored in a 3MB to 6MB file.

WORM

There are two varieties of WORM optical drives, the older 12-inch form factor and the newer 5.25-inch version. The 5.25-inch WORM drives lack interchange standards and are expensive and therefore not appropriate for personal computer use. The 12-inch WORM drives are used primarily in minicomputer environments.

Magneto-Optical

There are at least three varieties of MO drives: 5.25-inch, 3.25-inch, and the recently introduced 2.5-inch form factor. The 5.25-inch drives can store up to 1GB of data on a single disk. By comparison the 3.25-inch can store 128MB and the 2.5-inch (from JVC) can store 42MB. MO drives are used in applications where large amounts of data need to be stored (but need not be updated/rewritten very often), such as large image databases for engineering workstations. They also are used in workstation environments to replace tape for archival purposes. Like WORM, MO drives are not widely used in the PC environment, primarily for cost reasons.

Forces Driving the Market

The ODD market is driven primarily by the very high capacity requirements of image storage and online databases. Multimedia is expected to add its weight as a driving force behind the ODD market development in the near future.

Cost Barriers

ODDs are relative newcomers to computer mass storage. As a result they are still expensive. One exception is the CD-ROM, which is finding increasing use with online information services in office, library, and home environments. Current retail CD-ROM drive prices are equivalent to those of 120MB hard disk drives. CD-ROMs are increasingly becoming PC peripherals. On the other hand, WORM and rewritable drives are not part of the mainstream PC industry and are limited to archival tasks and as backup and image file storage devices for file servers, workstations, and larger computer installations. It should also be noted that the cost of rewritable media is relatively high.

ODD Forecast

The worldwide forecast discussed in the following paragraphs has been provided by Dataquest's Computer Storage group.

CD-ROM drives will dominate unit shipments, growing from 360,000 units in 1991 to more than 3.1 million by 1995 (see Table 1). The 134 percent compound annual growth rate (CAGR) for 3.5-inch (MO) rewritable drives stands out.

Figure 1 is an example of a leading-edge 3.5-inch magneto ODD implementation. A 16-bit microprocessor provides the overall drive control in Figure 1. The MPU uses 64KB of flash memory for code storage. As with all ODDs, this implementation uses a SCSI controller to provide single-ended SCSI I/O with the host computer. This function may become embedded in the near future.

Some high-end drives already use SCSI-II; the migration toward SCSI-II should continue as needs for higher data throughput intensify. An Optical Disk Controller chip set is used in the "data-path." The chip set directly interfaces to 64KB of DRAM, used as buffer memory.

Current implementations use between 64KB and 1MB of buffer memory; the size of the memory buffer is expected to grow as data transfer rates increase. Optical media exhibit much higher error rates (10^{12}) than do magnetic media (10^{6}). This in essence necessitates the use of a hardware error detection and correction scheme, using devices such as AMD's AM95C94 Advanced Burst Error Processor (ABEP). Software error detection/correction is too slow; optical media often produce bursts of errors many bytes long. The head positioning electronics uses a digital signal processor (DSP) for servo control of the laser. The trend toward DSP for head positioning control is a natural carryover from experience gathered from hard disk drive design.

The overall semiconductor content of an optical drive currently represents 20 to 25 percent of the factory average selling price (ASP). This figure is expected to come down to 15 to 20 percent as volumes increase and the disk drive electronics go through at least two stages of inevitable integration.

Opportunities for Semiconductor Vendors

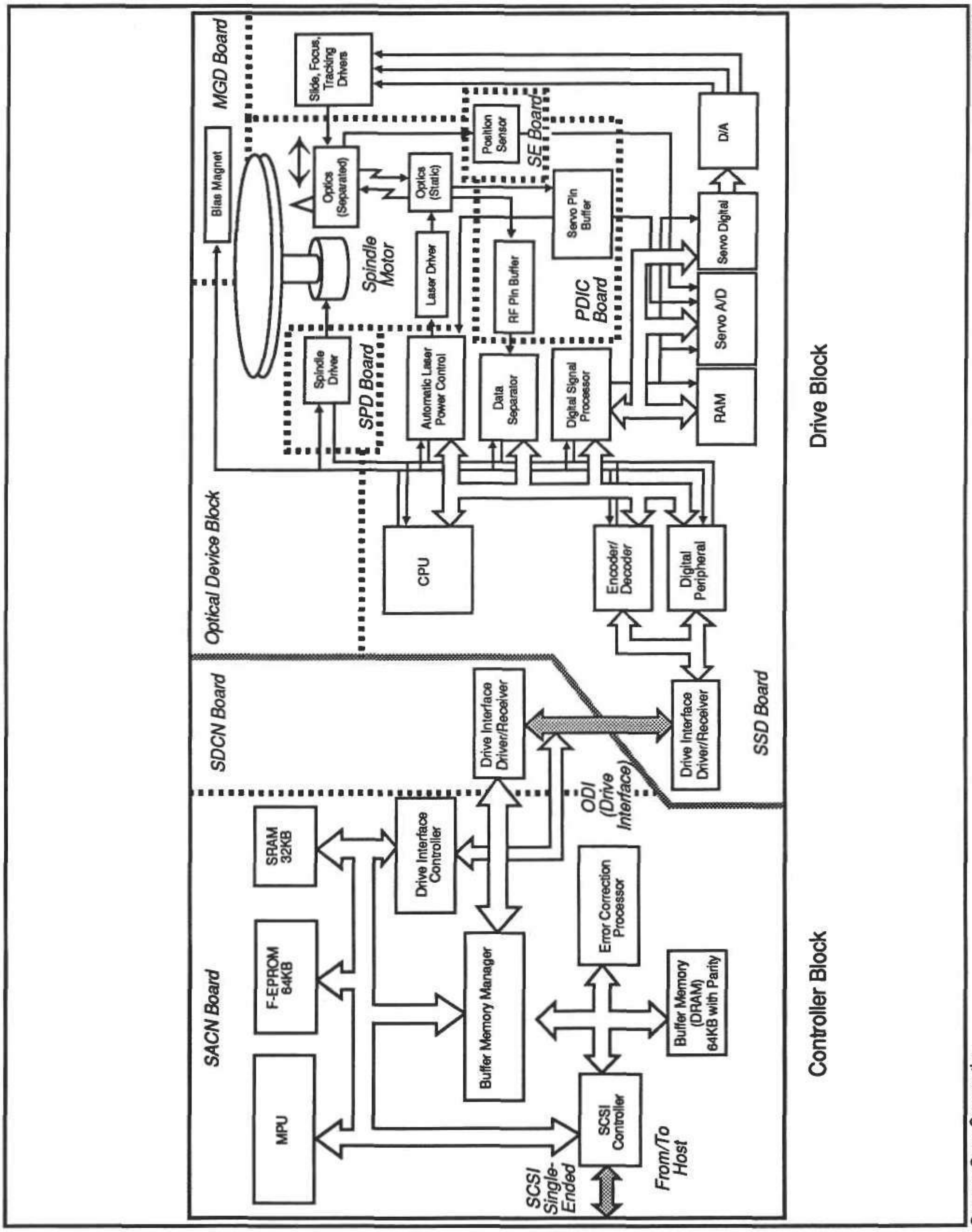
Table 2 is the worldwide optical drive forecast by drive type, drive factory ASP, estimated semiconductor content for the particular drive type, and semiconductor total available market (TAM). The CAGR for CD-ROM semiconductor TAM is expected to be 21 percent from 1991 to 1995; the growth is likely to be fueled by multimedia and consumer-related applications. The WORM category shows signs of maturity with single-digit

Table 1
Optical Disk Drive Estimated Wordwide Consumption (Thousands of Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
CD-ROM	360	576	979	1,763	3,173	72.3
5.25-Inch WORM	69	87	108	132	158	23.0
12-Inch WORM	12	15	19	23	27	22.5
3.25-Inch Rewritable	12	48	136	246	360	134.0
5.25-Inch Rewritable	154	274	444	620	866	54.0
Total	607	1,000	1,686	2,784	4,584	65.8

Source: Dataquest (March 1992)

Figure 1
Control Electronics Block Diagram, 3.5-inch MO Drive



Source: Sony Corporation

Table 2
Worldwide Optical Drives

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
CD-ROM (K Units)	360	576	979	1,763	3,173	72.3
Factory ASP ($)	207	145	102	80	68	-24.3
Semiconductor Content ($)	49	33	22	16	12	-29.7
Semiconductor TAM ($K)	17,640	19,008	21,538	28,208	38,076	21.2
5.25-Inch WORM (K Units)	69	87	108	132	158	23.0
Factory ASP ($)	1,020	867	780	702	632	-11.3
Semiconductor Content ($)	244	199	171	147	126	-15.2
Semiconductor TAM ($K)	16,836	17,313	18,468	19,404	19,908	4.3
12-Inch WORM (K Units)	12	15	19	23	27	22.5
Factory ASP ($)	6,480	5,832	5,249	4,724	4,488	-8.8
Semiconductor Content ($)	1,555	1,341	1,154	992	897	-12.9
Semiconductor TAM ($K)	18,660	20,115	21,926	22,816	24,219	6.7
3.25-Inch Rewritable (K Units)	12	48	136	246	360	134.0
Factory ASP ($)	780	642	499	399	319	-20.0
Semiconductor Content ($)	187	147	109	83	63	-23.8
Semiconductor TAM ($K)	2,244	7,056	14,824	20,418	22,680	78.3
5.25-Inch Rewritable (K Units)	154	274	444	620	866	54.0
Factory ASP ($)	1,600	1,280	1,024	819	655	-20.0
Semiconductor Content ($)	384	294	225	171	131	-23.6
Semiconductor TAM ($K)	59,136	80,556	99,900	106,020	113,446	17.7
Optical Disk Drive Semiconductor TAM ($K)	114,516	144,048	176,656	196,866	218,329	17.5

Source: Dataquest (March 1992)

TAM growth rates. The opportunities for semiconductor vendors are very attractive in the 3.5-inch MO rewritable drives, where the CAGR is 78 percent. Overall the ODD semiconductor TAM is on the order of $114 million in 1991 and is expected to reach $218 million by 1995, a CAGR of 17.5 percent.

Table 3 lists the major players participating in the optical disk drive market. The market share estimates are preliminary.

It should be noted that it is often difficult to anticipate the success and rate of acceptance of consumer products such as the CD-ROM. As a result this segment of the forecast may prove to be conservative at the fringes of the forecasting period.

Dataquest Perspective

ODDs do not compete directly with hard disks for computer mass storage. The CD-ROM, for example, is in reality a quasipublishing medium, not a storage peripheral. Optical drives are increasingly driven by multimedia and consumer applications. As the PC-to-user interface becomes more dependent on images (which require far more space than hard disks can provide), reliance on optical storage will increase. As standards inevitably evolve and prices for small form factor drives fall, we should see the development of a significant market for both drive makers and semiconductor vendors.

By Nicolas Samaras

Table 3
Major Players and Preliminary 1991 Market Share

CD-ROM	(%)	WORM 5.25-Inch	(%)	WORM 12-Inch	(%)	Rewriteable 5.25-Inch	(%)
Sony	40	Panasonic	38	LMSI	32	Sony	48
Hitachi	20	Pioneer	18	Sony	30	Ricoh	19
NEC	11	Ricoh	18	Hitachi	20	Panasonic	13
Toshiba	10	ISi	10	Toshiba	10	Maxoptix	8
Panasonic	6					Canon	6
LMSI	6						
Chinon	4						
Pioneer	2						
Others	1		15		8		6

Source: Dataquest (March 1992)

Semiconductor Opportunities in the Fax/Modem Market

In this article, Dataquest examines key semiconductor applications market and design trends in the fax/modem market, with an emphasis on the high-growth PC/workstation fax/modem functionality application. We also discuss a forecast model for worldwide revenue and unit shipments for fax/modem semiconductors, based on fax and modem system shipment trends.

Worldwide Semiconductor Forecast for Fax/Modem Applications

Table 1 shows Dataquest's worldwide revenue and production units market estimates for standalone fax systems, standalone modem systems, and PC/workstation fax function units. Along with Figure 1, Table 1 shows the derived worldwide total available market (TAM) semiconductor opportunity for applications in standalone fax systems, standalone modem systems, and PC/workstation fax/modems.

Standalone G-3 and G-4 Fax Systems Market

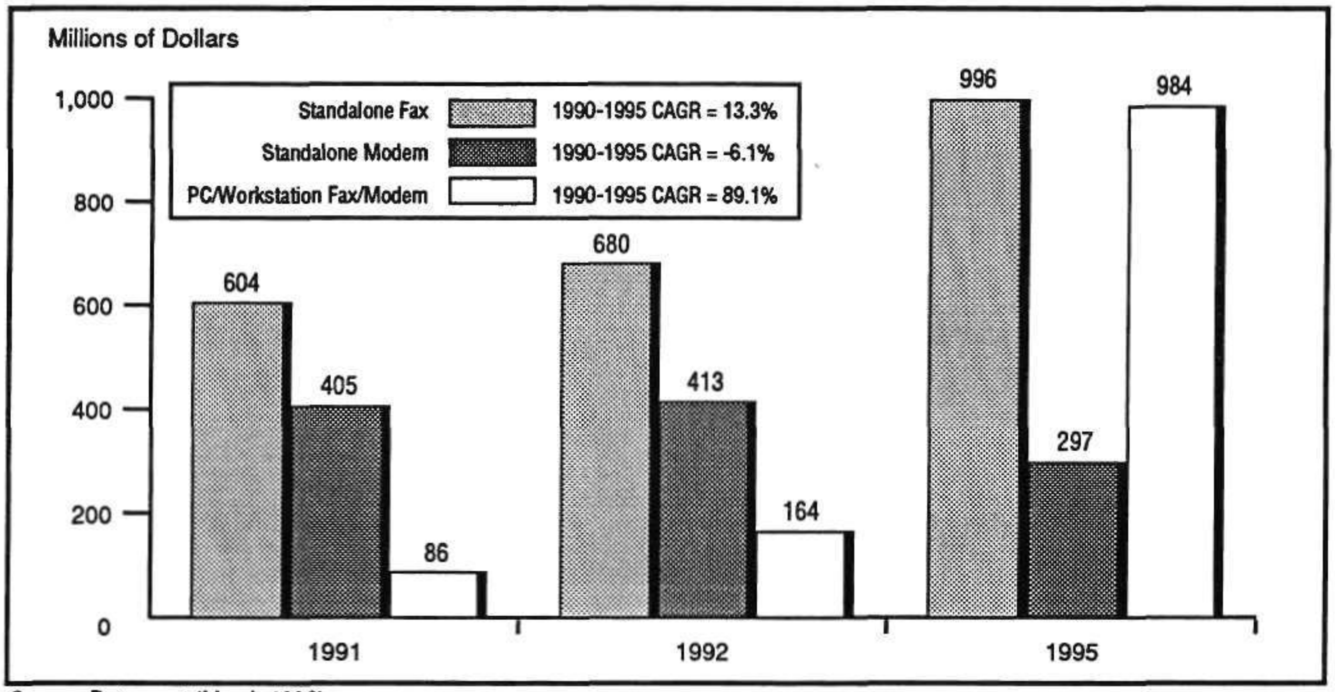
The worldwide standalone Group-3 and Group-4 fax systems market is expected to continue healthy growth, with a compound annual growth rate (CAGR) of 8.4 percent from $6 billion in 1990 to $9 billion by 1995. The associated worldwide semiconductor TAM for standalone fax systems is expected to increase at a healthy 13.3 percent CAGR

Table 1
Worldwide Fax/Modem Applications Market Forecast

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
G-3, -4 Fax Systems Revenue ($M)	6,000	6,500	6,900	7,600	8,300	9,000	8.4
Units (Millions)	6.61	8.05	9.72	12.09	14.79	17.53	21.6
ASP ($)	908	807	710	629	561	513	-10.8
Semiconductor TAM ($M)	533	604	680	787	899	996	13.3
Modem Systems Revenue ($M)	3,200	3,040	2,888	2,744	2,606	2,476	-5.0
Units (Millions)	11.64	13.51	16.50	18.29	20.85	24.76	16.3
ASP ($)	275	225	175	150	125	100	-18.3
Semiconductor TAM ($M)	407	405	413	366	313	297	-6.1
World PC/Workstation Unit Shipments (Millions)	24.39	26.85	30.14	34.89	41.15	48.8	14.9
% Equipped with Fax/Modem Capability	1	3	8	15	25	40	109.1
PC/Workstation fax/modem OEM Units forecast	0.24	0.81	2.41	5.23	10.29	19.52	140.2
Semiconductor Content/Unit ($)	50	45	41	36	33	30	-10.0
PC/Workstation OEM Fax/Modem Semiconductor TAM ($M)	12	36	98	191	337	576	116.2
World PC Units Installed Base (Millions)	114.08	136.96	163.18	194.426	1,231.97	276.28	19.4
Installed Base % Penetration with PC Fax/Modem Add-In Cards	0.5	0.8	1.0	1.5	3.0	5.0	58.5
PC Fax/Modem Add-In Card Units Market (Millions)	0.57	1.10	1.63	2.92	6.96	13.81	89.2
PC Add-In Fax/Modem Semiconductor TAM ($M)	29	49	66	106	228	408	70.2
Total PC/Workstation Fax/Modem Semiconductor TAM ($M)	41	86	164	297	566	984	89.1

Source: Dataquest (March 1992)

Figure 1
Worldwide Fax/Modem Semiconductor Market



Source: Dataquest (March 1992)

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from $533 million in 1990 to $996 million by 1995. G-3 fax systems will comprise more than 98 percent of the total system units shipped each year through 1995.

Integrated Services Digital Network (ISDN)-based G-4 digital fax systems will begin to penetrate the market in significant volumes only beyond 1995. Improvement in G-3 fax speeds to 14,400 bits per second (bps), together with enhanced error detection/correction codes and image algorithms, is expected to prolong the life cycles of G-3 fax systems. The slow investment pattern in ISDN infrastructure and the lack of low-priced ISDN end-user terminal equipment will continue to constrain the growth of G-4 fax systems. Beyond 1995, photographic quality full-color document and still-image transmission requirements are expected to drive healthy growth in ISDN-related G-4 fax systems.

Standalone Modem Systems Market

The worldwide standalone modem systems market is expected to decline in revenue at 5 percent CAGR from $3.2 billion in 1990 to $2.5 billion by 1995. The associated worldwide semiconductor TAM for standalone modem systems is expected to decline at 6 percent CAGR from $407 million in 1990 to $297 million by 1995. The rapid growth of private LANs and wide-area networks (WANs) for enterprisewide distributed computing has had a significant adverse impact on the growth of the standalone modem market. The evolution of the bridge/router LAN/WAN market, together with its mushrooming switched public high-speed, high-bandwidth interfaces such as SONET, frame-relay, and SMDS, has continued to constrain the growth of the private enterprisewide standalone modem market.

The V.22bis and V.32 modem market segments represent the only two significant growth segments for modem unit shipments in North America. Other segments such as 212A protocol modems and 9.6-Kbps dial-up modems are expected to show substantial declines in unit shipments over the next five years.

PC and Workstation Fax/Modem Market

The PC/workstation fax/modem semiconductor applications market represents by far the largest growth opportunity for semiconductor vendors. Growth in this market is driven basically by ease of use, cost, quality, and user convenience and privacy issues. Companies such as Phoenix Technologies are now offering complete OEM fax/modem design solutions for PC manufacturers to provide cost-effective, value-added functionality.

The advent of Personal Computer Memory Card International Association (PCMCIA) smart card technology will enable the development of a substantial aftermarket for fax/modem expansion capabilities to the portable computing market. Semiconductor companies such as Intel are offering solutions at every level, ranging from OEM modem/fax add-in board and chip set products through shrink-wrapped PCMCIA modem/fax card solutions distributed through mass-merchandising channels to the high-growth aftermarket.

Dataquest estimates that only 1 percent of the worldwide PC/workstation unit shipments in 1990 were equipped with fax/modem functionality. However, we forecast that almost 40 percent of PC/workstation unit shipments will be equipped with fax/modem functionality by 1995. Traditional PC users who bought modem-only capabilities for accessing remote data are rapidly converting to add-in fax/modem entry-level cards that offer convenient functionality. We forecast the worldwide semiconductor TAM opportunity for PC/workstation integrated fax/modem functionality to grow at a phenomenal 89 percent CAGR from $41 million in 1990 to $984 million by 1995. In addition to the forecast assumption that 40 percent of the new PC/workstation unit shipments by 1995 will have built-in fax/modem capability, we also make a conservative assumption that the add-in PC fax card market will penetrate 5 percent of the worldwide installed PC base by 1995.

Table 2
Key Fax/Modem System, Boards/Add-In Cards, Semiconductor Companies

Standalone Fax	Standalone Modem	Fax/Modem Boards PC Add-In Cards	Fax/Modem Cards Chip Sets
Sharp	Codex	Intel	Intel
Murata	Racal-Milgo	US Robotics	Yamaha
Canon	UDS	Everex	Cirrus Logic
Ricoh	Hayes	OmniTel	Rockwell
Panasonic	IBM	AT&T/Paradyne	National
Toshiba	AT&T/Paradyne	Racal-Milgo	Sierra
Xerox	GDC	Codex	AT&T
NEC	US Robotics	Cardinal	Phylon
Pitney Bowes	Telebit	Rockwell	Motorola
Fujitsu	Multi-Tech	SGS-Tomson	AMD
Siemens	NEC	Yamaha	Siemens
	Fujitsu	Cardinal	NEC
	Siemens	Ven-Tel	Toshiba
	Intel		Fujitsu
	MicroCom		
	OmniTel		
	Data Race		
	Cardinal		
	Rockwell		

Source: Dataquest (March 1992)

Design Trends in Fax/Modem Systems, Boards, and Chip Sets

Table 2 lists key OEM fax/modem systems, board/add-in card, and semiconductor companies that participate in the fax/modem market. The high-volume single-user implementation of fax/modem functions is rapidly migrating to highly integrated chip set solutions. Hence, the standalone fax/modem system market is relatively flat while the PC add-in fax/modem card and motherboard fax/modem chip set market is expanding rapidly. Some major fax/modem design trends include the following:

- There is a trend toward feature-rich multimedia-oriented solutions that seamlessly integrate voice, data, and image communication. Digital signal processor (DSP) semiconductor companies such as Analog Devices, AT&T Microelectronics, DSP Group, and Texas Instruments are developing versatile, shrink-wrapped solutions that bundle together DSP silicon, firmware, applications drivers, and upgradable user functions such as fax, modem, voice mail, and still/moving image compression and transmission.

  The ultimate goal is to integrate such general-purpose DSP silicon as value-added functionality on PC/workstation motherboards. The user can access fax, modem, voice mail, and image communications functions within applications programs. A common serial interface add-in card provides the remaining fax/modem/voice analog line interface in the appropriate serial protocol.

- There is a trend toward highly-integrated fax/modem chip set solutions implemented in submicron mixed-signal technnology, 3.5V low-power, small form-factor packages for portable PC applications. Typical fax/modem chip sets offer 2,400-bps modem and 9,600/14,400-bps G-3 fax capabilities, along with limited voice mail features in certain applications. Dataquest expects portable PC fax/modem chip sets to evolve to meet the needs of a new generation of portable communications devices that incorporate wireless radio-frequency modem, fax, cellular telephone, and wireless LAN functionality.

  Entry-level fax/modem PC chip sets are volume-priced in the range of $30 to $50. Increasingly, fax/modem semiconductor companies are offering bundled silicon/software driver packages that provide turnkey solutions to portable PC and add-in modem/fax card vendors. The development of efficient algorithms and firmware is an increasingly complex task that can consume more than 50 percent of engineering development resources.

- Compression technology is playing an increasingly significant role in integrated voice/modem/fax applications. The development of efficient compression algorithms that can be tightly linked to the fax/modem chip set without compromising performance or cost is a key differentiating factor in cost-effective portable PC designs where hard-disk storage capacity can be a constraint. Built-in fax/data/voice auto switches, together with call-protocol detection such as DTMF line signal detection, are desirable design features.

- High bandwidth interface (network transmission speeds of T-3 and above) and Joint Photographic Experts Group/Motion Picture Experts Group (JPEG/MPEG/JBIG) image compression protocol support is being built into midrange and high-end fax/modem semiconductor solutions targeted at client/server distributed computing and enterprise networking applications.

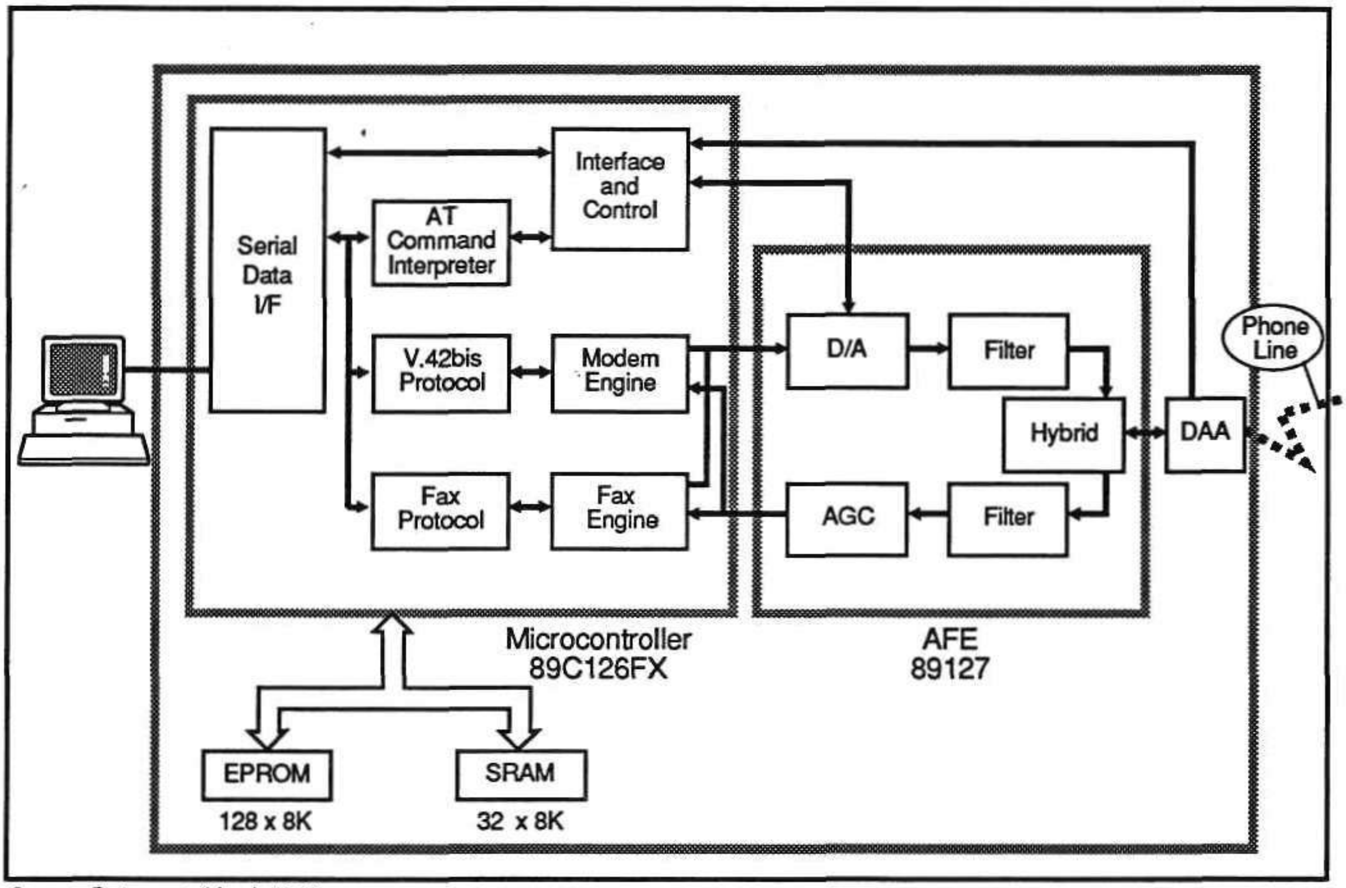
Typical Integrated Fax/Modem PC Application

Intel's 89C124FX chip set illustrates the tightly integrated fax/modem functionality being designed into PCs. Figure 2 shows the key functional blocks in the Intel PC fax/modem application design. The application is capable of 9,600 bps fax with 2,400 bps data modem (V.22, V.22bis). The data modem functionality is enhanced by MNP1-5 and V.42-V.42bis error correction and data compression protocol.

The solution is partitioned into the 89C126FX microcontroller, which executes DSP algorithms for modulation, demodulation, and data formatting. It also performs error correction/data compression as well as AT and EIA/TIA-578 user interface functions. The mixed-signal front end is handled by the 89127 AFE, which provides digital-to-analog conversion, filtering, AGC, two-wire hybrid conversion, and telephone line data access (DAA) interface.

Flexible power-down management control, which is a crucial feature of portable PC

Figure 2
Intel's 89C124FX PC Fax/Modem Solution



Source: Dataquest (March 1992)

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designs, is provided through modes selected by the AT command set. The PC fax/modem chip set solution is bundled together with the Intel/ DCA Communications Applications Specifications (CAS) software driver interface that enables PC users to fax information directly from within industry-standard applications programs.

Dataquest Perspective

The worldwide fax and modem semiconductor applications market represents a silicon-rich, fast-growing opportunity that will more than double in size from $981 million in 1990 to $2.3 billion by 1995. In particular, the PC/ workstation fax/modem functionality market represents a particularly attractive market as users migrate to an untethered, multimedia-oriented communications environment that will emphasize seamless, integrated voice/data/ graphical image networking. Semiconductor companies that can offer well-packaged fax/ modem silicon and software solutions can exploit a fast-growth global semiconductor market segment that will hit $984 million by 1995.

By Krishna Shankar

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q. What are the key trends, sizes, and players in the North American cable TV industry?

A. Table 1 provides Dataquest's analysis of the cable TV market in North America.

The key OEMs are General Instrument, Scientific Atlanta, Zenith Cable, Oak Communications, Pico Macom, T E Products, Digital Sound, Eidak, Macrovision, Electroline, and Pioneer Communication.

The key trends are as follows:

- VideoCipher II (GI) descrambling is a de facto industry standard, and GI proposes VideoCipher II Plus. There also is a pending lawsuit regarding scrambling.
- Outside mounted boxes; addressable; integrated receiver; compression for video on demand.

The industry drivers are as follows:

- 35 is moving to 100-channel capability for video-on-demand.
- Audio "Title" on demand, and voice services

Q: In what environments are Redundant Arrays of Independent Disks (RAIDs) used?

A: RAIDs are used in supercomputers, technical and business computers, and in the PC LAN server environment.

Q: Who are the leading suppliers, by environment?

A: The leaders are as follows:

- Supercomputers: IBM, Fujitsu, Maximum Strategy, and Thinking Machines
- Technical computers: Auspex, Ciprico, and Storage Concepts
- Business computers: Acer/Altos, Array Technology, Control Data, Data General, NCR, SF2, Storage Computer, and Storage Tek
- PC LAN Servers: ALR, Compaq, CORE International, DELL, NCR, and Storage Concepts

Q: What is the worldwide forecast for the various segments of the LAN/fiber-distributed data interface (FDDI) ASSP semiconductor market?

A: The total worldwide ASSP market opportunity for LAN/FDDI chip sets is forecast to grow at a 27 percent compound annual growth rate from $350 million in 1990 to $1.2 billion by 1995. Ethernet-based LAN ASSPs that address the high-volume PC/workstation networking functionality segment will continue to represent the

Table 1
North American Cable TV Market

	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Subscribers (Millions)	54.9	57.9	60.1	62.8	65.6	68.4	4.2
TV Homes (Millions)	93.1	94.2	95.3	96.6	97.8	99.1	1.3
% Penetration (TV Homes)	59.0	61.5	63.0	65.0	67.0	69.0	2.9
Terminal Retirement/Upgrade (Millions)	4.1	4.4	4.6	6.0	6.9	7.2	13.2
Terminal Shipments (Millions)	8.3	7.4	6.8	8.7	9.7	10.0	7.8

Source: Dataquest (March 1992)

largest market opportunity, growing to $500 million by 1995. Token-Ring ASSPs that cater mainly to the IBM networking solutions market and multiprotocol, high-end intelligent hub and internetworking bridge, gateway, and router market will grow at a high 32 percent CAGR from $75 million in 1990 to $300 million by 1995.

National Semiconductor's recent licensing agreement with IBM will stimulate growth in the Token-Ring ASSP market because of its leadership position in the ethernet market and its ability to provide an effective second source (besides Texas Instruments) for the multiprotocol arena.

The FDDI/copper-distributed data interface (CDDI) segment represents the highest growth-rate segment of the worldwide LAN ASSP semiconductor market, growing from $25 million in 1990 to $250 million by 1995. The evolution of FDDI-II for high-performance multimedia networking, together with the emergence of point-to-point fiber connections such as HIPPIE and Fiber-Channel for server-peripheral connection application(s) is expected to result in even higher potential growth of the fiber-based network ASSP semiconductor market

Table 2 shows the opportunities in the worldwide LAN semiconductor ASSP market.

Table 2
Worldwide LAN Semiconductor ASSP Market Opportunity (Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Ethernet	200	240	289	347	416	500	20.1
Token-Ring	75	99	131	172	227	300	32.0
FDDI/CDDI	25	40	63	100	158	250	58.5
Other	50	57	66	76	87	100	14.9
World	350	436	548	694	888	1,150	26.9

Source: Dataquest (March 1992)

In Future Issues

The following topics will be addressed in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in hand-held PCs
- Opportunities in printers

For More Information . . .

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9202 February 10, 1992

In This Issue...

Market Analysis

Inquiry Summary

Dataquest's Semiconductor Application Markets inquiry summary is designed to inform clients of commonly asked questions and Dataquest's respective answers. No confidential information provided by our clients is included in this material. The information contained in this publication is believed to be reliable, but it cannot be guaranteed to be correct or complete.

Market Analysis

Is the ISDN Market Finally Ramping Up?

Integrated Services Digital Network (ISDN) is a collective term for a series of telecommunications standards recommended by the International Telegraph and Telephone Consultative Committee (CCITT). These standards will have a strong influence on the global telecommunications industry for a diverse collection of applications ranging from digital voice, data, and fax communication through integrated broadband multimedia wide area networks (WANs) for audio, still image, graphics, and motion video communication. This article provides an update of global ISDN market trends and ISDN semiconductor chip set market opportunities for the next five years.

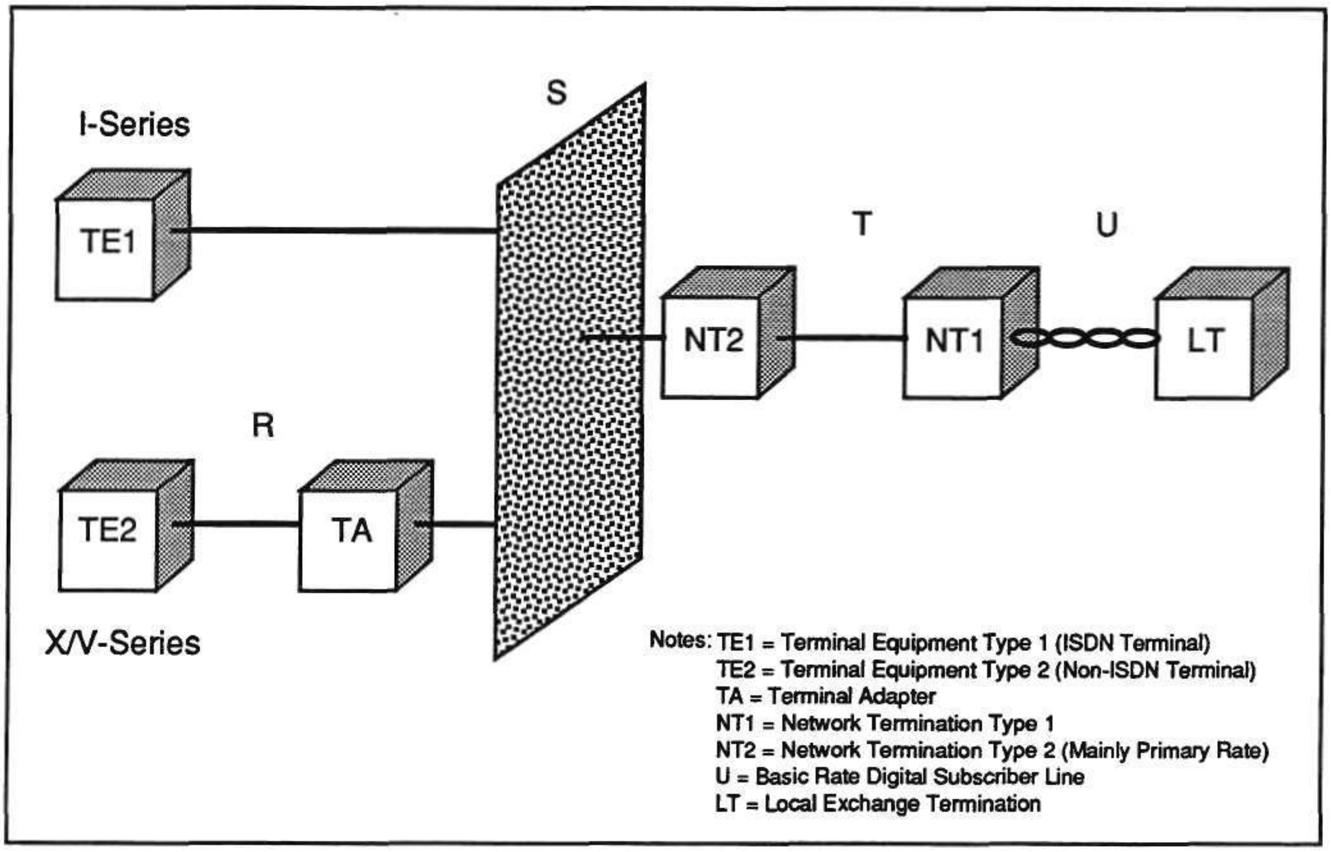
ISDN Definitions and Standards

The CCITT recommendations define the following two forms of ISDN access:

- The worldwide basic rate access standard consists of two 64-Kbps B-channels for voice and one 16-Kbps channel for data, making a total bandwidth of 144 Kbps suitable for transmission across two-wire loops between subscribers and central offices (COs) or PBXs.
- Europe, Korea, Hong Kong, and Singapore's primary rate access consists of 30 B-channels and 1 D-channel, with a total bandwidth of 2.048 Mbps. In contrast, the United States, Japan, and Taiwan's primary rate access standard has a bandwidth of 1.544 Mbps.

The configuration of ISDN access for basic rate service is shown in Figure 1. TE1 represents new ISDN terminal equipment that connects directly to the ISDN line at the S-interface. TE2 represents existing equipment such as RS-232-C or X.21 terminals. This equipment can connect to

Figure 1
ISDN Functional Entities



Source: Dataquest (February 1992)

the S-interface via a terminal adapter (TA). The NT2 is a multiplexer that concentrates two or more TE1s or TAs. The NT1 provides physical and electrical termination between the S-interface and the U-interface transmission line. The U-interface transmission is two-wire transmission at 144 Kbps. Transmission at the S-interface is four-wire transmission and requires substantial rewiring of most buildings to be accommodated.

The ISDN Chip Set Market

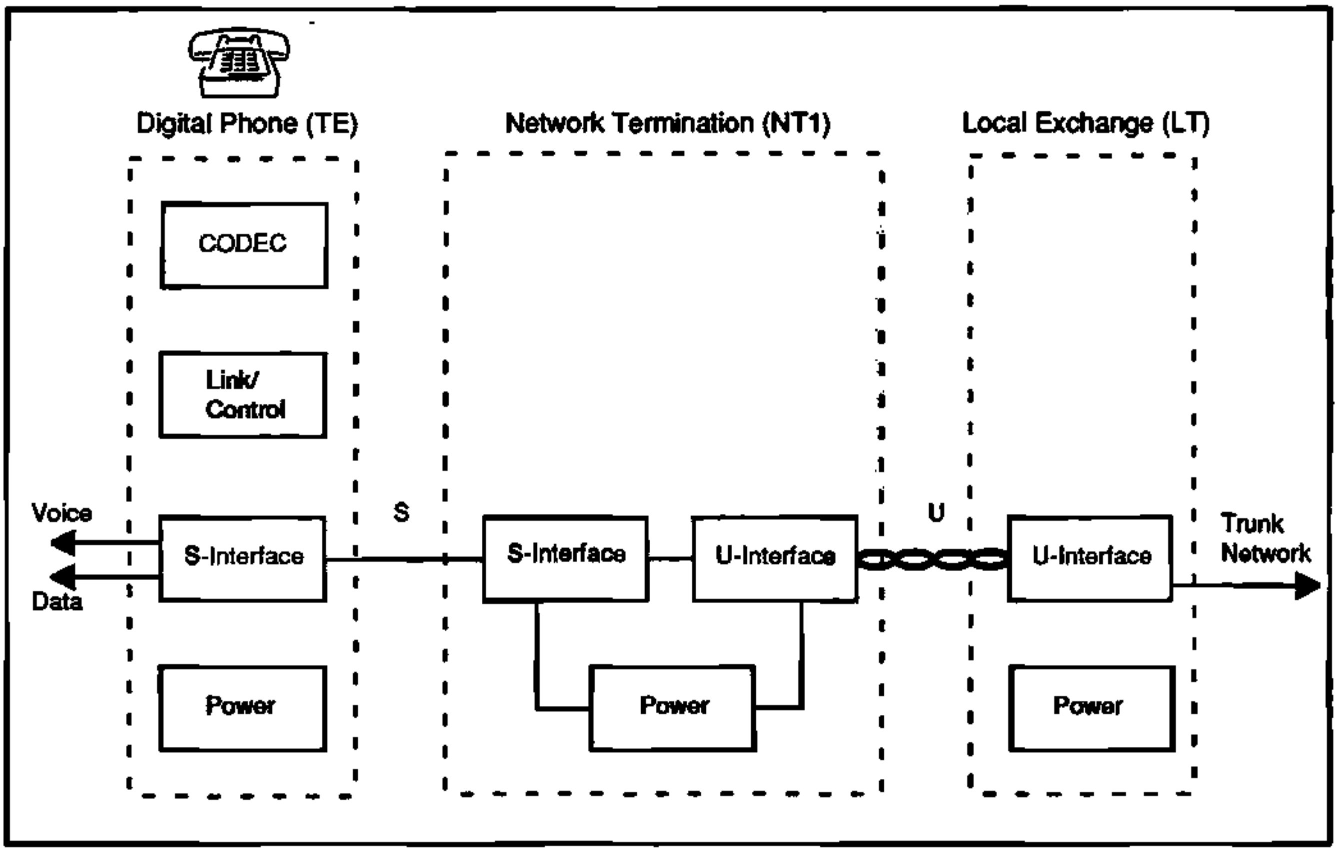
The same type of ISDN IC is used in several different ISDN applications. Figure 2 is an illustration of a functional example of an ISDN chip set for a digital telephone handset connected to a CO exchange via a U-interface. Most vendors offer a modular family of CMOS devices that can be mixed and matched for any given application. It is desirable to have a single interchip ISDN bus standard for connectivity at the IC level so that ISDN OEM vendors can have the maximum freedom in designing their system for the most optimum cost/performance trade-off.

ISDN IC Functions

Public CO exchange and premises terminal equipment will be composed mainly of the following types of ISDN ICs:

- U-interface IC—Acts as an echo-cancelling, 192-Kbps digital transceiver for twisted-pair subscriber loops
- S-interface IC—Serves as a four-wire transceiver providing link layer functions
- Microcontroller IC—Provides layer 2, Link Access Protocol Data (LAPD) data link control; may also perform higher-level functions (for example, keyboard control)
- CODEC/filter IC—Performs coder/decoder (CODEC) circuit and filter functions for videophone/videoconferencing applications

Figure 2
Main ISDN Chip Functions



Source: Dataquest (February 1992)

- Rate-adapter IC—Enables adaptation of the ISDN B-channel to non-ISDN protocols (for example, V.24 and X.21) for TA applications
- Power supply IC—Performs voltage regulation, line driver, and power-down functions

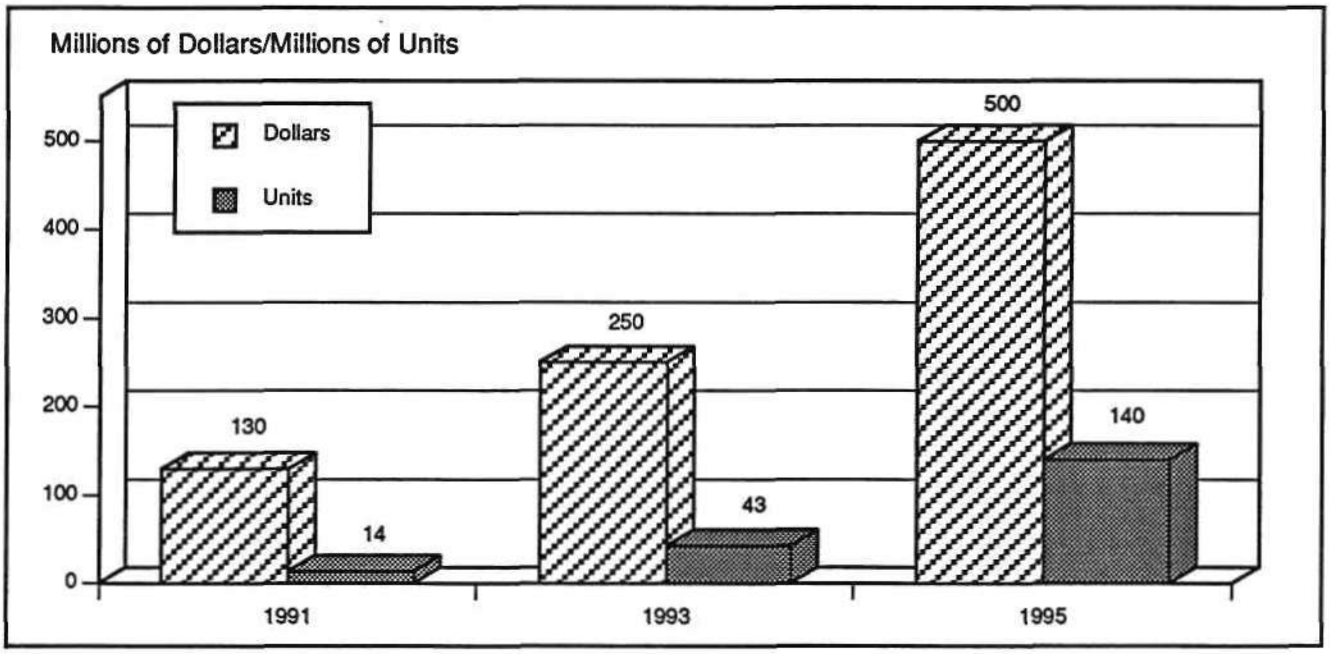
Worldwide ISDN Semiconductor Market Forecast

Figure 3 shows the growth of the worldwide ISDN semiconductor chip set business in revenue and shipments between 1991 and 1995. Dataquest predicts that the worldwide ISDN chip set market will grow at a healthy compound annual growth rate (CAGR) of 44.3 percent, from $80 million in 1990 to $500 million by 1995. In terms of ISDN chip set shipments, the growth will be even faster: a CAGR of 75 percent, from 8.7 million units in 1990 to 140 million units by 1995. Dataquest believes that the North American, European, and Japanese ISDN semiconductor markets will grow at comparable rates over the next five years because of coordinated, intense efforts to get national ISDN connectivity under way in the three regions.

Dataquest believes that the worldwide ISDN semiconductor market is finally showing signs of healthy growth as equipment and service providers settle on standards and tariff issues.

Table 1 lists the shipments forecast for the different types of ISDN chip sets between 1990 and 1995; Table 2 illustrates sample prices for different ISDN chip set types. U-interface ISDN chips constituted the biggest portion of the market between 1988 and 1991 as a result of the infrastructure CO linecard investments and also the

Figure 3
Worldwide ISDN Chip Set Revenue and Unit Shipments Forecast



Source: Dataquest (February 1992)

Table 1
Worldwide ISDN Chip Set Shipments Forecast (Millions of Units)

	1990	1992	1995	CAGR(%) 1990-1995
U-Interface	1.0	1.6	2.9	23.7
S-Interface	4.0	9.3	33.3	52.8
Link Controller	0.7	3.2	33.3	116.5
Voice CODEC	0.8	3.4	30.0	106.4
Video CODEC	0.1	0.1	2.5	90.4
Rate Adapter	0.5	1.7	11.8	88.1
Power Supply	1.7	5.1	26.3	72.9
Total	8.8	24.4	140.1	73.9

Source: Dataquest (February 1992)

Table 2
Worldwide ISDN Chip Set Sample Prices

	1990	1992	1995	CAGR(%) 1990-1995
U-Interface ($)	35.0	26.5	17.5	-12.9
S-Interface ($)	6.0	4.6	3.0	-12.9
Link Controller ($)	6.0	4.6	3.0	-12.9
Voice CODEC ($)	5.0	3.8	2.5	-12.9
Video CODEC ($)	75.0	52.0	30.0	-16.7
Rate Adapter ($)	8.5	6.4	4.3	-12.9
Power Supply ($)	3.8	2.9	1.9	-12.9

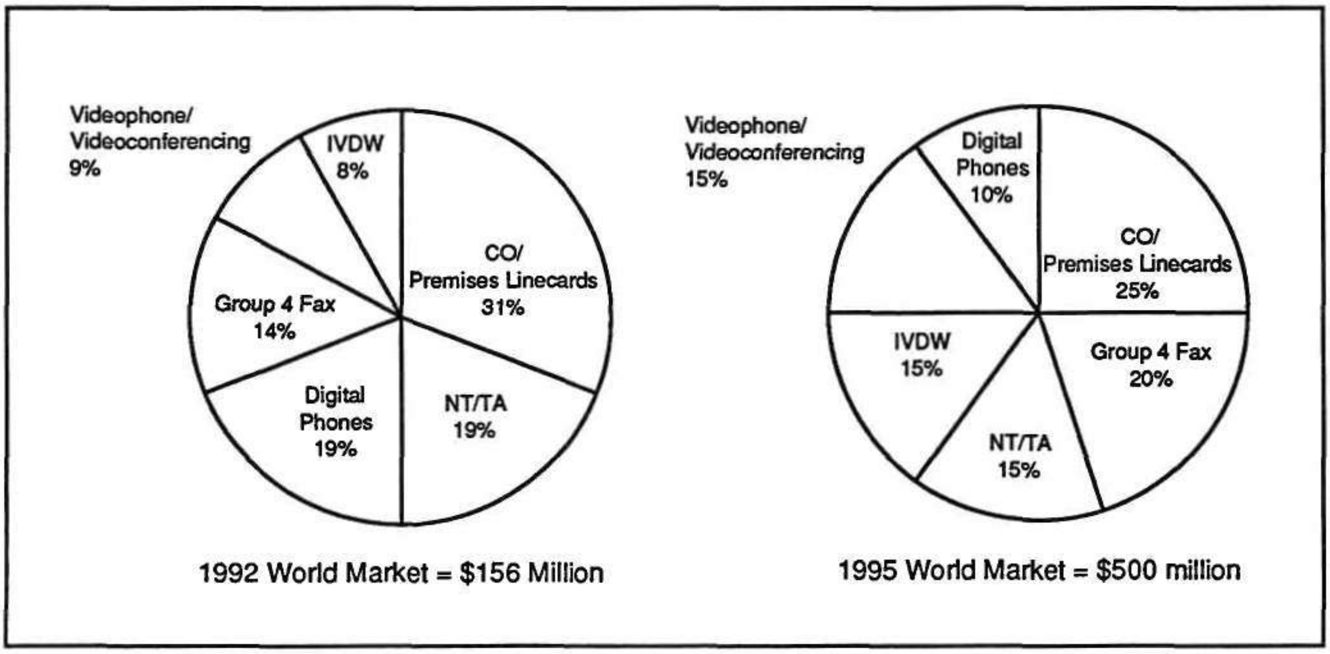
Source: Dataquest (February 1992)

evolution of the 2B1Q U-interface market. However, by 1995 the infrastructure investment in U-interface should be complete. The S-interface and link-controller markets should be the biggest segments because of the proliferation of end-user customer premises ISDN terminal equipment such as Group 4 faxes, intelligent voice/data workstations (IVDW), videophones, and digital phones. Dataquest believes that ISDN-based videophone/videoconferencing systems will stimulate growth of an ISDN video CODEC chip market.

ISDN Applications

Figure 4 illustrates the worldwide ISDN semiconductor market segmented by various end-use application markets. Linecards (CO and premises PBX) and digital feature phones were the largest ISDN semiconductor application markets in 1990. However, Group 4 fax systems together with IVDWs and videophone/videoconferencing systems are projected to be the largest ISDN semiconductor application markets by 1995.

Figure 4
Worldwide ISDN Chip Set Market by Application (Millions of Dollars)



Source: Dataquest (February 1992)

Table 3
Typical Chip Set Content for Key ISDN Applications

	U-Interface	S-Interface	Link Controller	Voice CODEC	Video CODEC	Rate Adapter	Power Supply
CO Linecard (LT)	X						X
Network Termination (NT)	X	X					X
Terminal Adapter		X	X			X	X
IVDW		X	X	X	X	X	X
Group 4 Fax		X	X				X
Digital Phones		X	X	X			X
Videophone/Videoconferencing		X	X	X	X		X

Source: Dataquest (February 1992)

The major ISDN applications over the next five years include CO and PBX linecards (LT), network termination (NT) at customer premises, terminal adapters to allow existing non-ISDN terminal equipment connection, IVDWs, Group 4 digital fax, digital feature phones and handsets, and videophone/videoconferencing systems. In Table 3, typical IC uses for the key ISDN applications are described.

Group 4 digital fax/color fax machines and personal videophone/videoconferencing systems may be the barnburner applications that ignite true growth in the ISDN chip market. ISDN-based video communication appears to have the most desirable hardware cost and performance features per unit of bandwidth. Other applications such as digital feature phones and integrated voice/data networks have to compete with viable, lower-cost alternatives such as private voice/data WANs.

North American Regional Trends

In general, the North American market has thus far not lived up to its growth expectations. However, ISDN technology has had several spinoff benefits such as more rapid network digitization, frame relay deployment, and rapid adoption of SS-7 for network signaling, among others. All the major regional Bell operating companies (RBOCs) and major long distance carriers such as AT&T, US Sprint, and MCI Communications Corporation have completed ISDN trials and now offer basic rate ISDN connectivity.

Semiconductor companies, ISDN OEM equipment companies, and ISDN service companies need to take a long-term market-creation viewpoint in providing enabling, ubiquitous user applications at affordable prices.

Dataquest's U.S. public network telecommunications research group predicts that ISDN will not achieve ubiquitous deployment and critical mass before the 1995 to 1997 timeframe. The factors constraining North American ISDN market growth include competition from alternative high-speed broadband voice/data networks in the public and private domain, a lack of red-hot applications uniquely suited to ISDN technology, a lack of compatibility between different ISDN equipment and service vendors, the high cost of ISDN implementation, and the lack of sustained investment in the U.S. telecommunications infrastructure due to the weak economy.

However, the recent agreement among major telecommunications equipment and service companies to standardize their products around the homogeneous National ISDN-1 standard by mid-1992 should stimulate growth in the ISDN semiconductor market. Also, the evolution of the 2B1Q semiconductor market to provide the U-interface for the digital added main line (DAML) and the advent of high-bit-rate digital subscriber loop (HDSL) have allowed telephone companies to transmit to T-1 networks on two effective pairs of lines in the local loop. The use of "pair-gain" technology involves the use of a single basic rate ISDN twisted pair to support two voice lines. Greater multiples of voice lines are being considered by using higher bit-rate U-interfaces than the standard 144-Kbps basic rate and by using low bit-rate ADPCM CODECs. Pair-gain appears to be the first application in which ISDN-dedicated ICs will appear; for example, a U-interface and a PCM voice CODEC can be integrated into one IC.

Dataquest Perspective

Dataquest believes that the worldwide ISDN semiconductor market is finally showing signs of healthy growth as equipment and service providers settle on standards and tariff issues. New applications such as Group 4 digital fax/color fax, and personal videophone/videoconferencing systems may be the much-needed catalyst for ISDN market acceptance. Semiconductor companies, ISDN OEM equipment companies, and ISDN service companies need to take a long-term market-creation viewpoint in providing enabling, ubiquitous user applications at affordable prices. Europe's unified 1992 telecommunications strategy, Japan's concerted ISDN push led by Nippon Telephone and Telegraph Corporation, and the recently announced U.S. National ISDN-1 initiative could well propel the worldwide ISDN semiconductor chip set market onto a high-growth path that could surpass $500 million by 1995.

By Krishna Shankar (San Jose, California)
Jonathan Drazin (Denham, United Kingdom)

Opportunities in Midrange and Large Systems: "Openness" Changes the Technology

The traditional markets for midrange computer, mainframe computer, and supercomputer systems are changing dramatically, and so is the opportunity for semiconductor suppliers. Some general changes include the following:

- A trend toward the decentralized client/server model of computing using distributed machines optimized for networking, efficient mass storage, and on-demand number crunching
- A trend toward open systems with common operating systems (UNIX), programming interfaces, windowed graphical user interfaces (for example, X Window), and in some cases standard buses
- A trend toward microprocessor-based scalable, multiprocessor architectures that can take an OEM line from workstation to supercomputer

Overall market growth for these systems is projected to be modest; nevertheless, product mix changes caused by the above factors will provide ample opportunity for chip suppliers positioning themselves to take advantage of the trends.

Technology: Need for Speed, Differentiation

Although there is a clear trend toward so-called open systems, OEMs are reticent about "commoditizing" their hardware and therefore will continue retaining many proprietary technologies. We can expect such hardware indexes as cycle time, memory and mass storage size, I/O performance, connectivity, and fault tolerance to be the primary hardware differentiators. For larger systems, cost of ownership issues such as replacing liquid cooling with air cooling will impact type of chip technology employed.

OEM cost control will be more pronounced in the future as midrange systems and even supercomputers are aggressively marketed much like workstations. Novel system architectures and the economies of chip technology will be relied on to assist OEMs in hitting price/performance targets. It would not be surprising to see market life cycles for larger machines shorten dramatically over the coming years because of competitive pressures brought on by open systems.

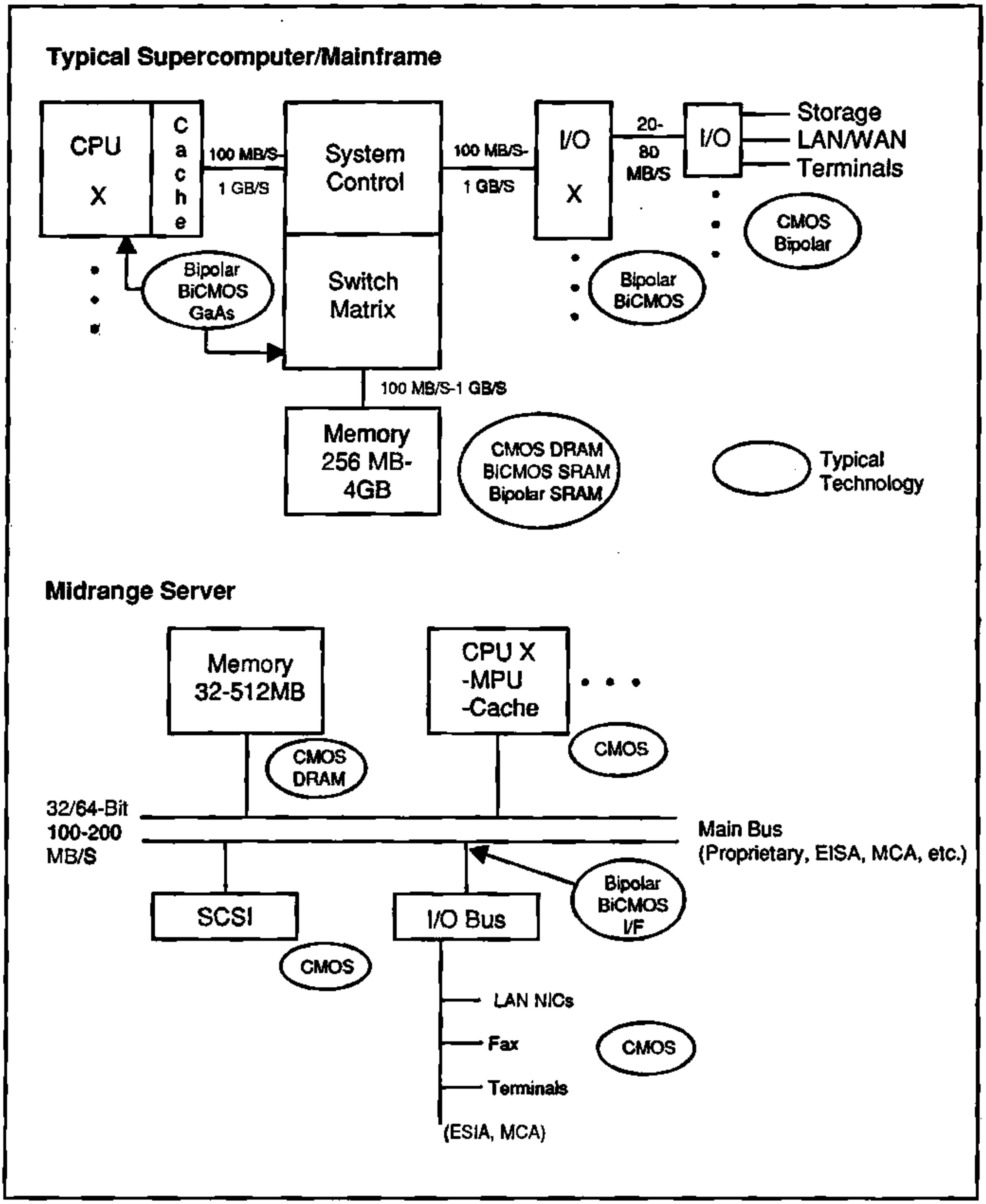
For the next five years, CMOS will be the dominant technology used for midrange systems and in many large/fast systems. Although debatable, it is believed that CMOS ICs will become very power inefficient somewhere between 75-MHz and 125-MHz clock rates unless dramatic process improvements are made. However, with multiprocessor architectures, which lessen the pressure for single-CPU performance, CMOS will certainly be able to address the bulk of the market through 1995 before application of alternative technologies (such as multichip modules and BiCMOS) is required.

BiCMOS technology will continue to find a moving target with sporadic large-scale use as 25+ mask layers, in some cases, continue to drive its high cost. BiCMOS logic and SRAMs—emitter-coupled logic (ECL) and input/output (I/O)—will find increasing use but mainly in speed/current drive-critical pockets. ECL and its bipolar variants will continue battling with GaAs technology for supercomputers and with BiCMOS for speed-critical applications in midrange and mainframe machines. Some companies are offering ECL technologies based on less than 15 mask layers. ECL's broad availability, inherent speed (100ps gate delays), and current drive advantage should enable it to remain the technology of choice for the majority of high-end applications. Despite the recent drop in GaAs prices, there remain only a handful of suppliers and adopters to date. Several producibility issues still cloud the market's perception of digital GaAs technology.

Midrange Technology Trends

Midrange computers are defined as multiuser computers costing from $20,000 up to several hundred thousand dollars and including such systems as the IBM AS/400, most of the Digital Equipment Corporation (DEC) VAX line, and departmental servers from companies like Hewlett-Packard and Sun Microsystems. Perhaps the most visible forms of the emerging midrange computer are servers, which can be configured with several gigabytes of disk capacity, tape backup, and multiple-LAN network interface cards for connection to users. Figure 1 is a block diagram of a generic scalable server architecture and a mainframe/supercomputer system. Some specific semiconductor technology requirements of future systems are presented in Table 1.

Figure 1
Midrange/Server and Mainframe/Server Systems



Source: Dataquest (February 1992)

Table 1
Semiconductor Technology in Large Computers
(Mid-1990s Requirements)

	Midrange	Mainframe/Supercomputer
Main Memory	DRAM	DRAM/BiCMOS (ECL I/O) SRAM
Avg. MB	140MB	2GB
Access Time	60ns	10ns
Cache Memory	CMOS SRAM	ECL, GaAs SRAM
Avg. MB/CPU	512KB	1MB
Access Time	15ns	1ns
Logic/MPU	32/64-bit MPU, ASSPs/ASICs	ASIC-based/MPU
Technology	CMOS	ECL (bipolar), BiCMOS, GaAs, CMOS
Avg. Gate Delay	1ns	100ps
Avg. Gates/System	400K-2M	4M-8M per processor
Main Bus/Crossbar Switch Speed	40MB-200MB/sec.	500MB/sec.-4GB/sec.

Source: Dataquest (February 1992)

Scalable MPU Architectures

Increasingly, midrange and large-scale computers will incorporate reduced-instruction-set computing (RISC) and complex-instruction-set computing (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 scaled-up, multiprocessor versions of workstation families. The trend is toward OEM-controlled MPU architectures, with the Sun (SPARC), HP (PA-RISC), and DEC (Alpha) architectures being notable examples. Examples of architectural choices for midrange systems include the following:

- Sun—SPARC (40 MHz) and Viking (new SPARC)
- IBM—Proprietary and Power
- Digital—486, MIPS R3000A/4000, proprietary (Alpha)
- Hewlett-Packard—PA-RISC
- Data General—881XX
- NCR—X86
- Compaq—X86
- Tandem—MIPS R3000

In addition to proprietary buses, open versions like MCA, EISA, and VME are often employed as either the main or I/O bus in midrange systems. Because of the multiprocessor architectures, the main bus can require 200-MB/sec. or higher bandwidth. Fiber Channel and Futurebus+ are under consideration as open-systems-standard, high-performance buses of next-generation designs.

Mainframe and Supercomputer Technology Trends

These systems include the traditional mainframes from companies such as IBM and Fujitsu Ltd. as well as high-end transaction-processing machines like those from Tandem, Convex's minisupercomputers, traditional supercomputers from Cray and NEC, and the massively parallel machines from Intel and Thinking Machines.

Scalability Too

Opinion appears to be diverging from the custom-CPU, high-performance computer design school of thought. The low-end systems ($1 million to $2 million) are turning to scalable, multiprocessor MPU architectures in next-generation designs. As an example, Cray is reportedly adopting both the Sun SPARC and the DEC Alpha MPUs into multiprocessor architectures. However, the bulk of these high-end systems will continue needing faster logic and memories as shown in Table 1. Multichip modules (MCMs) will continue to be employed to reduce off-chip delay and to manage thermal dissipation. New MCM technology can manage beyond 100 die with two to three dozen layers of fine-pitch interconnect. Many of the next-generation MCM-based systems will be air cooled, greatly reducing system cost of ownership.

Most of the OEMs interviewed indicated that their logic and memory designs are increasingly being partitioned to minimize the use of power-hungry and expensive technology without compromising performance. Therefore, CMOS is being mixed with ECL (or similar current-oriented technology), BiCMOS, and even GaAs in the same machine. Increasingly GaAs and ECL are being used only on crucial data path areas (for example, key registers and primary cache) and less for total system usage.

Parallelism Is Perpendicular

Clearly, massively parallel architectures are getting a toehold in the world of performance computing. The concept of parallel computing basically involves the partitioning of instructions and data—single instruction/multiple data (SIMD) or multiple instruction/multiple-data (MIMD)—across hundreds of computing elements (often 32-bit or 64-bit MPUs). Computing elements usually have dedicated interface logic, memory management, and memory ranging from a few megabytes to hundreds. Intel, with its i860-based system, and Thinking Machines, with its SPARC-based systems, are examples of upcoming parallel offerings.

Some success has been achieved to date at shipping machines to sophisticated R&D centers. However, the extreme labor intensity of getting applications running (for example, simulations) is expected to limit mainstream utilization until ease-of-usage issues are solved.

Chip Opportunities Abound

Qualitatively, we have identified the following specific areas as significant semiconductor market opportunities within future midrange computer, mainframe computer, and supercomputer market segments.

32/64-Bit MPUs

One of the trends is toward multiprocessor RISC with such companies as DEC, HP, and IBM investing further into proprietary families and other OEMs using merchant families such as X86, MIPS, and SPARC. BiCMOS and ECL RISC MPUs are becoming technically achievable; perhaps they have just been a little ahead of their time to date. With most of the MPUs absorbing the FPU and small amounts of cache, new features could include larger primary caches and even secondary caches for increased performance. Multiprocessing features are expected on new MPUs. Many systems will be employing RISC MPUs to manage overhead and I/O functions independently of the main CPU group.

System Logic

In cases where standard buses are used with X86, MIPS, or SPARC MPUs, system logic ASSP chip sets will find opportunity. System logic will remain an ASIC opportunity with the proprietary architectures. ASIC system logic opportunities are similar to those for workstations: cache and DRAM management, serial and parallel I/O control, and bus controllers/transceivers (for example, S bus and Futurebus+).

Midrange systems will continue to utilize CMOS gate arrays and cell-based ICs. CMOS PLDs will continue to have a role where nonrecurring engineering costs and time to market are critical. Mainframes and supercomputers will continue to use a mixture of BiCMOS, ECL, and GaAs gate arrays and a growing level of cell-based ICs. Because of the relative sophistication of large/fast system designers, the tendency to date has been to rely more on gate arrays, but predefined megafunctions are starting to become more popular. ECL designs exceeding 40K gates are now possible with 20-watt power dissipations. BiCMOS ASICs with 150K gates are being used already, and GaAs ASICs are laying claim to 40K gate capability.

Communication

Opportunities in the communications areas include the following:

- Movement is toward SCSI II for fast and/or wide-bus (20-MB/sec.) control of disks and their arrays and also for redundant arrays of inexpensive disks (RAID).

- The directly addressable device interface (DADI) with a 40-MB/sec. bandwidth is being discussed as the internal system interface after SCSI II.
- Fiber-distributed data interface (FDDI) (100 Mbps), Fiber Channel (up to 1,600 Mbps), Futurebus+ (more than 2,000 Mbps), High-Performance Parallel Interface (HiPPI) (800 to 1,600 Mbps), and IBM's ESCON (Enterprise Systems Connection) (200 Mbps) are examples of high-speed communications buses. FDDI is well established as the principal LAN backbone choice for the next few years. HiPPI appears to be gaining favor for higher-speed interprocessor communications needs. Fiber Channel is being mentioned in conjunction with disk arrays and jukeboxes. All of these will be opportunities for ASSPs and ASIC library controller functions, switches, and transceivers.

Memory

Increasingly, the large/fast systems are turning to commodity CMOS DRAMs for main/extended memory as their architectures evolve. SRAMs will continue to be used in many supercomputers as main memory and for nearly all machines in caching and register roles. Densities and speeds are outlined in Table 1.

The Systems Market

Table 2 presents Dataquest's worldwide forecast for midrange, mainframe, and supercomputer systems. 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

Table 2
Worldwide Midrange/Large Computer System Revenue and Shipments Forecast

System	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Revenue ($M)							
Supercomputer	1.8	1.9	2.1	2.4	2.6	2.9	11.0
Mainframe	30.3	29.0	28.5	28.0	27.7	27.1	-1.7
Midrange	29.9	29.9	30.7	31.7	32.6	33.4	2.8
Total	62.0	60.8	61.3	62.1	62.9	63.4	1.0
Units (K)							
Supercomputer	0.8	0.9	1.1	1.2	1.4	1.6	15.5
Mainframe	15.1	14.5	14.2	14.1	13.9	13.6	-1.6
Midrange	1,025.2	1,038.9	1,080.3	1,129.6	1,175.6	1,218.0	4.1
Total	1,041.2	1,054.3	1,095.6	1,144.9	1,190.9	1,233.2	4.0

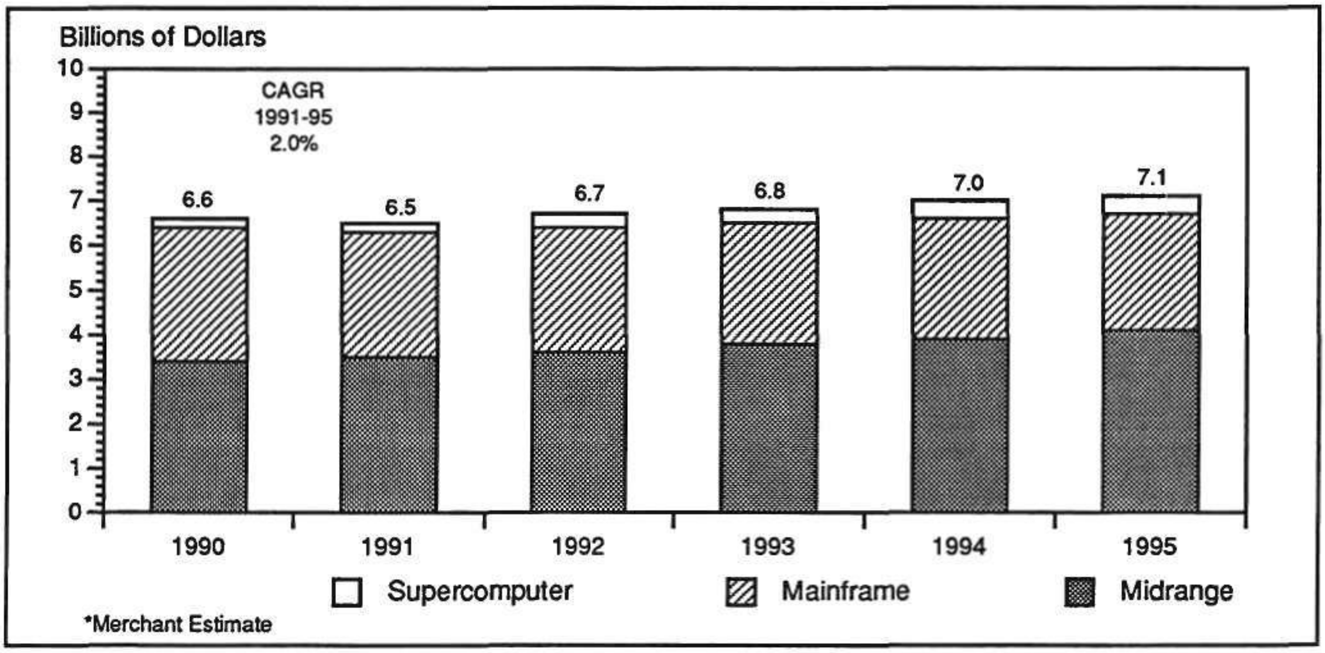
Note: Some columns will not add to totals shown because of rounding.
Source: Dataquest (February 1992)

Table 3
Worldwide Computer Systems Market Share Based on 1991 Revenue

Supercomputer		Mainframe		Midrange	
Company	Share (%)	Company	Share (%)	Company	Share (%)
Cray Research	36.3	IBM	57.7	IBM	20.4
IBM	22.4	Fujitsu	8.5	DEC	12.8
Convex	8.2	Hitachi	7.8	HP	6.2
Fujitsu	5.6	NEC	5.3	Fujitsu	6.0
DEC	4.8	Unisys	4.7	NEC	5.7
Others	22.7	Others	16.0	Others	48.9

Source: Dataquest (February 1992)

Figure 2
Worldwide Midrange/Large Computer Semiconductor Market



Source: Dataquest (February 1992)

machines in certain applications. Likewise, midrange system growth is being clipped by the LAN clusters as well. Across all performance categories, server versions that are oriented toward providing resources (storage, computing, and printing) to LAN clusters are growing rapidly.

Table 3 lists the key OEMs in each of the three areas ranked by market share based on revenue. Cray and IBM control the bulk of the supercomputer market. Likewise, IBM dominates the mainframe market with Fujitsu and Hitachi—one-seventh its size in this market. The midrange market remains much more fragmented, with IBM and DEC controlling 32 percent.

The Semiconductor Market

Dataquest estimates that the total worldwide merchant semiconductor market represented by midrange, mainframe, and supercomputer systems was $6.5 billion in 1991 and will grow to $7.1 billion by 1995 (see Figure 2). Logic (with MPU and interface functions) consumes a greater than 60 percent share of the mainframe/supercomputer market because of multi-CPU configurations and extensive use of multichip modules. DRAM and SRAM account for the majority of the remaining 40 percent.

Dataquest Perspective

Clearly, midrange and high-performance systems present different types of market opportunities to chip suppliers. In the future, midrange computers will look like scaled-up, I/O-intensive versions of the workstation architecture. Therefore, many of Dataquest's recommendations about workstation opportunities apply here as well. The most pronounced of those recommendations is developing close relationships with OEMs (design team, purchasing, and others). Volume opportunities exist for CMOS varieties of DRAM, fast SRAM, 32/64-bit MPUs and associated chip sets, and ASICs.

In performance-oriented systems, the fragmentation between massively parallel and high-speed few-processor systems will present different technological opportunities to chip suppliers. The high-speed-oriented systems will continue to need even higher speed and integrated ECL I/O bipolar, BiCMOS, and GaAs ASICs and memories. Parallel and scalable multiprocessor large systems will offer CMOS opportunities not unlike those identified for midrange systems. Expect this market to remain heavily vertically integrated (that is, IBM supplies IBM, for example), making outside design-ins challenging and sometimes transitory.

By Gregory Sheppard

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Q: What are the forecast and outlook for BiCMOS mixed-signal semiconductor ICs in telecommunications application markets?

A: High-performance BiCMOS technology has the key advantages of high-frequency operation, mixed-signal capabilities, and high noise immunity, coupled with the high logic integration density of CMOS technology. True high-performance BiCMOS technology will have separately optimized bipolar and CMOS transistors. Hence, the technology will be relatively expensive, costing one and one-half to two times more than pure CMOS technology. However, BiCMOS has a natural price premium market in mixed-signal telecommunications markets such as cellular telephone/personal communications networks, wireless LANs, wireless PBX, paging devices, hand-held radio frequency terminals, wireless modems/faxes, mobile radio systems, T-1/T-3/SONET multiplexers, and satellite broadcasting equipment.

Many first-generation telecommunications systems are initially designed using BiCMOS mixed-signal ASIC gate-array and standard-cell methodologies because of their time-to-market advantages. Subsequently, as market economies of scale and competition develop, the second- and third-generation designs are silicon-area optimized in order to fulfill the needs of a high-volume, mixed-signal BiCMOS telecommunications application-specific standard product (ASSP) chip set market. Dataquest believes that the worldwide mixed-signal BiCMOS microperipheral/ASSP semiconductor market for telecommunications applications will grow dramatically at a compound annual growth rate of 38 percent, from approximately $200 million in 1992 to $500 million by 1995.

Q: Is flash memory replacing UV EPROM?

A: Even though the majority of flash memory ICs conform to the JEDEC standard pinouts, flash memories are not replacing EPROMs directly. The primary reason is, of course, cost. The 1Mb flash EPROM costs about $10, whereas the 1Mb EPROM costs $4. Replacing the EPROM in an existing board design with a flash memory does not make sense because the system most likely cannot exploit flash's main advantage over EPROM— that is, its ability to alter the stored data without its being removed from the socket. As a result, flash is used mostly in new designs, where the electrical rewrite ability can be designed in.

Q: What are a couple of good applications for flash memory?

A: Two good flash memory applications are the following:

- Automotive (in engine and transmission management control electronics)—The easy availability of 12V makes this an ideal application for the standard flash EPROM products. The fact that this happens to be the least expensive flash (EPROM derived), comes as a bonus in an extremely cost-conscious industry. The automotive applications may drive the development of flash EPROM (12V program) for the foreseeable future.
- Personal computers—Here the flash memory is increasingly used to replace EPROMs in BIOS. This arrangement allows for easy in-system upgradability of the BIOS code allowing new features to be integrated into existing systems. The portable notebook PC market seems to be embracing flash technology. It should be noted that this market demands low-voltage devices and in the long run may drive the 5V and 3V flash memory technology. Another area is that of memory cards used in palmtop PCs. Finally, flash memory is used in solid-state disks (hard disk emulation/replacement).

In Future Issues

The following topics will be addressed in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in fax and modem hardware
- Opportunities in optical disk drives

Errata

In the article entitled "The Pen-Based Computer: The 'Walkman' of the 21st Century?" in Semiconductor Application Markets Worldwide *Dataquest Perspective* issue 9201, which was dated January 20, 1992, Table 1 contained inaccurate totals. Table 1 of the article entitled "Workstations: A Silicon-Rich Application Comes of Age" was improperly aligned. We apologize for any confusion this may have caused and reprint both tables here with correct information.

Table 1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
Laptop	3,172	3,592	3,998	4,370	4,744	10.6
Notebook	686	1,441	2,760	4,934	7,180	79.9
Pen-Based	96	353	1,590	3,498	4,370	159.8
Companion	NA	756	1,478	2,663	4,246	77.7*
Hand-Held	503	1,559	3,087	5,588	9,365	107.7
Total Portable	4,457	7,701	12,913	21,053	29,905	60.9

NA = Not available
*1992 through 1995
Source: Dataquest (February 1992)

Table 1
Worldwide Workstation Forecast

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Entry-Level							
Units (K)	246	310	524	1,040	1,915	2,950	75.6
Factory Revenue ($M)	3,381	2,867	4,023	7,032	10,567	11,753	42.3
Traditional/Super							
Units (K)	138	205	263	312	367	428	20.2
Factory Revenue ($M)	3,714	5,508	6,558	7,868	8,798	9,364	14.2
Graphic/Project							
Units (K)	2.5	2.9	3.4	4.6	5.5	6.6	22.8
Factory Revenue ($M)	261	300	332	414	456	509	14.1
Total							
Units (K)	386	518	791	1,356	2,287	3,385	59.9
Factory Revenue ($M)	7,357	8,675	10,913	15,314	19,821	21,625	25.7

Source: Dataquest (February 1992)

For More Information . . .

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

SAWW-SVC-DP-9201 January 20, 1992

In This Issue...

Market Analysis

Workstations: A Silicon-Rich Application Comes of Age

At last that other volume computer application, the workstation, is emerging as a million-unit opportunity for purveyors of semiconductors. The growth of workstations and their server versions is being propelled by a broad-based expansion out of traditional markets. In many ways the workstation is the ideal chip market, for the following reasons:

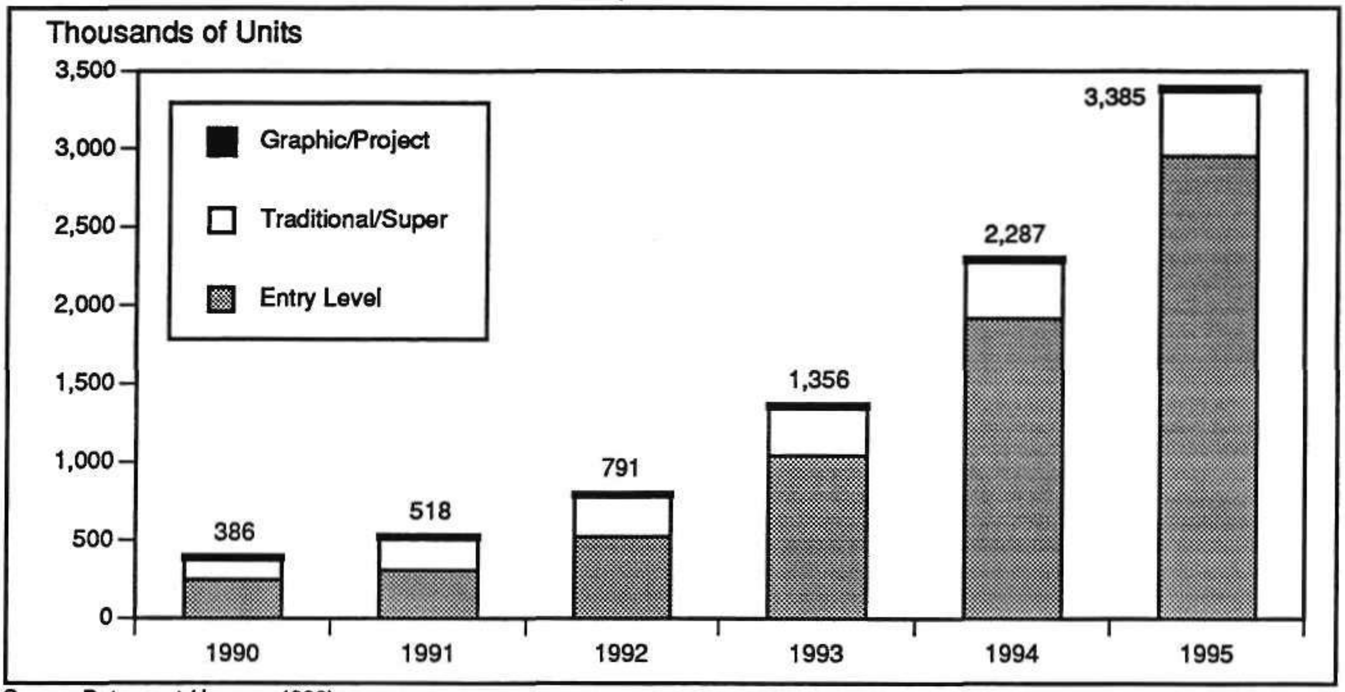
- $1,000-plus semiconductor content
- Multiple opportunities for application-specific standard products (ASSPs) (now with high enough volumes to amortize NRE investment)
- Memory array intensive
- Galvanizing standard CPU architectures and buses
- Frequent design-in windows with 12- to 18-month product life cycles

This semiconductor market for workstations is fiercely competitive, and chip companies are battling for alliances and joint development relationships with OEMs.

System Forecast: New Markets

Figure 1 and Table 1 present the worldwide workstation forecast from Dataquest's workstation group. On a unit basis the market is expected to have a 59.9 percent compound annual growth rate (CAGR) from 1991 to 1995. Workstations are generally defined as systems that use multiprocessing operating systems and have embedded networking nodes, high-performance graphics, and local mass storage. Although the definitions for workstations and high-end PCs can get blurred, the workstation group does make the definition assignments on a per company/model basis.

Figure 1
Worldwide Workstation Forecast



Source: Dataquest (January 1992)

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Source: Dataquest (January 1992)

The entry-level category of workstations (sub-$10,000 price) will dominate the unit volumes, as it brings powerful computing down to the $5,000 price point. New markets such as manufacturing automation, publishing, and the business desktop will complement the traditional design automation stronghold. Demand will be greatest in Japan, Asia/Pacific, and Europe. Entry-level system demand will be spurred by the entrance of advanced computing environment/advanced RISC computing (ACE/ARC) systems and the introduction of the object-based Windows NT operating system that also allows workstations to run DOS applications.

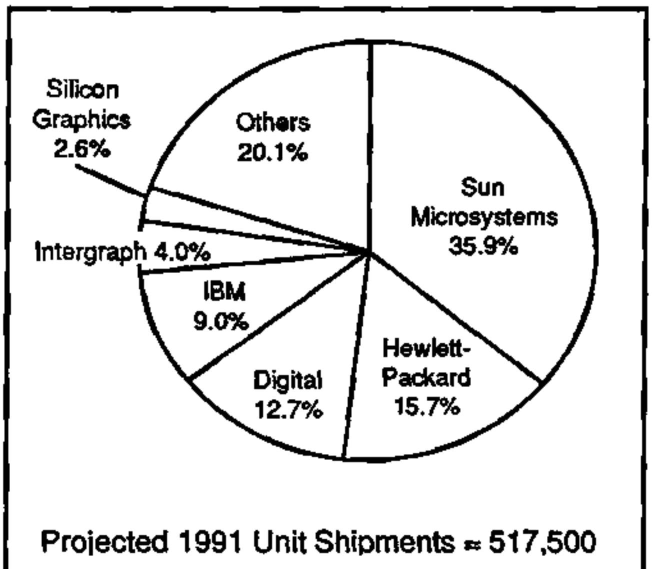
Dataquest includes the Intel Corporation 586-based machines in the entry-level category. The market share leader in entry-level systems is Sun Microsystems Inc., while Hewlett-Packard Company leads the traditional/superworkstation category ($10,000 to $50,000). Silicon Graphics Inc. leads the $100,000 class graphic/project category.

The Gladiators

Figure 2 shows the unit market share of key vendors. Sun Microsystems continues to be the unit leader, with about 36 percent of the market. During 1991, Sun, HP, and Silicon Graphics roughly maintained market share, while Digital Equipment Corporation and Intergraph Corporation lost share. IBM increased its market share by 50 percent as the RS/6000 family continued shipping well. Sun and especially Digital suffered from product transition lulls, whereas HP and Silicon Graphics scored product hits.

The Others category is up from 16 percent in 1990 because companies such as NeXT Computers, NEC Corporation, Toshiba, and Fujitsu began capturing larger parts of the market. The Acer Group, Hitachi, MIPS Computer Systems Inc., Mitsubishi, Omron, Sony, Sumitomo Electric, Tektronix Incorporated, Unisys Corporation, and Xerox Corporation are significant others as well. The SPARC clone vendors generally lack market channel access and have yet to make a sizable impact on the market.

Figure 2
1991 Projected Workstation Market Shares



Source: Dataquest (January 1992)

Alliances, Initiatives, and Operating Systems

The year 1991 was dizzying in terms of major announcements affecting the workstation market. The ACE Initiative now has 79 signatories including Acer, Compaq Computer Corporation, Digital, NEC, Olivetti, Silicon Graphics, and Zenith Data Systems. Windows New Technology (NT) by Microsoft Corporation and ACE UNIX by The Santa Cruz Operation (SCO)/UNIX System Laboratories are the twin operating systems for ACE. ACE covers both X86 architectures on the low end and ARC on the high end. ARC is based on the MIPS Computer Systems R3000 and R4000 processors. Developer kits for both operating systems (OSs) were to begin shipping in December 1991. Commercial availability of application software running under the two OSs is slated to arrive by mid-1992. Volume shipments are projected to start in 1993.

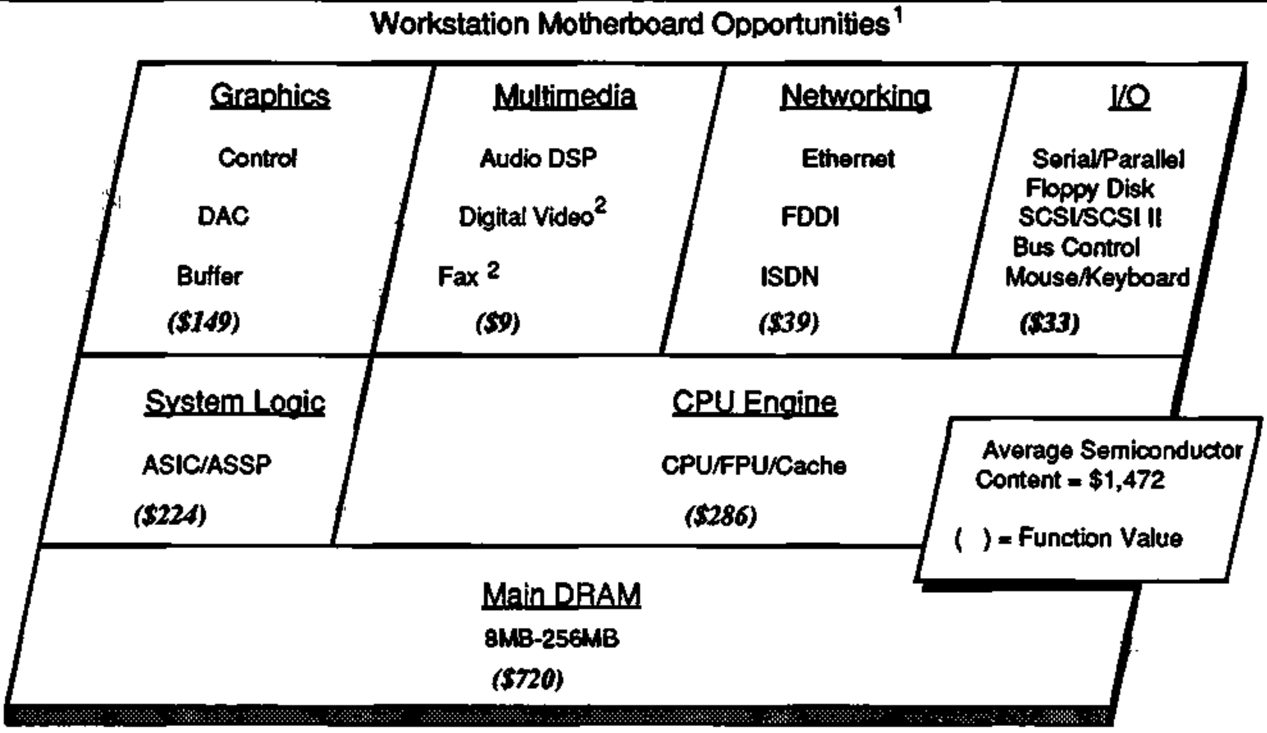
The alliance of Apple Computer Inc. and IBM on multiple fronts, including RISC processors and an object-based operating system (via their Taligent venture), should impact the market in the 1993 to 1994 time frame. Motorola Incorporated will help produce a version of IBM's POWER RISC processor for use in new workstations/servers and PCs from Apple and IBM.

Sun Microsystems' SunSoft unit will help extend Sun's influence into the PC world by porting its Solaris OS to DOS platforms.

Semiconductor Opportunities

Semiconductor opportunities within workstations are proliferating as more features are added in a never-ending battle to differentiate hardware. There are many opportunities for standard CPU engines, system chips sets, and various functional ASSPs. Figure 3 shows an average workstation motherboard where the average semiconductor bill of materials costs more than $1,400 today. The entry-level machine averages about $1,100 in semiconductor content, the traditional averages $1,800, and the graphic/project supercomputer averages more than $6,600.

Figure 3
Workstation Motherboard Opportunities



1 Others include 0.5MB nonvolatile memory, clock/calendar, interface logic, and PLD.

2 Add-in card initially, value not included.

Source: Dataquest (January 1992)

Functional Trends

What opportunities will the next few generations of workstations offer and what semiconductor technology will they need? Table 2 outlines some of the mainstream system requirements Dataquest sees for the machine of the future.

CPU Engine/Cache

The trend is toward either highly integrated 32/64-bit RISC solutions for the entry-level versions or multiprocessor architectures for high-end machines. The integrated microprocessing (MPU) is absorbing the FPU, the memory management unit, and primary cache. In order to power the mainstream systems of 1995, CPU clock frequencies will need to exceed 100 MHz, if not 200 MHz on critical paths. BiCMOS and emitter-coupled logic process technology is already being employed to accomplish this in some cases. Figure 4 depicts the most recent market share numbers for various RISC processor types.

The need for SRAM-based cache is shifting to a buyer-optional item for secondary cache for low-end systems but will remain as standard in high-end systems. Most likely there will be a need in future machines for sub-5ns access SRAM, for up to 128KB instruction/data cache (in 16- or 18-bit widths). At these extreme speeds close CPU-cache tuning will be required. There is a developing market for processor-specific SRAM (timing and multiplexing, among others). In some cases pre-engineered CPU boards may be needed. Multichip modules are being discussed for use two or three generations ahead (1994 to 1995).

System Logic

The age of workstation system logic chip sets has emerged, initially for the MIPS architecture and now for SPARC as well. Current generation chip sets (mainly ASIC-based) can range from 6 to 12 parts and accommodate I/O and

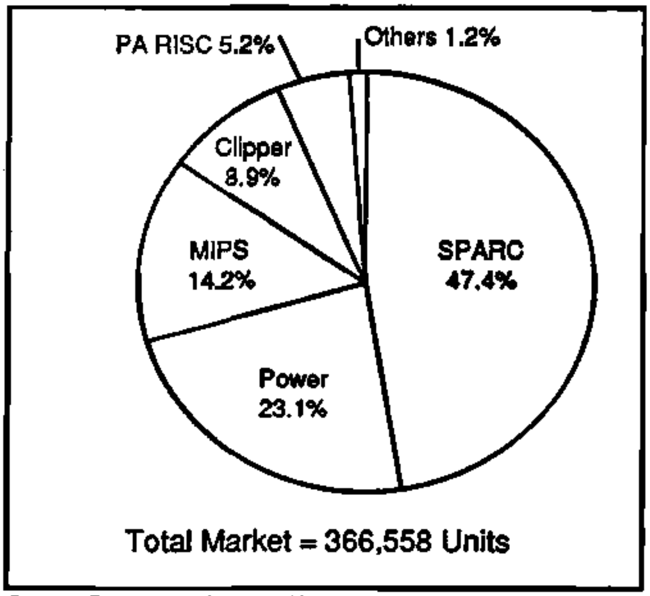
Table 2
The $10,000 Workstation

	1990	1991	1992
CPU			
MIPS	16	57	100
SPECmark	11	52.6	100.4
Mflops	1.7	17	30
Memory			
Standard (MB)	8	32	64
Maximum (MB)	40	512	1024
Memory Types	1Mb and 4Mb	16Mb	16Mb
Storage			
Standard (MB)	207	420	600
Standard Features	Ethernet	Ethernet	Ethernet
	2-D Graphics	3-D Graphics	3-D Graphics
		CD-Quality Audio	CD-Quality Audio
		Voice Input	Voice Input
		Video In/Out	Video In/Out
			Fax
			Voicemail/Phone

Source: Dataquest (January 1992)

memory management functions. More integrated versions for 1992 have been reduced to as little as 3 (excluding video). In both cases, the availability of chip sets and designs (for example, ARC) lower the barrier considerably for new workstation entrants.

Figure 4
Workstation RISC Processor Market Shares



Source: Dataquest (January 1992)

Main Memory

Already averaging more than 50 percent of the system bill of materials, main DRAM usage is expected to grow exponentially. Main memory usage continues to be driven by more sophisticated applications software and networking, as well as new memory intensive functions such as multimedia (sound and image handling). Table 3 shows our estimate of main memory needs by system class through 1995. Expect workstations to continue to be early adopters of new DRAM generations (such as 4Mb and 16Mb) as short system life cycles allow them to do so.

Graphics and Video

Manufacturers will continue to emphasize and refine graphics. Entry-level systems are witnessing the embedding of the graphics subsystem onto the motherboard while the high-end systems are still maintaining one or more add-in accelerator cards. Mainstream pixel

Table 3
Workstation Main Memory Configuration (MB, Excluding Parity Requirements)

	1991	1993	1995
Entry-Level	16	24	32
Traditional	24	48	72
Super Workstation	64	512	1,024
Graphic/Project	128	1,024	2,048

Source: Dataquest (January 1992)

resolutions are currently in the 1,152/900 through 1,280/1,024 range with 256 colors. Broader availability of windowing graphical user interfaces (GUIs), 3-D graphics (for example, Silicon Graphics licensing its library), and the incorporation of digital video over the next few years will put pressure on to raise resolutions toward 2 million pixels and 24-bit photorealistic color. This will create continued opportunities for new graphics controllers, RAMDACs, and DRAM/VRAM buffer memory (moving from 1MB to as much as 32MB).

Digital video will remain principally an add-in card business for the next two or three years as image editing tools enter the market. Joint Photographic Experts Group (JPEG) is the preferred compression scheme for image compaction for transmission and storage today. Motion video applications are employing JPEG as well but are expected to move to Motion Picture Experts Group (MPEG) I for applications not requiring real-time capture. Digital video processing requires video digitization, color space conversion, compression, and SRAM and DRAM/VRAM buffers to complement the existing graphics subsystem. Digital video and sound capability on the workstation would also stimulate the attachment of CD-ROM (or equivalent) drives.

Communication, Audio, and Interfaces

Workstations are designed for networking from the ground up, with LAN nodes on the motherboard. Multiple nodes support the attached "clients" on emerging server versions. Ethernet will continue to be the mainstream workstation LAN standard for the foreseeable future, with 10 Base T (twisted-pair media) versions on the low and fiber-distributed data interface (FDDI)/copper-distributed data interface (CDDI) appearing for versions configured for high network traffic or bandwidth requirements (for example, sharing video/images).

ISDN S/T codecs should begin to appear on many versions (or as add-in cards). With U interface (public interface) standard and tariff issues mostly settled, workstations that are part of wide area networks and have the ability to send Group IV faxes would prove highly desirable.

CD-quality audio input and output for speech or music has proven to be a desirable feature in workstations. Dataquest's workstations analysts are confident that audio processing will become a standard function. Some designs are blending the Integrated Services Digital Network (ISDN), fax, and audio functionality together into a single communications function. At the core of audio processing is 8- to 18-bit A/D and D/A conversion and amplifiers, with a medium performance digital signal processing (DSP) MPU or equivalent and an SRAM buffer (256Kb). The bit stream runs between 1.2 and 1.5 Mbps.

In either market, low-end or high-end, strategic engineering/manufacturing relationships between supplier and customer will be very important to success.

SCSI will continue to be the hard disk interface of choice. It will gradually be replaced by higher-performance SCSI II (wide and fast versions). External access to SCSI will grow in popularity with the emerging popularity of attachable CD-ROM drives and scanners.

Most of the bus architectures are open in the sense that third-party add-in boards can be accommodated. Sun/SPARC systems have S bus, the ACE/ARC group and HP have specified Extended Industry Standard Architecture (EISA), IBM has Micro Channel Architecture (MCA), and Silicon Graphics has VME. Futurebus+ may be needed for even higher performance/bandwidth. The primary IC opportunity for buses is in the form of controllers (sometimes part of system logic) and interface logic. With bus speeds getting faster and higher current drive more crucial, BiCMOS interface logic is proving a logical choice in new designs.

Workstation Semiconductor Forecast

Figure 5 and Table 4 show Dataquest's estimate of the workstation semiconductor market. Rigid disk controller, display, and add-in board content are excluded. We expect the semiconductor opportunity represented by workstations to grow at a rate exceeding 50 percent, beginning at $762 million in 1991 and reaching $4.7 billion by 1995. Key semiconductor needs are for DRAM (more than half the bill of materials), 32/64-bit RISC MPUs, and ASIC/ASSP functions and chip sets for various purposes.

Dataquest Perspective

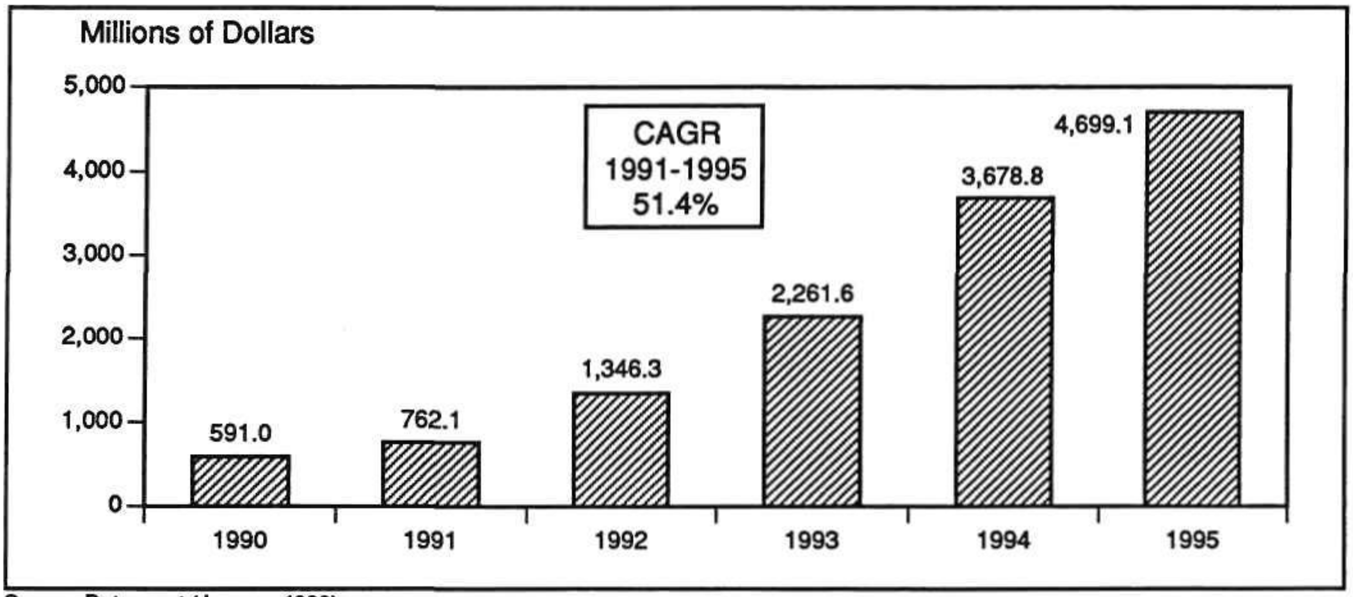
Clearly workstations will be a sound opportunity through the mid-1990s. There will most likely be an OEM shakeout in the entry-level class eventually as scores of companies keep entering under the ACE/ARC and SPARC banners. We predict that standard architectures, buses, and OSs once again will create a monster market. OEM cost control and simultaneous efforts to differentiate hardware will become more prevalent.

As the previous analysis shows, DRAMs will be in big demand for housing the images of new-age OSs, networking, and graphics, among others. There are plenty of opportunities for value-added integrated ASICs and ASSPs, not to mention 32/64-bit RISC and DSP MPUs. Communications functions such as ethernet, ISDN (with fax), and SCSI will also lend themselves to various combinations among themselves and onto system chip sets. It is even conceivable that by 1995 the entry-level workstation motherboard could be like the PCs today with 6 to 10 ICs (excluding memory).

The traditional workstation category and other high-end versions might be a better market for performance-oriented, low-margin-averse chip suppliers. In either market, low-end or high-end, strategic engineering/manufacturing relationships between supplier and customer will be very important to success. The reason is in the grand goal of workstation hardware providers: get to market quicker, through the right channels, at a better performance-for-the-price point.

By Gregory Sheppard

Figure 5
Worldwide Workstation Semiconductor Market Forecast



Source: Dataquest (January 1992)

Table 4
Semiconductor Opportunities in Workstations
(Millions of Dollars)

	1991	1995	CAGR (%) 1991-1995
Functions			
CPU Engine/Cache	145.1	485.4	35.2
System Logic	116.4	417.1	37.6
Main Memory*	372.8	3,011.2	68.6
Graphics/Buffer	77.1	561.9	64.3
Audio Processing	4.7	44.0	75.3
I/O Processing	17.1	54.2	33.4
Networking	20.2	81.2	41.6
Miscellaneous	8.8	44.0	49.5
Total	762.1	4,699.1	57.6
ICs			
MPU	135.3	465.1	36.2
System ASICs/ASSPs	116.4	417.1	37.6
DRAM/VRAM ($/Millions of MBs)*	414.2/10.5	3,427/192.5	6.2
SRAM	12.5	20.1	12.6
Ethernet Chip Set	14.5	64.7	45.3
ISDN S/T Codec	-	16.8	NA
SCSI/SCSI II Adapter	5.5	17.0	32.6
Bus Controller	6.7	16.9	26.0
SCC (or Equivalent)	4.1	20.3	49.2
Audio DSP	3.6	17.2	47.8
Audio A/D, D/A	1.0	6.8	61.5
Graphic Controller	23.3	91.4	40.7
RAMDAC	12.4	54.4	44.7
Interface Logic/PLD	5.2	20.3	40.6
Clock, Nonvol. Memory Miscellaneous	7.4	44.0	44.1
Total	762.1	4,699.1	57.6

*Assumes DRAMs reach $16.80/MB by 1995.
NA = Not applicable
Source: Dataquest (January 1992)

The Pen-Based Computer: The "Walkman" of the 21st Century?

Pen-based computers (PBCs) represent a new class of machines that quickly captured the spotlight in personal computing. These computers may evolve into something significantly different from today's PCs. It is safe to say that current advances in technology have allowed us to revisit the past, the past being the use of pen and paper as the primary form of communication.

Today's pen-based computer is a notebook PC minus the keyboard. The user interacts with the computer using a penlike device. The pen is the primary input device and as such it is no different than a mouse, except in its (familiar) ease of use. It is very difficult to sign or free-form write using a mouse, which is a pointing device.

The pen is much more. Together with the software and the hardware that drive it, the pen turns an ordinary PC into a useful, easy-to-use tool. At least, that is the expectation, which is partly derived from our familiarity with using pens and our belief that computers are useful tools. Combining the two makes sense.

The pen may or may not be connected to the computer by a cord in a pen-based system. There are basically three types of pens: The resistive type connects to the PC like a mouse; the capacitive and the electromagnetic types need no connection. There are pros and cons to any type of pen used. But the pen should not be considered by itself; the software and hardware that drive it form an entity that either works or renders the pen-based computer useless. Specific implementation is a key element in the design of pen-based systems.

The keyboard is an option; most pen-based computer manufacturers offer one because a keyboard is a far more convenient device for entering text of any length. Most people can type faster than they can write. Then again, a keyboard isn't necessary for the millions of people who never learned how to use one effectively. This is a subtle but important difference that differentiates pen-based computers from traditional PCs. A far greater number of people can use a pen than can use a keyboard. By using a pen as an input device instead of the keyboard, computer manufacturers can tap a much larger market than that served by traditional PCs.

Meeting Potential

Pen-based PCs represent a new field in computers and as such need a lot of polishing to reach their potential. The major stumbling block at present is the lack of operating systems, which in turn translates into a limited number of software packages that can run on any given hardware platform. Early hardware entries had to use operating systems developed in-house and thus limited or eliminated the possibility of using off-the-shelf software applications. So far vendors of hardware have taken one of the following approaches:

- Developed in-house proprietary operating systems (OSs) and applications—for example, spreadsheets, personal information management (PIM) software, and word processors
- Used beta-site OS for pen computers from software vendors such as Microsoft Corporation and GO Corporation to develop applications (however, this ties their hardware releases to the release of the OS; NCR Corporation is an example)
- Implemented both of the above (Momenta Corporation developed a proprietary OS that can run either off-the-shelf Windows applications or in-house-developed software such as a PIM, a word processor, and a Lotus-like spreadsheet)

Specifications

A typical pen-based computer today weighs 5 lb and is about 8 × 11 × 1.5 in. It is able to run on batteries for three to six hours, depending on actual use and power management implementation. It is usually built around an Intel Corporation 20-MHz 386SX, 386SL microprocessor, or the newer 25-MHz 386SXL from Advanced Micro Devices Inc. (AMD). Main memory (DRAM) ranges from 2MB to 8MB for a standard configuration. The video graphic array (VGA) display is a 10-inch (diagonally measured) LCD with 640 × 580-pixel resolution and 16 to 32 shades of gray.

For mass storage the typical PBC uses a 40MB, 2.5-inch hard disk. Some PBCs use solid-state storage devices such as the 20MB solid-state disk from SunDisk Inc. or flash memory and flash cards. PBCs have no internal floppy and thus rely on communications software for uploading or downloading data. Alternately they use Personal Computer Memory Card International Association (PCMCIA)-type memory cards or docking stations for data transfers.

For communication PBCs typically offer an integrated modem/fax line, which simplifies connectivity. Some units offer modem/fax/voice capability.

The market for pen-based computers is relatively bright (see Table 1). Unit sales are expected to grow from 96,000 in 1991 to about 4.4 million by 1995. The compound annual growth rate (CAGR) for pen-based computers is 159.75 percent from 1991 to 1995, the highest in the portable PC market. The expected revenue also is substantial, as the average selling price is at least similar to that of a notebook PC.

Figure 1 represents the worldwide market forecast for pen-based computers.

Figure 2 shows pen-based PCs over the same period (1991 to 1995) as a percentage of the total

Table 1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	CAGR (%) (1991-1995)
Laptop	3,172	3,592	3,998	4,370	4,744	10.6
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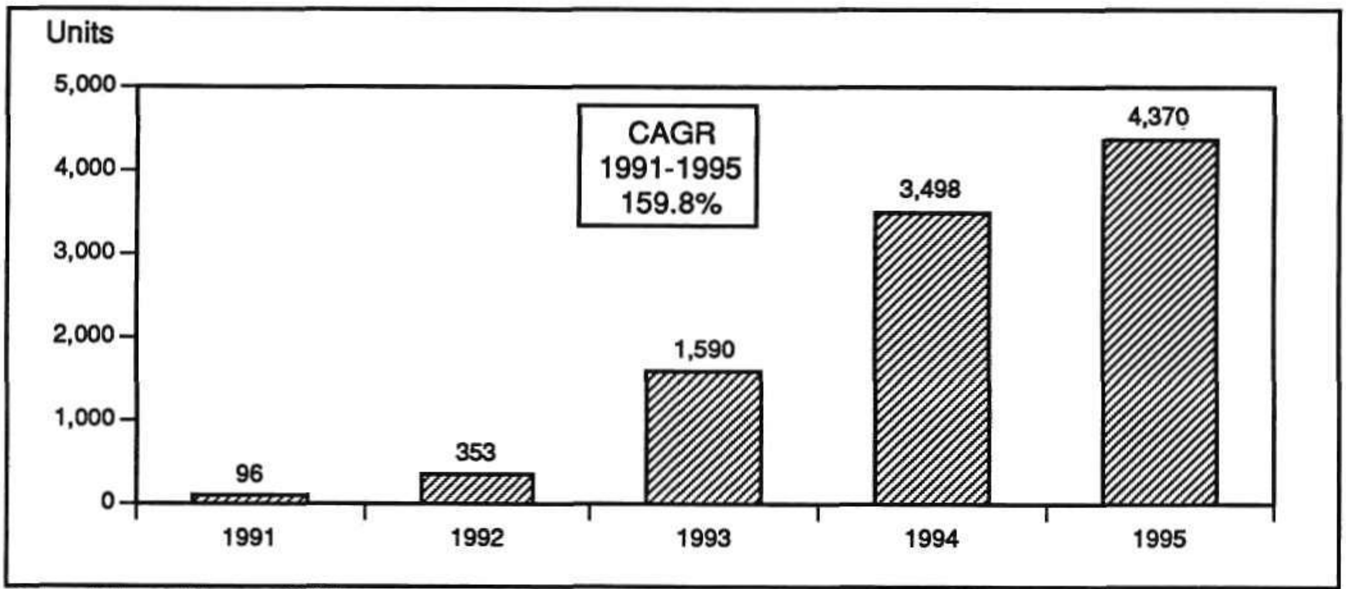
*1992 through 1995
Source: Dataquest (January 1992)

Figure 1
Worldwide Pen-Based PC Market Forecast (Thousands of Units)



Source: Dataquest (January 1992)

portable computer market. At 2 percent in 1991, the market is expected to grow to 15 percent by 1995.

The semiconductor content for a typical pen-based computer retailing of a $3,000 system is about $330. Figure 3 shows the cost distribution on a percentage basis. DRAM represents about 36 percent of the semiconductor content (in dollars). This amount is expected to increase, driven primarily by memory-hungry pen-based OSs.

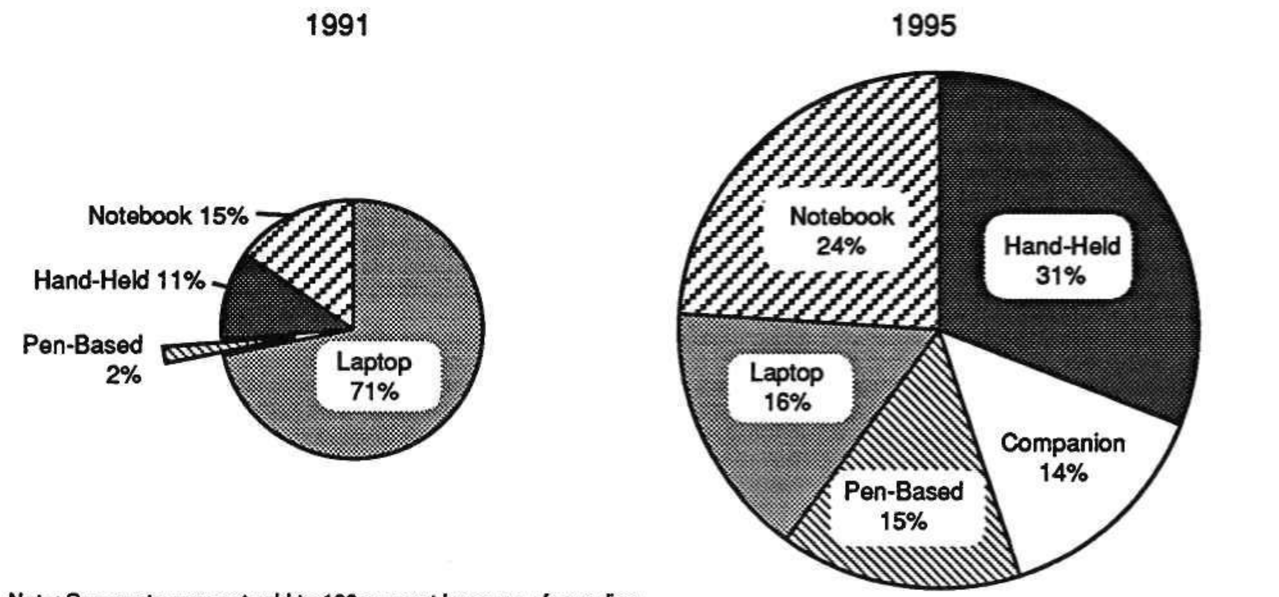
Table 2 shows the semiconductor cost breakdown of a current-generation pen-based computer.

Figure 4 shows Dataquest's total available semiconductor market estimate. Semiconductor revenue derived from PBCs will exceed $1 billion by 1994.

Major players in pen-based computing that offer hardware products include GRiD Systems Corporation, Momenta Corporation, NCR, Samsung, Sanyo Electric Co. Ltd., and Sony.

Major players in pen-based operating systems include GO Corporation (Pen Point), Microsoft (Pen Windows), and Communications Intelligence Corporation (PenDos).

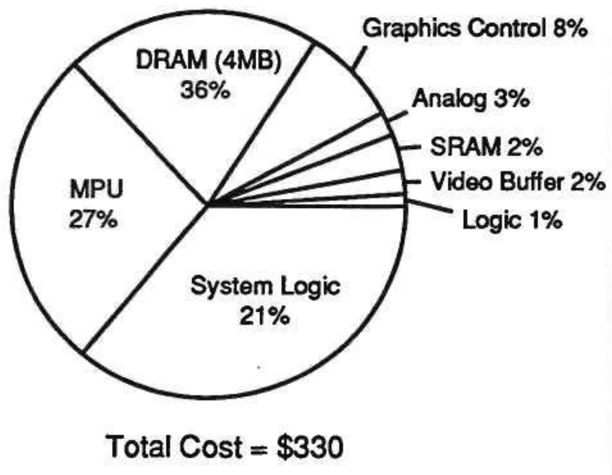
Figure 2
Portable PC Market, 1991 and 1995



Note: Segments may not add to 100 percent because of rounding.

Source: Dataquest (January 1992)

Figure 3
Semiconductor Content Cost for Pen-Based PCs



Source: Dataquest (January 1992)

Table 2
Semiconductor Content, Typical Pen-Based Computer

	Cost ($)
MPU	90.00
Main Memory (4MB DRAM)	120.00
System Logic	70.00
Graphics Controller	25.00
Video Buffer (PS-RAM)	8.00
Analog	10.00
Local Buffers (SRAM)	4.00
Logic	3.00
Total	330.00

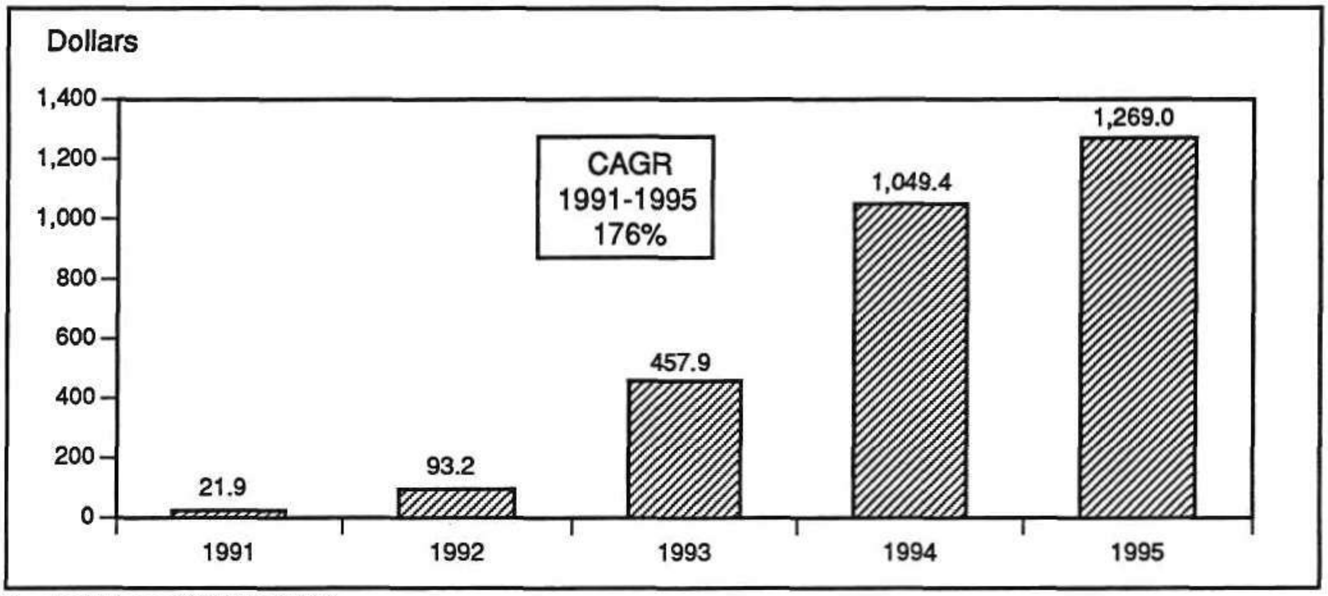
Source: Dataquest (January 1992)

Who is shipping OS? Both Pen Point and Pen Windows are at a beta-site stage right now. Both products are expected to be released by the second quarter of 1992. This delay in operating system introduction has retarded the availability of pen-based computers. Vendors such as Momenta and GRiD had to create their own OS in order to get to the market with a product.

Handwriting Recognition

Even though handwriting (character) recognition is desirable for a pen-based computer, at present it is not a critical item. Momenta's approach is (and rightly so) that the computer does not need to recognize everything sketched onto the screen.

Figure 4
Estimated Total Available Semiconductor Market, Pen-Based Computers (Thousands of Dollars)



Source: Dataquest (January 1992)

This position follows the logic that notes entered into a daytimer are for private use and need not be transcribed; they just need to be stored for future reference/retrieval. On the other hand, handwriting recognition is a desirable feature for Japanese consumers. Success here may translate into high sales for the manufacturer(s) of such pen-based systems.

Connectivity/Docking

A PBC is quite effective as a field or factory floor instrument, but it needs to download the information captured to a mainframe or a PC. That can be accomplished in a number of ways: using a PCMCIA (68-pin) port and memory cards as the transfer medium, or by using radio frequency or infrared communication. A docking station is another alternative.

With respect to communication, current-generation pen-based computers typically offer an integrated modem/fax. The addition of the fax capability is quite handy because it allows a user to receive or send a fax from any place that has a phone jack or to use a cellular phone from practically anywhere.

Applications

Pen-based systems are already used in retail stores. Customers sign for credit card purchases right on the screen of the pen-based PC, which captures the signature in a digitized form and stores it in a hard disk for after-hours phone transfer to a credit card clearing bureau. The use of a PBC instead of the regular credit card imprinter for signing for a purchase speeds up the transaction. Future off-line signature verification will be possible using a smart card (where the customer's signature stored in the smart card's nonvolatile memory is in binary form).

PBCs are very good at applications that require filling out forms. A good example is their use by public utility companies for reading electricity, water, and gas meters. Police departments use them to replace paper forms for traffic violations. In manufacturing they are used to fill out inspection reports. Banks and investment companies use PBCs to fill out standard contracts. They also are quite popular with insurance adjustors and are finding their way into real estate sales.

Dataquest Perspective

As is the case with anything new, it will take some time for pen-based systems to reach their potential. Today lack of operating systems is retarding the growth of this segment. This situation should change in 1992. From a CAGR point of view, pen-based PCs stand out. Over time the distinction between palmtops and pen-based computers may become blurred as palmtops begin to incorporate a pen as an input device. The fax communications capabilities of pen-based computers make them extremely useful to a great number of people who are on the go, substantially enhancing the total available market for pen-based systems. Dataquest believes that pen-based computers offer a significant market growth opportunity for systems manufacturers, software developers, and semiconductor vendors.

By Nicolas Samaras

Inquiry Summary

Semiconductor Application Markets Inquiry Highlights

Dataquest's response to specific questions from clients frequently can be useful for other clients. In this article we provide responses to three recent client questions.

Q: *What is Dataquest's latest worldwide computer forecast?*

A: See Table 1.

Q: *Who are the major players in smart card microcomputers?*

A: In the United States, the major players are Motorola Incorporated and start-up Catalyst Semiconductor. Motorola's key product is the MC68HC05SC21, an 8-bit single-chip microcomputer with 6KB of ROM, 128 bytes of RAM, and 3KB of on-board EEPROM. Programs can execute code from the on-board ROM or EEPROM.

Catalyst offers two products: the CAT62C580 with an 8-bit CPU, 3KB of ROM, 128 bytes of RAM, and 2KB of EEPROM. The CAT62C780 is a similar device with 6KB of ROM, 192 bytes of RAM, and 8KB of EEPROM. The 62C580 and 62C780 cannot execute code from EEPROM.

In Europe the major players are SGS-Thomson, Siemens, and Philips. SGS-Thomson offers the ST16623, with an 8-bit CPU, 224 bytes of RAM, 6KB of ROM, and 3KB of EEPROM. The ST16623 is code-compatible with the Motorola 68HC05SC21. SGS-Thomson also offers a version with 1KB and 2KB of EEPROM. Siemens uses an 8051-derivative microcomputer tailored to smart card applications.

In Japan the major players are Hitachi and Oki Electric Industry Co. Ltd. Hitachi offers the H8/310 8-bit CPU with 10KB of ROM, 256 bytes

Table 1
Dataquest's Worldwide Computer Forecast

	1990	1991	1992	1995	CAGR (%) (1990-1995)
Factory Revenue ($M)					
Supercomputer	1,757	1,901	2,110	2,890	10.5
Mainframe	30,305	28,994	28,475	27,100	(2.2)
Midrange	29,927	29,942	30,745	333,400	2.2
Workstation	7,357	8,675	10,913	21,625	24.1
PC	36,732	39,800	43,700	54,760	8.3
Unit Shipments (K)					
Supercomputer	0.8	0.9	1.1	1.6	14.9
Mainframe	15.1	14.4	14.2	13.6	(2.1)
Midrange	1,025.2	1,038.9	1,080.3	1,218.0	3.5
Workstation	386.1	517.5	790.5	3,385.0	54.4
PC	23,982.5	26,332.8	29,343.8	39,660	10.6

Source: Dataquest (January 1992)

of RAM, and 8KB of EEPROM. Oki offers the MSM62580 and MSM62780 (a joint development with Catalyst; see earlier description of product feature list).

The two most significant products are the Motorola 68HC05SC21 and Hitachi's H8/310.

Q: *What are the major applications using smart card microcomputers?*

A: In Europe the Motorola and SGS-Thomson devices are used as bank cards and for pay TV applications. The upcoming Pan-European Mobile Phone network, GSM, is another high-volume application. The most popular use of smart cards has been as prepaid tokens for payphones. The highest volume is in France, where Dataquest estimates that more than 60 million units were used in 1991.

In Future Issues

The following topics will be addressed in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in ISDN hardware
- Opportunities in performance computer systems

For More Information . . .

On the topics in this issue ....Gregory Sheppard, Sr. Industry Analyst (408) 437-8261
About online access .... (408) 437-8576
About upcoming Dataquest conferences ....(408) 437-8245
About your subscription other Dataquest publications ....(408) 437-8285
Via fax request .... Fax (408) 437-0292

Dataquest

Dataquest Vendor Profile

Semiconductor Application Markets

December 21, 1992

Quantum Corporation

Corporate Statistics

Headquarters Location	500 McCarthy Boulevard Milpitas, California 95035 (408) 894-4000
Date of Establishment	February 1980
Chairman	Stephen M. Berkley
Chief Executive Officer	William J. Miller
Number of Employees Worldwide	1,752
Number of Engineers	325
Number of Sales and Marketing Employees	312
Fiscal Year* 1992 Sales	$1.127 billion
Fiscal Year* 1991 Sales	$877.7 million
Calendar Year 1992 (First Six Months) Sales	$714 million
Subsidiaries	La Cie Ltd.

*Fiscal year ends March 31

Corporate Overview

Quantum Corporation was incorporated as a California corporation in February 1980 and reincorporated as a Delaware corporation in April 1987.

Quantum Corporation is a leading supplier of small form factor rigid disk drives (RDDs) for desktop PCs, workstations, and notebook computers. Quantum provides a broad range of 3.5-inch and 2.5-inch RDDs with capacities ranging from 40MB to 1,225MB. Quantum also designs and markets storage enhancement products that upgrade the capacity of existing desktop PC systems. The company markets its products directly to major OEMs through its worldwide sales force. In addition, the company's newly formed distribution organization, Quantum Commercial Products, focuses on the unique needs of the distribution channel, which includes major distributors, system integrators, smaller OEMs, and value-added resellers (VARs).

For more information on Quantum Corporation or the semiconductor application market, call Nicolas Samaras at (408) 437-8676

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SAWW-SVC-VP-9202

The current product line of Quantum's rigid disk drives is shown in Table 1.

Table 1
Quantum Products

Model Number	Capacity (MB)	Data Surfaces	Track Density (tpi)	Bit Density (bpi)	Interface
3.5-Inch Disk Drives					
ProDrive ELS 42AT	42.00	1	1,800	38,624	IDE
ProDrive ELS 42S	42.00	1	1,800	38,624	SCSI-2
LPS 52AT	52.00	2	1,330	29,307	IBM
LPS 52S	52.00	2	1,330	29,307	SCSI
LPS 80AT	85.00	4	1,330	29,307	IDE
ProDrive ELS 85S	85.00	2	1,800	38,624	SCSI-2
ProDrive ELS 85AT	85.00	2	1,800	38,624	IDE
LPS 105S	105.00	4	1,330	29,307	SCSI
LPS 105AT	105.00	4	1,330	29,307	IBM
LPS120	122.00	2	1,900	38,000	IBM
LPS120S	122.00	2	1,900	38,000	SCSI
ProDrive ELS 127AT	127.00	3	1,800	38,624	IDE
ProDrive ELS 127S	127.00	3	1,800	38,624	SCSI-2
ProDrive ELS 170S	170.00	4	1,800	38,624	SCSI-2
ProDrive ELS 170AT	170.00	4	1,800	38,624	IDE
LPS240S	245.00	4	1,900	38,000	SCSI
LPS240	245.00	4	1,900	38,000	IBM
ProDrive 425i	425.80	9	1,695	36,923	SCSI-2
ProDrive 425S	425.80	9	1,695	36,923	SCSI
ProDrive 425AT	425.80	9	1,695	36,923	IBM
LPS450S	450.00	6	2,150	49,731	SCSI
LPS450	450.00	6	2,150	49,731	IBM
ProDrive LPS 525AT	525.00	6	2,670	50,500	IDE
ProDrive LPS 525S	525.00	6	2,670	50,500	SCSI-2
ProDrive 700S	700.00	8	2,670	50,500	SCSI-2
ProDrive 1050	1,050.00	12	2,670	50,500	SCSI-2
ProDrive 1225S	1,225.00	14	2,670	50,500	SCSI-2
2.5-Inch Disk Drives					
Go-Drive 40S	42.00	2	1,801	46,900	SCSI
Go-Drive 40AT	42.00	2	1,801	46,900	IBM
Go-Drive 60AT	64.70	2	2,000	56,688	IBM
Go-Drive 60S	64.70	2	2,000	56,688	SCSI
Go-Drive 80AT	84.00	4	1,801	46,900	IBM
Go-Drive 80S	84.00	4	1,801	46,900	SCSI
Go-Drive GRS 80S	84.00	2	2,500	58,878	SCSI
Go-Drive GRS 80AT	84.00	2	2,500	58,878	IDE
Go-Drive 120AT	130.00	4	2,000	56,688	IBM
Go-Drive 120S	130.00	4	2,000	56,688	SCSI
Go-Drive GRS 160S	169.00	4	2,500	58,878	SCSI
Go-Drive GRS 160AT	169.00	4	2,500	58,878	IDE

Source: Quantum Corporation, Dataquest (December 1992)

Corporate History

Founded in 1980 to produce 8-inch diameter RDDs, Quantum proceeded to become a major supplier to this unique and trailblazing market. Microcomputers had just been developed and 8-inch flexible disk drives were the primary storage devices for this new segment of the computer market. Quantum produced the Q-2000 drive with storage capacities ranging from 10MB to 40MB (unformatted). After pushing the capacity to 85MB in 1982, Quantum made its move to higher technology and introduced fast access drives in 1983. These products used patented recording head positioning technology that was to keep the company in a leadership position for the rest of the decade. Its proprietary optical encoding, servo wedge, and temperature compensation technology was used in new Quantum products through 1991.

Joining the rapid movement to the 5.25-inch RDD market, Quantum introduced the Q-500 series of drives in 1982 with 20MB, 30MB, and 40MB devices, gaining 25 percent market share in its first year of shipments. The Q-540 was considered the most reliable product at that time and became an industry standard in small computers.

In April 1985, Quantum introduced an advanced 5.25-inch drive with half the height of most drives (1.625 inches versus 3.25 inches). This drive was also one of the first intelligent drives, embedding the disk controller in the drive, and was known as the Q-200 series. These drives offered 53MB to 80MB formatted capacities with the SCSI. Dedicated to producing its own SCSI interface semiconductor parts, Quantum found itself struggling to deliver on this promise. The software to run the intelligent drive and the design technologies for the chips were more complex than any disk drive company had previously encountered.

At the same time, 3.5-inch RDDs were first announced. Quantum's delivery of the Q-200 was delayed so long that the company's sales suffered. In June 1987, it became evident to Quantum management that an overhaul of corporate product strategy was necessary; the subsequent plans not only saved the company, but also put it in the positive position it enjoys in 1992.

The decision to spin off a group of engineers to develop a retail storage product had already been made. Headed by the current chairman, Steve Berkley, a small staff under the banner of "Bits in Space" started development of a disk drive mounted on a standard PC printed circuit card. The drive was a fully self-contained storage subsystem that the average computer user could simply plug into an IBM PC slot. The task force grew in numbers and moved into leased Dataquest office space, assuming the name of QEW (often thought to stand for Quantum Excess Workers). Plus Development was the final name for the subsidiary, and the 10MB Hardcard was formally announced in 1985.

Shortly after the Hardcard development came the decision to write off all previous 8- and 5.25-inch products. The decision was dramatic because, once the company turned its back on its revenue-producing stream of products, the entire future of Quantum rested on a newly announced series of 3.5-inch drives and the Plus Hardcard.

In retrospect, the company management still wonders if it should have delayed the phase-out, but the results ultimately produced the desired rebound in sales. As a result of the write-offs, Quantum realized a loss for the first time since its start up but has not looked back since. Figure 1 shows Quantum's quarterly sales volumes since the beginning of 1988.

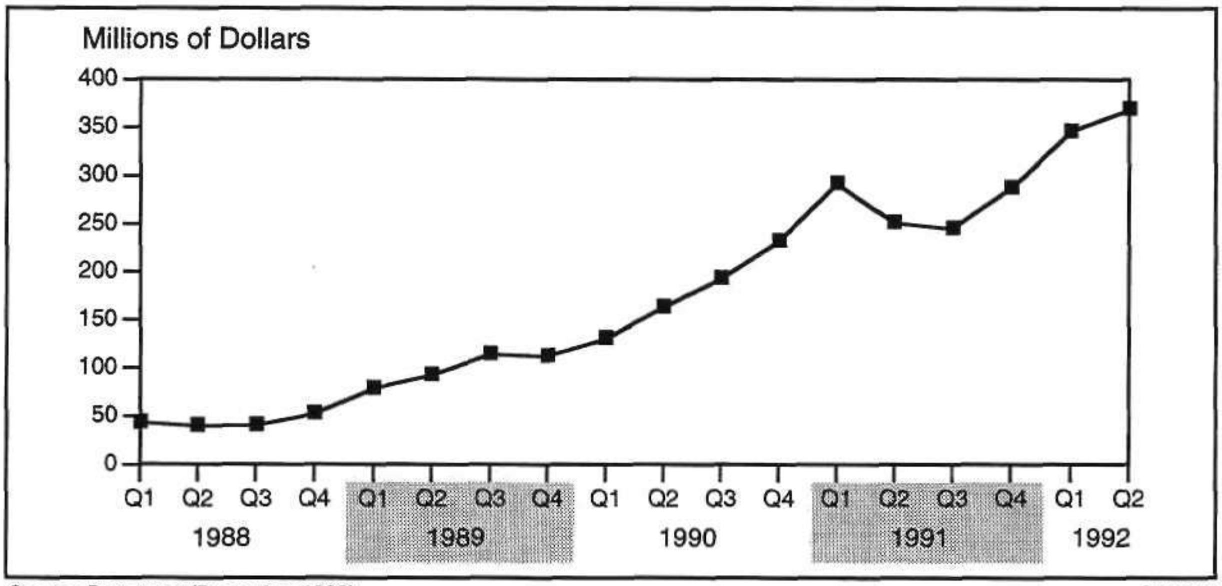
The ProDrive series of 3.5-inch drives sold more than 3 million units over its life span, with Apple Computer's use of the drives in its new Macintosh computers driving this success.

Operations

Quantum operates in an industry characterized by increasingly shorter product life cycles. Accordingly, the company is committed to developing new products and bringing them to market faster than ever before.

The rigid disk industry is also noted for rapid technological changes. To ensure that Quantum continues its pace of technological advancement, the company formed two R&D groups that concentrate on developing new technologies to increase the performance, reliability, and capacity of its RDDs. In order to achieve efficient volume production of new products, and to maintain the efficiency of current manufacturing lines, Quantum provides a continuous investment of

Figure 1
Quantum's Quarterly Sales Revenue



Source: Dataquest (December 1992)

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engineering resources to the development of tooling, production processes, and specialized test equipment.

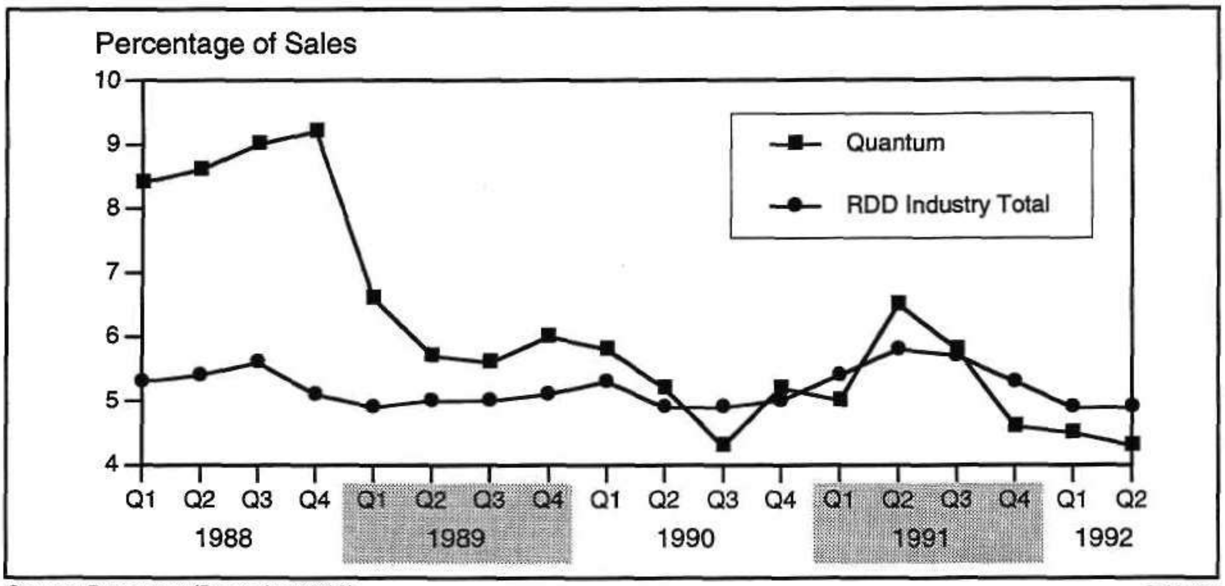
For the fiscal years 1992, 1991, 1990, and 1989 (ended March 31), the company's R&D expenses were $59.3 million, $43.3 million, $25.8 million, and $16.8 million, respectively. Figure 2 shows Quantum's R&D expenses as a percentage of sales, stated on a quarterly basis since 1987.

The figure shows that Quantum has normally spent a greater percentage of its sales revenue for developing new products than the total percentage spent by major RDD industry participants (Conner Peripherals, Maxtor Corporation, Micropolis Corporation, and Seagate Technology) combined. The sharp drop at the beginning of 1989 was not an indication of lower spending but a reminder that Quantum's sales volumes have grown rapidly.

Quantum is committed to a manufacturing strategy that will give the company a competitive edge in the disk drive industry. Quantum's manufacturing partner is Matsushita Kotobuki Electronics Industries Ltd. (MKE). MKE is a Japanese company renowned for its sophisticated, high-volume, electromechanical manufacturing capabilities. MKE currently manufactures the ProDrive LPS and ELS drives, Go-Drive Series, Passport products, and Hardcard products. MKE's primary factory is located in Ipponmatsu, Japan.

There has been an eight-year relationship between the two companies, scheduled for renegotiation at the end of 1992. MKE constructed a new disk drive factory in Ireland in 1992 specifically to manufacture Quantum disk drives. There is little likelihood that the companies will

Figure 2
R&D as Percentage of Sales



Source: Dataquest (December 1992)

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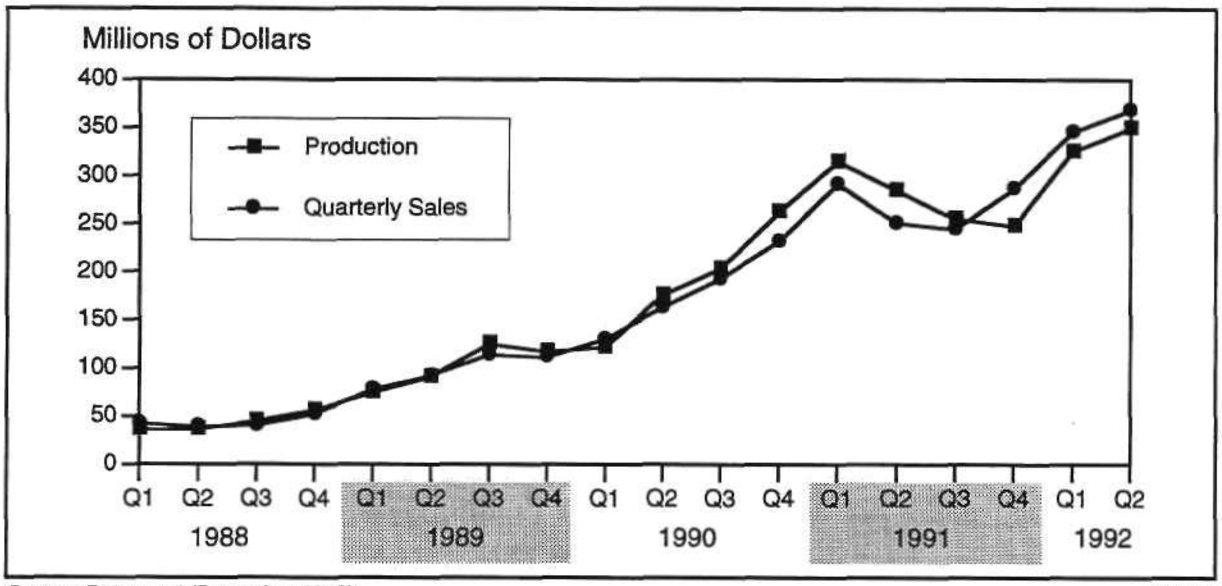
not be able to come to accord on a new agreement. Quantum also operates a factory in Milpitas, California, where its high-capacity ProDrive products are currently produced. This new facility contains three Class 10 clean rooms, automated workstations, sophisticated robotics, and continuous flow processing.

In fiscal 1992, more than 80 percent of Quantum's sales were derived from products manufactured by MKE. MKE has exclusive worldwide manufacturing rights to Quantum products, while Quantum retains exclusive worldwide rights to design and market these products. Quantum provides forecasts of its needs and places orders approximately 90 days before delivery requirements. The two companies renegotiate the pricing structure periodically, usually annually.

Quantum and MKE purchase components, some of which are made to Quantum's specifications, from outside vendors. Most of the components used in its products are available from more than one supplier. In the past, limited availability of certain key components has constrained the company's revenue growth. The entire disk drive industry has been in a backlog situation in 1992, and these shortages, in most cases, can be attributed to conservative inventory management by component suppliers and drive makers alike. Quantum has allocated most of its product to the OEM channel during this period, resulting in some shortages in the distribution channel.

Figure 3 shows Quantum's ability to manage inventories and balance sales forecasts to build forecasts as presented to MKE. The line marked "production" is actually the quarterly sales total adjusted by the change in inventory from the previous quarter. If the line exceeds

Figure 3
Inventories and Sales



Source: Dataquest (December 1992)

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the sales curve, it is an indication of building to inventory. When the "production" curve is below the sales curve, the company's products are likely on allocation. This curve vividly shows the disk drive recession in 1991, when too many products were built at first. However, production rates were curtailed, and the market then caught up to inventories and production rates—which resulted in shortages.

The result of the relationship between Quantum and MKE is that Quantum does not require capital investment in massive production capacity. As a result, the company has remained debt-free.

Organization

Quantum's corporate management organization chart normally defies traditional logic. The style of Quantum management has been described as "Dial 1-800-MBA." Each person in a responsible position is, indeed, highly educated. Beyond formal schooling, Quantum's culture is steeped in creativity and tempered with common sense. Quantum is led by a chairman with a bent toward the offbeat Hardcard and a personal desire to overtake Conner Peripherals position as No. 2 in the RDD industry. Mr. Berkley came to the company with a background in market research and strategic planning.

David Brown, Quantum's vice chairman, was the founding vice president of engineering. Mr. Brown was cofounder of Plus Development, returning to Quantum in 1986 to engineer the company's transition to 3.5-inch products. He became president and COO in 1987 and was promoted to vice chairman in 1989. (Mr. Brown's pending retirement is one of the longest running rumors in Silicon Valley.)

In a surprise announcement in March 1992, William J. Miller was made CEO. Mr. Miller came to Quantum after 11 years with Control Data Corporation (CDC). He also served as president and CEO of Imprimis Technology at the time it was acquired by Seagate Technology. Mr. Miller's years of experience, along with his outgoing personality, make him a visible spokesperson for Quantum and a strong CEO.

Quantum has two executive vice presidents. Joseph T. Rodgers, who is also CFO and secretary, was vice president of finance at Quantum in 1980 and has held top corporate positions throughout its history. Michael A. Brown is Quantum's executive vice president, in charge of day-to-day operations of the business. Mr. Brown joined the company in 1984 as a product manager and advanced rapidly as the company grew. He became vice president of marketing in June 1990 and was promoted to his current position in February 1992. As a result, Mr. Brown is one of the fastest-rising young managers in the industry and—definitely—the youngest corporate general manager.

One of the unique features of Quantum's organizational structure is its lack of a president. The other is the alignment of the operational units into market-demand segments. The first business units formed were the business PC group and the portable storage group. The two groups have recently been combined into the business PC/portable storage group. This consolidated group is managed by Marlin Miller. The latest unit to be announced was the high-capacity storage group, headed by Robert Maeser. This group was formed to concentrate on the upscale market, such as workstations and midrange computers. (Mr. Maeser was once vice president of the Imprimis small disk division in Oklahoma City, Oklahoma.) The business units are formed to control product development, manufacturing, and marketing of products that are directed to solving problems in specific applications.

Marketing

Quantum markets its products directly to major OEMs through its worldwide sales force. There are 13 sales offices in the United States and Canada. Additional offices are located in Europe, Taiwan, Japan, and Singapore. During fiscal 1992, Quantum's largest OEM customer was Apple Computer, which accounted for approximately 25 percent of consolidated sales, compared with 34 percent in fiscal 1991 and 42 percent in fiscal 1990. No other customer accounted for sales in excess of 10 percent in fiscal 1992, 1991, or 1990. Some of Quantum's other big-name buyers include Acer, AST Research, CompuAdd, Dell, Hewlett-Packard, Intel, Olivetti, Samsung, Sun Microsystems, Tandy, Unisys, and Zenith.

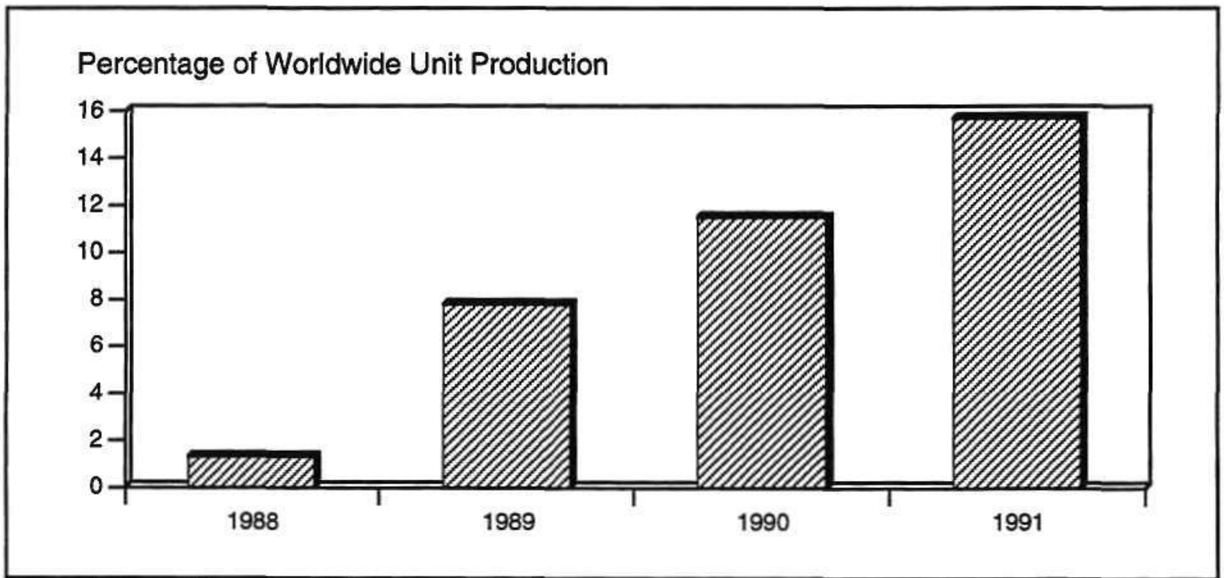
The accomplishments of Plus Development in the retail distribution channel have been pathfinders for the storage subsystem industry. One of its keys to success was its ability to establish a strong worldwide brand recognition. Plus Development was merged back into Quantum in 1991. The management was put in charge of all distribution strategies for the company, which is now known as Quantum Commercial Products (QCP). Quantum's lone subsidiary, La Cie Ltd., comes from an acquisition and is a direct marketing company that serves the Apple Macintosh aftermarket.

QCP's major distribution customers include Arrow Electronics, Future Tech, Ingram Micro-D, and Marshall Industries. Sales to the distribution channel accounted for 36 percent of sales for fiscal 1992, increased from 31 percent in 1991.

Quantum maintains sales offices throughout the world. International sales, which include sales to foreign subsidiaries of U.S. companies, accounted for 52 percent of sales for fiscal 1992, compared with 45 percent of 1991 sales and 32 percent in 1990. Repair facilities are located in Milpitas, Singapore, and Frankfurt, Germany.

Quantum has enjoyed an increased market share of the total worldwide 3.5-inch disk drive market every year since it began production of these drives. Figure 4 shows the company's market share as a percentage of total production. Dataquest believes that Quantum will continue to increase its share of both the 2.5-inch and 3.5-inch markets.

Figure 4
Quantum's 3.5-Inch Worldwide Market Share as a Percentage of Production



Source: Dataquest (December 1992)
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Dataquest Perspective

Quantum's position in the merchant RDD market appears secure. The advantages that assure its success include the following:

- The MKE manufacturing relationship that provides top-quality, high-yield products without constant physical plant capital expenditures from Quantum
- A solid patent portfolio, recently reinforced by a full cross-licensing agreement with Seagate Technology
- Sound management—people and principles
- Strong OEM relationships with major computer vendors
- Superior distribution experience and packaged products for that market
- A product portfolio that meets a broad range of system requirements in the fastest-growing markets

The following potential risks in Quantum's future are speculative, but could materially affect its success:

- Collapse of the MKE relationship and loss of the manufacturing facilities
- Loss of the Apple contract for any reason
- Inability to advance recording density technology so as to miss the product window on future generations of high-capacity disk drives

There are no indications that any of these risks will become a reality.

All in all, Quantum's future appears secure. More rapid movement into the worldwide distribution market is under way and will tend to give further incremental revenue growth to an already aggressive OEM sales program.

Dataquest Vendor Profile

Semiconductor Application Markets

September 7, 1992

Sony Corporation

Corporate Statistics

Headquarters Location	Tokyo, Japan
Date of Establishment	May 1946
Chairman	Akio Morita
Chief Executive Officer and President	Norio Ohga
Number of Employees Worldwide	95,600
Number of Sony USA Optical Division Employees	99
Number of USA Optical Marketing and Sales Personnel	77
Number of Sony Optical-Related R&D Employees	250 (in Japan)
Fiscal Year* 1990 Sales Revenue	¥2,879,856 million
Fiscal Year 1991 Sales Revenue	¥3,616,517 million
Calendar Year 1991 Optical Products Revenue	U.S.$239.7 million
Number of Optical Business Partners	75

Sony Corporation was one of the first major Japanese companies to enter the optical storage market. Its R&D work, covering all aspects of optical technology, dates back to the 1970s. Since the first shipment of its 12-inch write-once drives in December 1984, Sony introduced many new drives and disks. Sony started shipping the first 5.25-inch rewritable drives in the fourth quarter of 1988, beating its nearest rivals—Ricoh Corporation and Olympus Corporation—by about six months. In February 1991, Sony announced that it had developed the IRIS Thermal Eclipse Reading (IRISTER) technology, which enables the readout of data in the sequence of very small recording pits that are much shorter than the resolution limit of conventional optical theory. When used with conventional laser technology, IRISTER technology provides for a sixfold increase in the storage capacity of current magneto-optical (MO) disks. In June, Sony announced that its research staff had successfully developed a technology that would triple the

For more information on Sony Corporation or the semiconductor application markets industry, call Gregory Sheppard at (408) 437-8261

*Fiscal year is from April to March.

storage capacity of compact disks. This technology uses the blue semiconductor laser. Sony believes that, with the development of blue-light lasers, even greater densities can be achieved with the IRISTER MO disks, resulting in a storage capacity of more than 20 times that of existing disks.

Sony Corporation has a vision and maintains a strong commitment to the optical storage business as a strategically important unit. The high level of commitment and dedication of resources are reflected in Sony's dominant market position in the optical storage drive and disk markets.

This profile takes a closer look at where Sony's optical business stands today and comments on Sony's future directions in this emerging market.

Corporate Overview

Sony is a leading manufacturer and marketer of audio-video equipment and software. Sony's brand is well known all over the world. Sony has aimed for a global operation for the past 40 years and operates many affiliates at home and abroad, including 689 consolidated affiliates and 15 stockholding companies. Consolidated overseas sales account for 75 percent of its total sales.

Sony has two major operations in electronics and entertainment. The businesses under these two operations are as follows;

- Electronics
  - Video equipment—23 percent of total sales revenue
    - VCRs for home use, laser disc players, video equipment for broadcast and professional use, still-image video cameras, and videotapes
  - Audio equipment—25 percent of total sales revenue
    - Compact disc (CD) players, minicomponent stereos, hi-fi components, radio-cassette tape recorders, headphone stereos, digital audio tape (DAT) players, radios, car stereos, audio tapes, and audio equipment for professional use
  - Televisions—16 percent of total sales revenue
    - Color television sets, monitors, satellite broadcast reception systems, projectors, displays for professional use, and giant display systems
  - Other products—16 percent of total sales revenue
    - Semiconductors, electronic components, computers, telephones, telecommunications equipment and AF systems, and data storage products

- Entertainment
  - Music entertainment—11 percent of total sales revenue
    - Music- and image-based software produced by Sony Music Entertainment Inc. and Sony Music Entertainment (Japan) Inc.
  - Film entertainment—9 percent of total sales revenue
    - Columbia Pictures Entertainment Inc.—which includes Columbia Pictures, Tri-Star Pictures, Columbia/Tri-Star International Releasing Corporation, Columbia Pictures Television, Merv Griffin Enterprises, and Loew's Theater Management Corporation

Sony's business mix shows a clear awareness of the interrelated nature of hardware and software. Through its firm commitment to R&D, Sony built a reputation as a pacesetter in the electronic equipment industry.

Sony's regionally controlled companies are strategically located in the United States, Europe, and Asia; a four-point world system (including Japan) has been established. The top international managers meet twice a year to formulate global management strategies.

Promising long-term products include the minidisc (MD), high-definition television (HDTV), and multimedia. Sony is investing considerably in these products. The MD is the digital audio replacement for the conventional cassette tape recorder and offers portability, fast program selection, and playback using 64mm-diameter photomagnetic discs. Sony has begun marketing a 32-inch HDTV for ¥1.3 million and is demonstrating the format at its Tokyo and Osaka showrooms. Sony also supplies HDTV movies in the laser disc format. Together with the U.S. companies Apple, Microsoft, and Motorola, Sony is developing multimedia equipment in CD-ROM XA and interactive CD (CD-I) formats.

As an enabling technology and integral part of multimedia computing, the CD-ROM product line is particularly important in Sony's overall optical storage strategy. Sony was the codeveloper with Philips of the CD technology, both for audio and data storage.

The Sony 12-inch write-once/read-many (WORM) technology is widely used in many U.S. government applications, such as patent data and the national archives. Sony continuously demonstrates to its users its commitment to this technology by introducing new products with better price/performance ratios and, at the same time, promises backward compatibility with its installed media. Sony's 5.25-inch rewritable drives show up in many third-party vendors' optical library product offerings. The company is a major supplier of 5.25-inch rewritable and multifunction drives to OEMs and resellers in the United States. Sony is the first company to offer a complete solution, with its 3.5-inch MO drives, to computer reseller channels.

Organization

Sony created a massive U.S. organization—Sony USA Inc.—to ensure a leadership role in optical data storage. Two individual subsidiaries—under Ken Iwaki, the president of Sony USA Inc.—handle products related to optical technology. These subsidiaries are Sony Corporation of America and Sony Electronic Publishing Company. Sony USA Inc. provides financial, tax, and administrative services to its subsidiaries.

Sony Corporation of America

Sony's Computer Peripherals Products Company (CPPC), under Sony Corporation of America, is chartered for the marketing and sales of Sony's optical storage products in the United States. The nationwide marketing coverage of CPPC is subdivided by having marketing managers for each type of optical drive. The sales coverage is divided by channel type and the appointment of each salesman to the targeted channel representing all the storage products. CPPC's headquarters is in San Jose, California; the staff at headquarters directs the business activities. The 12-inch WORM division is in Park Ridge, New Jersey. Engineering and local technical support are located in Boulder, Colorado.

In early 1991, Sony formed a separate optical media group—Sony Recording Media of America—to address all aspects of the media business. This group operates as a subset of the overall recording media operations in the United States. The optical media group oversees all aspects of the growing optical media business, including distribution issues. As part of the commitment to optical technology, Sony Recording dedicated the Sony Recording Media Laboratory in Boulder, Colorado, this past February. The new facilities provide testing, evaluation, and problem-resolution services for a wide range of magnetic and optical storage technologies—including quarter-inch cartridge tape; 8mm and 4mm digital data storage data cartridges; 1/2-inch, 19mm, and 1-inch mass storage digital instrumentation cartridges; and 5.25-inch and 3.5-inch MO rewritable and write-once media. The laboratory will be equipped to handle quality assurance, environmental, and electrical testing operations.

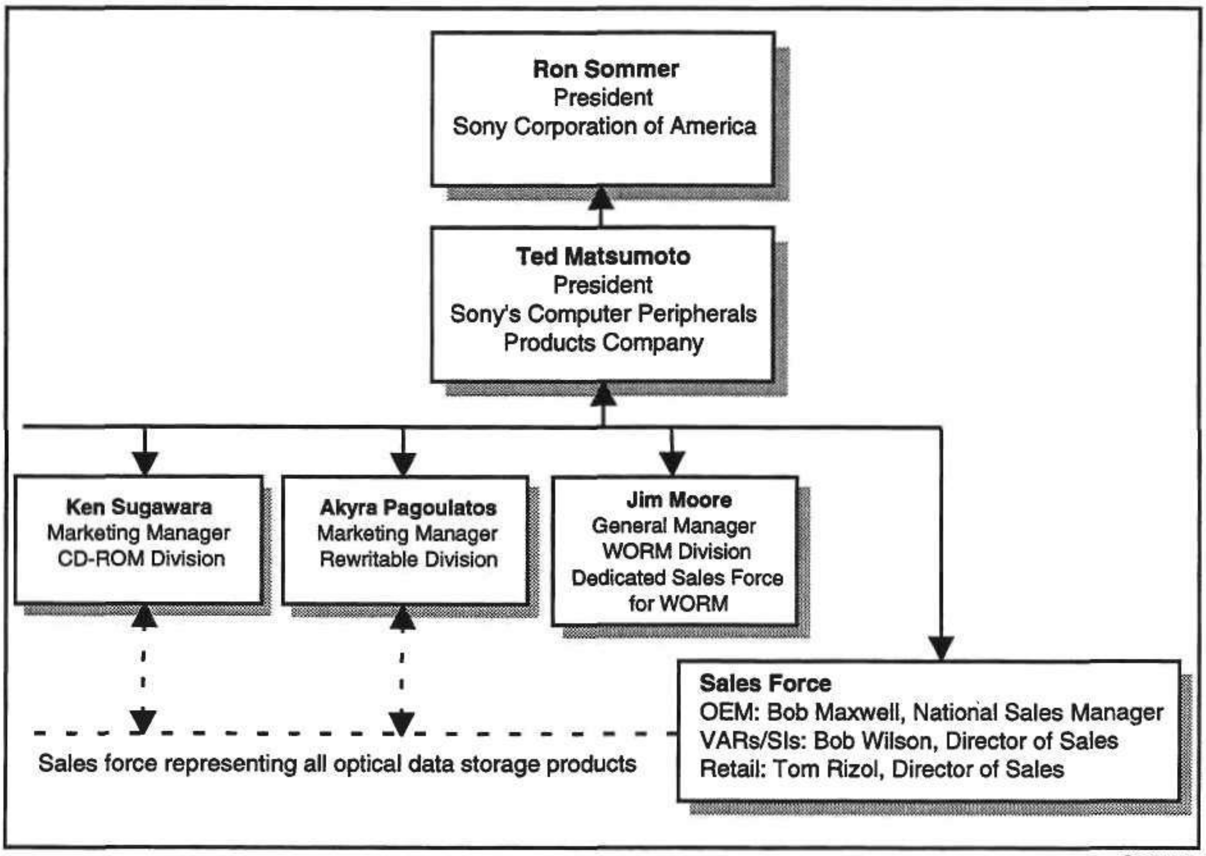
Ted Matsumoto is the president of the Sony's CPPC. As shown in Figure 1, the product marketing team reports to Mr. Matsumoto.

Sony Electronic Publishing Company

Sony Electronic Publishing Company (SEPC) creates, produces, and distributes interactive and multimedia software products for the business, entertainment, and educational markets. SEPC officially began operations on April 1, 1991, and joined Sony Pictures Entertainment and Sony Music Entertainment as subsidiaries of Sony Software Corporation, a division of Sony USA Inc.

Michael P. Schulhof, president of Sony Software, serves as chairman of SEPC. Olaf Olafsson is president of SEPC. Reporting to Mr. Olafsson, Robert Headrick is vice president of SEPC and directs

Figure 1
Sony's Optical Data Storage Business Units



Source: Sony Corporation, Dataquest (September 1992)

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the activities of SEPC's Publishers Data Service Corporation, Multimedia Productions, and Recorded Media divisions.

SEPC specializes in developing software products using optical storage technology. The company works closely with other companies in developing, marketing, and distributing CD-ROM software products for its own markets, as well as providing services that enable third-party vendors to become CD-ROM software developers. SEPC also provides marketing and sales support for Sony's CD-ROM and laser disc manufacturing operations.

In addition, SEPC works with other Sony companies developing software for new consumer electronic markets. SEPC licensed, manufactured, and bundled the software for Sony's Laser Library, a PC-compatible CD-ROM system for home use. SEPC developed and produced most of the electronic book titles for Sony's Data Discman electronic book player. The company is also pursuing opportunities in emerging optical technologies for the children's and interactive markets. The operating divisions under SEPC and their charters and key executives are as follows:

- Division—Publishers Data Service Corporation (PDSC), Monterey, California
  - Charter—To provide authoring software and technical support to assist companies in becoming electronic and optical publishers
  - Services—Data preparation and formatting, production, consultation, and project management
  - Key executive—Greg G. Smith, general manager
- Division—Multimedia Productions, Monterey, California
  - Charter—To license, develop, market, and distribute optical-based software products
  - Products—CD-ROM for OEMs; for electronic book players; and for PC-, MPC- and Mac-based CD-ROM systems (Products are distributed through retail outlets and VARs.)
  - Key executive—Francis M. Juliano, optical publishing manager
- Division—Recorded Media, San Jose, California
  - Charter—To provide sales, marketing, and technical support for the CD-ROM and laser disc service of Sony's Digital Audio Disc Corporation (DADC), including mastering, replication, disc production, packaging, and distribution
  - Key executive—Bob Hurley, national sales and marketing manager
- Division—Sony Imagesoft, New York, New York
  - Charter—To develop, produce, and market video game software for video game systems

Optical Storage Marketing

Sony markets and sells optical mass storage products— both independently with its own brand name through retail channels and in concert with OEMs, VARs, systems integrators (SIs), and distributors worldwide. Sony has forged long-term OEM relationships with large system vendors such as the Hewlett-Packard Company (HP), Sun Microsystems, and Apple Computer. In the United States alone, Sony has more than 38 VARs, SIs, and distributors in its camp.

Sony's keen awareness of the importance of software is demonstrated by its close marketing and business partnership with Microsoft in CD-ROM XA and other multimedia-related markets.

Sony positions itself as the company that provides a full range of mass storage products. Sony's overall marketing message comes through loud and clear to potential customers—that is, when the customer buys mass storage products from Sony, the customer is working with Sony to come up with the most practical solution for the application. The issues are not optical versus magnetic or rewritable and multifunction optical versus write-once optical; rather, Sony helps its customers identify those applications that require a combination of those technologies.

Sony identifies various appropriate applications for its optical storage devices and focuses its marketing resources on penetrating those target market segments.

For CD-ROM drives, Sony targets the major system vendors for its OEM business. Sony has been successful in securing these accounts. Among the major OEM customers are Sun Microsystems, Apple, and other first-tier PC-clone vendors. Sony also focuses on the national and regional distributors—which, in turn, sell to smaller OEMs, VARs, and SIs.

At the end of 1991, Sony began to experiment selling direct to end users through retail channels with its Laser Library, which is a plug-and-play CD-ROM drive bundled with software titles targeted at home users. Dataquest believes that this move signifies the shift in Sony's marketing focus from OEM, VAR, and SI channels to direct channels through retail.

The objective of this new strategy is to saturate all the possible distribution channels before the competition. Sony is prudent in pursuing this strategy because of its high leverage on Sony's broad brand name recognition and readily available retail channels, which have been selling Sony brand consumer electronics for years.

In addition, Sony is the most experienced consumer electronic marketer among the electronics manufacturers. This core competence is clearly leveraged all the way from the Laser Library product introduction, advertising, title selection, packaging, to pricing.

Recognizing the WORM technology is an application-specific medium, Sony focuses this technology in vertical markets. The targeted industries include the following:

- Medical
- Legal and law enforcement
- Banking
- Seismology
- Government
- Pharmaceutical
- Financial institutions

Sony understands that the utilization of WORM technology is determined by the software and system components designed around it, and its functionality is tailored to meet the specific needs and requirements of the individual applications. To offer the total solution, Sony has developed a network of VARs, SIs, and OEMs. These groups design the software needed to drive the WORM optical hardware. Through this network, the hardware and software are seamlessly integrated into systems that are completely suited to each market and use. Table 1 shows a sample of Sony's WORM technology business partners.

Sony introduced 5.25-inch rewritable optical technology in October 1988. Sony produces and distributes 5.25-inch and 3.5-inch rewritable optical media, drives, and subsystems. The company focuses its marketing resources on the following target markets through OEMs, VARs, SIs, and national and regional distributors:

- Publishing
- CAD/CAM/CAE
- Legal and financial services
- Medical and scientific imaging

Target applications are as follows:

- Primary, online storage
- Data archiving
- Data distribution
- Secondary backup
- Database management
- LAN file server
- CD-ROM premastering
- Software distribution
- Fault-tolerant systems
- Data security

As the first vendor shipping 5.25-inch rewritable drives, Sony won many resellers to its camp. These resellers incorporate Sony's drives into their systems or resell the standalone drives to their specific vertical markets. A sample of the major Sony's resellers is shown in Table 2.

Overall, Sony employs the pulling strategy for its optical product line to increase the size of the total market in order to maintain its market share leadership position. The company invested significant amounts on education and promotional coverages. Dataquest estimates that, in the first six months of this year alone, Sony spent $750,000 to $1 million on advertising its optical rewritable products. The resources available to Sony's Optical Product Division, the commitment to this "foundation technology" from the top management, and the marketing group with a strong sense of product ownership are among the many competitive advantages that Sony has over other players.

Table 1
Sony's Write-Once Disk Business Partners

Partners/Location	Product/Description	Industry Specialty
Applied Programming Technologies Inc. Lake Success, NY	Network Object Storage Software—Transparent jukebox management software	Document Imaging
Aquidneck Systems International Inc. N. Kingstown, RI 02852	The Optical Archiving System—A high-speed caching controller for optical disk drives and autochangers	Document imaging
Borett Automation Technologies Westlake Village, CA	AUTOMAN VLC Jukebox series of automated tape/disk library assistant products	Robotic vision and document imaging markets
Data General Corporation Westboro, MA	OpStar—An optical disk storage solution with file management software for AViiOn systems	Health care, insurance, government, publishing, law, financial services, manufacturing, energy and oil, document imaging, and aerospace
Data Tree Corporation San Bernardino, CA	Imaging systems and management and database management services	Imaging
Epoch Systems Westborough, MA	The Epoch Data Server—Hierarchical storage management, online archiving, backup and disaster recovery, and robotic library management	CAD/CAM, seismic, imaging, mapping, financial, education, and government
GeneSys Data Technologies Hunt Valley, MD	ImageFind and ImageExtender—Document management systems for PCs and mainframe applications	Banking
Indus International Inc. West Salem, WI	ODIN—An electronic archiving and retrieval system for UNIX workstations	Manufacturing and service organizations
LaserData Inc. Tyngsboro, MA	Document management software for PCs running MS-DOS and Windows	Government, financial records, legal services, medical records, and insurance
Micro Dynamics Ltd. Silver Spring, MD	Multiuser Archive & Retrieval System—A multiplatform-based document imaging system	Legal services, education, technical documentation, customer services, and new drug applications.

(Continued)

Table 1 (Continued)
Sony's Write-Once Disk Business Partners

Partners/Location	Product/Description	Industry Specialty
Minolta Corporation Ramsey, NJ	MI MS 1000 system—PC-compatible document image management system	Hospitals, schools, insurance, banks, and government agencies
Perceptics Corporation Knoxville, NJ	LaserSystem and LaserStar—Optical disk storage subsystems for Digital's VAX, Sun, and IBM workstations	Pharmaceutical, geophysical, insurance, banking, financial, government, medical, and manufacturing
Plexus Software Sunnyvale, CA	The Plexus Extended Data Processing product—A distributed software system that allows users to integrate industry-standard hardware components into image-processing solutions	Pharmaceutical, insurance, financial, and government
QStar Technologies Inc. Rockville, MD	QStar ViewStore—A jukebox management software and optional modules for hierarchical storage	Government
SAIC Imaging Solutions San Diego, CA	MOSAIC document management/imaging system that runs exclusively on IBM's VM operating system	Government
Tandem Computers Cupertino, CA	Parallel image-processing computers running Guardian and UNIX operating systems	Finance, security, government, international money transfer, and ATM
U.S. Design Columbia, MD	Document image storage system for Digital's VMS-based systems and Sun UNIX workstations	Financial
ViewStar Corporation Emeryville, CA	Document work flow processing system—A fully distributed open system running on PC LANs	Financial

Source: Sony Corporation, Dataquest (September 1992)

Table 2
Sony's Rewritable Disk Business Partners

Partner/Location	Product/Description	Industry Specialty
Digital Equipment Corporation Merrimac, NH	The DEC RWZ01-AA—A standalone 5.25-inch rewritable optical disk system that supports multiple VAX units and workstations through SCSI and Q-bus connections	Government, education, and contracting and archival users
NKK Corporation San Jose, CA	The N-556MS—A fixed form factor, two-disk drive, 56-cartridge autochanger The N-5160—A library system available in 160- or 144-cartridge, 4-drive configurations	OEMs and SIs for public resale
Eastman Kodak Company Rochester, NY	The 560E ADL—An optical automated disk library system for imaging applications	
Alphatronix Research Triangle Park, NC	Optical libraries for Digital's VMS, UNIX, and PCs	Aerospace
American Digital Systems Inc. Sudbury, MA	5.25-inch rewritable optical drive systems for VMS and UNIX	
Applied Digital Systems Fairport, NY	5.25-inch multifunction optical drive for Sun's platform	
Aviv Corporation Burlington, MA	Optical library systems for VMS and UNIX	
Computer Systems Technology Irvine, CA	3.5-inch and 5.25-inch rewritable optical disk drives for UNIX and VMS	
Mass Micro Systems Sunnyvale, CA	The DataPak MO/128—A 3.5-inch rewritable optical drive system for Macintosh platform	
MicroNet Technology Irvine, CA	MicroOptical line—Optical subsystems for PCs, Macintoshes, and NeXT workstations	
Mitsubishi Kasei Tokyo, Japan	3.5-inch rewritable optical drive standalone systems	

(Continued)

Table 2 (Continued)
Sony's Rewritable Disk Business Partners

Partner/Location	Product/Description	Industry Specialty
Optima Technology Corporation Irvine, CA	3.5-inch and 5.25-inch rewritable optical drives for UNIX and DOS	
Peripheral Land Inc. Fremont, CA	Infinity optical line—Optical subsystems for PCs and Macintoshes	Desktop publishing
Pinnacle Micro Inc. Irvine, CA.	3.5-inch and 5.25-inch rewritable optical disk drives for Sun platform	
Procom Technology Inc. Costa Mesa, CA	The MEOD650 and MEOD128 for PCs, Macintoshes, and UNIX	Vertical markets
R Squared Englewood, CO	5.25-inch rewritable optical disk drives for Sun platform	
QStar Technologies Inc. Rockville, MD	Rewritable and multifunctional network storage solutions for UNIX platforms	Medical
Scitex America Corporation Bedford, MA	5.25-inch rewritable optical drives with its electronic prepress systems	Prepress and manufacturing
Unbound Inc. Huntington Beach, CA	5.25-inch rewritable optical drives and library systems for UNIX and VMS	
ZZYZX Workstation Peripherals San Diego, CA	3.5-inch and 5.25-inch rewritable optical disk drives and library systems for UNIX	

Source: Sony Corporation, Dataquest (September 1992)

Product Strategy

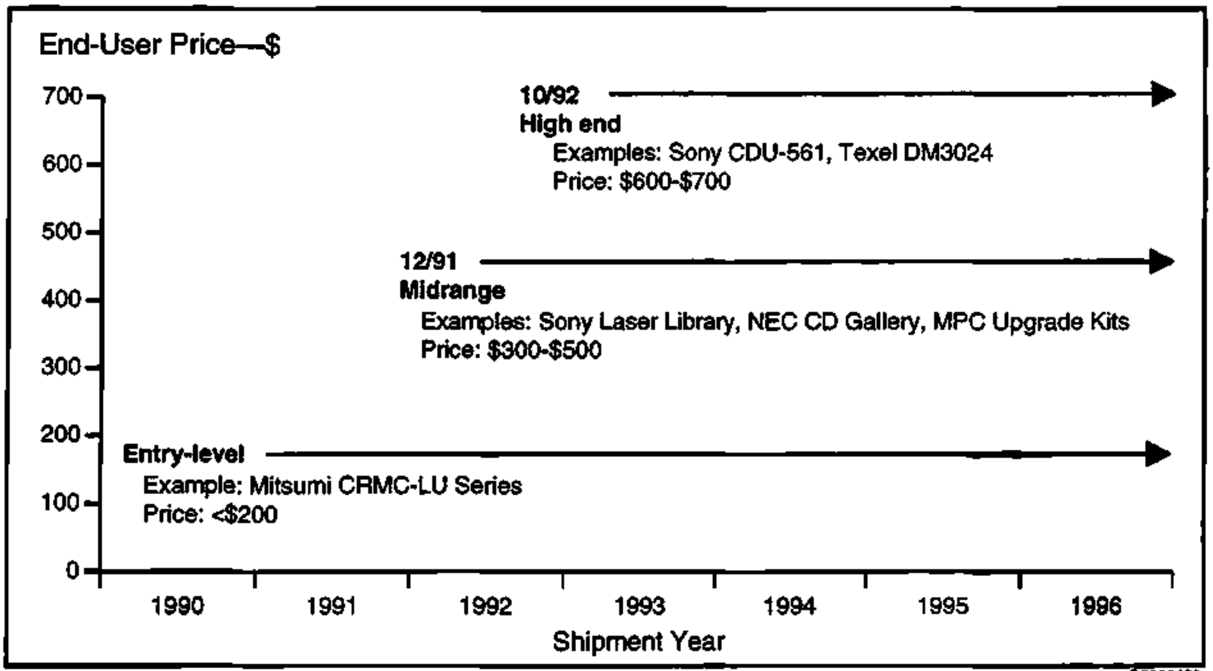
Sony is determined to remain the dominant worldwide supplier of optical mass storage technologies and products. To accomplish this objective, Sony has identified the markets where its core competence and resources match up with the business opportunities. Sony's product strategy, in Dataquest's opinion, reflects that marketing savvy.

CD-ROM Drives

Dataquest segments CD-ROM products into three major categories according to performance, functionalities, and prices, as shown in Figure 2. The high end is emerging with Sony's announcement of CDU-561. This class of products is designed to take advantage of the emerging multimedia applications. These products should offer sustained data transfer rate of 300 KB/sec. and average access time below 300ms; they should be able to transfer digital audio data directly across the SCSI bus. The drive also should have the capability to support CD-I, DVI, CD-ROM XA, and Photo-CD. The midrange includes the current generation of products. Most of Sony's existing CDU line falls into this category.

Sony's CD-ROM product strategy is to focus on the high-end and midrange segments. Sony has little interest in the low end. This strategy makes sense because the Sony name carries a premium, and the low-end market is extremely price-sensitive. In addition,

Figure 2
CD-ROM Drive Product Segmentation



Source: Dataquest (September 1992)

Sony believes that the demand for the low-end segment is likely to decline in the next few years, when users realize that they really need a CD-ROM drive that will be adequate to run all the multimedia applications as well as text applications.

Sony will vigorously pursue opportunities for its portable multimedia CD-ROM-player technology. The player has a very small package (approximately 7 inches wide, 2 inches high, and 6 inches deep) and is a self-contained personal information device. The system includes a CD-ROM XA drive, 16-bit PC-compatible microprocessor with MS-DOS operating system in ROM, LCD display panel, speaker, QWERTY keyboard, and a cursor pad. This player will create new markets for CD-ROM technology beyond desktop PCs and workstations.

Dataquest projects that Sony will continue its bundling product strategy, such as its Laser Library system. Dataquest expects a Laser Library II to include a broader range of CD titles and appeal to business users in addition to home users.

WORM Drives

Sony is committed to WORM technology because of its large installed base and investment in this market. Dataquest believes that Sony will pursue new product strategy in the automated optical library systems with a focus on the midrange and low end. Sony will provide backward and forward compatibility for its new generation of WORM drives and continue to improve the capacity, performance, and reliability without price increases. The WORM product will remain a niche product.

Rewritable Drives

Sony believes that 3.5-inch rewritable drives have the best chance to penetrate the mainstream desktop computing market among all rewritable optical storage products. However, compared with the performance of other manufacturers' latest products, Sony's 3.5-inch drive is not competitive. For example, Fujitsu's new product, the Model M2511A, offers a rotational speed of 3,600 rpm and an average access time of 38ms. This new drive from Fujitsu, scheduled to ship in September 1992, will present a serious challenge to Sony.

To fight the competition, Sony is taking its 3.5-inch rewritable disk drive to the retail channel under its own brand name. Considering the reluctance among OEMs to incorporate 3.5-inch rewritable into their systems and the lack of volume commitment from OEMs, VARs, and distributors, Sony is forced to take this alternative. With this approach, Sony can accomplish the following objectives:

- Establish a strong brand name position among end users
- Make the drives more affordable by getting one layer closer to the users
- Create awareness and demand in the market to encourage OEM volume purchases

Sony is also eyeing the installed base of SyQuest and Iomega. Sony will be very aggressive in its media and drive pricing in order to win the mind-set of current removable storage users.

In the next few years, Sony will increase the 3.5-inch storage capacity to 325MB, introduce new products at a faster pace, and pursue an overall manufacturing cost leadership strategy. The higher-capacity drive depends on commercially available blue lasers. Meanwhile, Sony will introduce products with incremental performance improvements and shorten the product cycle.

In the 5.25-inch rewritable arena, Sony has been selling the SMO-S501 series for four years. This is a successful product, as illustrated by the facts that it has the largest installed base and more than 40 VARs and SIs have carried this product. However, the competition for 5.25-inch rewritable market share is tougher than ever now, with other vendors—such as Ricoh, Panasonic, and Maxoptix—introducing better price/performance drives.

Dataquest has observed that an increasing number of Sony's resellers are switching to other drive manufacturers. Sony's weakening position in the reseller channel is largely due to its aged product. One tactic that Sony is likely to use is to cut the price and reduce inventory to prepare for its new 1.3GB drive introduction in the next six months. In addition to the increased capacity, Sony will also pursue the optical library market by providing ruggedized versions to jukebox vendors. Dataquest does not believe that the Sony's multifunction drive will have a serious impact on the market until 1995.

Sony Optical Product Offerings

Sony provides optical data storage products that range from CD-ROM to 12-inch WORM libraries. This section describes the optical data storage products that Sony offers (see Table 3).

CD-ROM Drives

Sony offers seven CD-ROM drives to the OEM, VAR, and SI market. They include the following:

- CDU-541—5.25-inch half-height internal drive, vertical or horizontal installation, with an embedded SCSI-2 (rev. 10) controller and 64KB ring buffer
- CDU-535—5.25-inch half-height internal drive, vertical or horizontal installation, with a Sony bus controller and 8KB ring buffer
- CDU-561—5.25-inch half-height internal double-speed drive with an embedded SCSI-2 controller and a 256KB ring buffer
- CDU-6211—5.25-inch half-height external drive, vertical or horizontal installation, with an embedded SCSI-2 bus controller and 64KB ring buffer

Table 3
Sony's Optical Storage Solution Lineup

Model	Type	Form Factor (Inches)	Maximum Capacity	Suggested Retail Price ($)	Availability
WDD-931/901	WORM	12	6.55GB	29,500	Summer 1992
WDA-E330	Jukebox 12 disks	12	78.6GB	OEM	Fall 1992
WDA-610	Jukebox 50 disks	12	328GB	OEM	Now
SMO-E501	RW internal	5.25	650MB	4,650	Now
SMO-S501A	RW external	5.25	650MB	4,750	Now
SMO-E511	Multifunction internal	5.25	594/650MB	4,895	Now
SMO-P301	RW internal	3.5	128MB	1,950	Now
SMO-S301	RW external	3.5	128MB	2,045	Now
RMO-S350[1]	RW external	3.5	128MB	2,295	Now
CDU-561	CD-ROM	5.25	640MB	NA	September 1992
CDU-541	CD-ROM	5.25	640MB	OEM	Now
CDU-6211	CD-ROM	5.25	640MB	OEM	Now
CDU-7211	CD-ROM	5.25	640MB	949.95	Now
CDU-7205[2]	CD-ROM	5.25	640MB	699	Now

NA = Not available
[1] Sony-branded, 3.5-inch, rewritable optical drive bundled with software, hardware, and firmware
[2] The Sony Laser Library System bundled with six information, learning, and entertainment disks
Source: Sony Corporation, Dataquest (September 1992)

- CDU-6205: 5.25-inch half-height external drive, vertical or horizontal installation, with a Sony bus controller and 8KB ring buffer
- CDU-6150—5.25-inch dual-drive subsystem with a Sony bus controller and 8KB ring buffer (discontinued as of writing)
- CDU-7211: 5.25-inch half-height external drive with SCSI bus interface and 64KB buffer

Sony also offers a bundled CD-ROM package, called Laser Library. Sony targets this product at the home market through retail channels. The bundled software titles include *Compton's Family Encyclopedia, Microsoft Bookshelf, Mammals: A Multimedia Encyclopedia, Mixed-Up Mother Goose, Languages of the World,* and *Software Toolworks World Atlas.* The Laser Library is sold at a retail price of $699.

CD-ROM XA

CD-ROM XA is a standard supported by Sony, Philips, and Microsoft for interactive multimedia training, point-of-purchase, and electronic catalog applications. Sony's two CD-ROM XA development products are as follows:

- PCY-311—Audio-encoding card for ADPCM compression/decompression and audio interleaving
- CDB-X10—Interface card for IBM-PC/AT computers that enable Sony bus CD-ROM drives to run CD-ROM XA applications

Sony announced the technology for a portable CD-ROM XA player in March. The prototype player includes a CD-ROM XA drive, 16-bit PC-compatible microprocessor with MS-DOS operating system in ROM, LCD display panel, speaker, QWERTY keyboard, and a cursor pad.

CD Write-Once

The Sony Write-Once subsystem is designed for CD-ROM prototyping, premastering, secure publication of sensitive data, and low-volume in-house publication of CD-ROM discs.

Sony introduced a high-speed CD Write-Once subsystem and demonstrated the product, the CDW-900E, at the International Conference & Exposition on Multimedia and CD-ROM in March. Discs recorded on the CDW-900E conform to the Red Book (audio CD), Yellow Book (CD-ROM), CD-ROM XA, and Green Book (CD-I) digital formats for use with currently available drives supporting these standards.

The CD Write-Once subsystem consists of two components—a data encoder to organize the information into CD-ROM format and a write-once optical disc drive in the CD-ROM form factor for recording the information on disc. The system works with IBM PCs and compatible machines, Macintoshes, and UNIX-based PCs and workstations.

3.5-Inch Rewritable

Sony joined the 3.5-inch MO drive race in June 1991 with its introduction of internal and external versions—the models SMO-P301 and SMO-S301, respectively. The products were made available in October. Both products offer 128MB of capacity, average access time of 50ms, average seek time of 40ms, and average latency time of 10ms. The sustained transfer rate is 625 KB/sec., and the rotational speed is 3,000 rpm. At the introduction, Sony expected the end-user price of the drives to be less than $2,000 and the disk less than $60.

On June 20, Sony introduced a plug-and-play solution of the 3.5-inch MO drive, the model RMO-S350, to tap into the computer dealer channels. The RMO-S350 stores 128MB of rewritable information on a 3.5-inch MO disk. It uses a SCSI-2 interface for high throughput and has an average seek time of 40ms with a 4 MB/sec. burst transfer rate. This product is Sony's SMO-S301 bundled with software and firmware.

Three kits are available for this external drive: The RMO-K100 Macintosh kit, the RMO-K200 Standard PC kit, and the RMO-K300 MicroChannel kit. All kits include an interface card (if required), device driver and utility software, SCSI cable, and a reference and user manual. The RMO-S350 has a suggested retail price of $2,295.

5.25-Inch Rewritable and Multifunction Drives

Sony was the first company to introduce 5.25-inch rewritable optical technology, in October 1988. Today, the company manufactures and markets 5.25-inch rewritable and multifunction drives, optical media, and subsystems.

Sony's 5.25-inch rewritable drives store up to 650MB of data on erasable, reusable, removable optical disks. The drives feature an average seek time of 70ms, a short-stroke time of 22ms, and a high-speed data transfer rate of 7.4 Mbps (sustained) or 1.2 MB/sec. (burst). Sony's line of rewritable optical drives includes the SMO-S501A, which is an external standalone disk drive incorporating the SMD-E501 together with its own power supply; the SMO-E501, which is an internal drive with an embedded SCSI controller; and the SMO-E511, which is an internal multifunction drive that reads both rewritable and WORM media.

The SMO-E511 multifunction drive features the same performance as other members of the SMO product family. The drive has an embedded SCSI controller and can store 650MB of data on either a rewritable or write-once optical disk. It has a burst transfer rate of 1.2 MB/sec., short-stroke seek time of 22ms, and average positioning time of 70ms.

Sony discontinued its older models, such as SMO-D501, SMO-C501, and SMO-S501.

12-inch WORM and Library Products

Sony introduced its 12-inch Write-Once system in 1985, with a capacity of 3GB per platter. In 1989, the second-generation write-once system was introduced with the industry's highest capacity of storage at 6.55GB per disk.

At the 1992 Association for Information and Image Management (AIIM) show, Sony announced two 12-inch write-once optical products—the WDD-931 optical drive and the WDA-E330 miniautochanger.

The WDA-931 has a capacity of 6.55GB on a 12-inch Sony Century Media disk and a 900-KB/sec. sustained data transfer rate. This drive includes an embedded controller and supports the SCSI-2 interface. Sony also introduced the WDD-901 write-once optical disk drive to connect to the WDD-931 master drive. Up to 7 WDD-931 drives can be daisy chained on a single SCSI bus, and up to 7 WDD-901 drives can be daisy chained to each WDD-931. This makes it possible to configure a system consisting of up to 56 drives for a maximum of 367GB of online storage.

Sony is quoting a mean time between failures (MTBF) of 15,000 power-on hours. The drive has a "laser save" function that automatically turns off the laser after the WDD-931 has not been accessed for a certain number of minutes. The drive turns on again when the next access command is received. The user can set the time at which the automatic blackout activates on the host computer in a range from 2 to 2^7. This laser save function significantly extends the life of the laser.

The WDA-E330 write-once, optical miniautochanger stores up to 78.6GB of data on 12 12-inch WORM disks and delivers a 900-KB/sec. sustained data transfer rate. The miniautochanger, with an innovative architecture and electronics design, can achieve a quick disk-loading time of less than 3 seconds. Sony offers this library system as an entry-level jukebox storage solution. According to Sony, the cost per megabyte for the WDA-E330 is about $0.56 per megabyte including jukebox, drive, and media. In addition, three WDA-E330 miniautochangers can be daisy chained to provide more than 235GB of online information.

Optical Media

Sony offers a complete lineup of data media products, ranging from MO disks to microfloppy disks. Sony's media products include 12- and 5.25-inch WORM and 3.5- and 5.25-inch rewritable disks.

Concurrently with its 3.5-inch rewritable optical disk drive announcement in June 1991, Sony announced the technology of its Optical-Read Only Memory (O-ROM). This new optical-publishing technique extends the capabilities of Sony's SMO-300 Series of 3.5-inch optical disk cartridges with read-only capabilities similar to CD-ROM. Sony's O-ROM disk is capable of storing 120MB of information. With O-ROM disk technology, a company records images, sound, text, or computer data using premastering software on a Sony 3.5-inch rewritable optical disk. The information on the "master disk" can then be sent to Sony, where the information is pressed into O-ROM disks as part of the manufacturing process. Because O-ROM disks have an aluminum recording layer much like a standard CD-ROM disk, the O-ROM disks will be able to be reproduced at a very low unit cost, according to Sony.

Sony teamed up with Autodesk Inc. to demonstrate the potential of O-ROM technology. Autodesk created a sample Image Library O-ROM disk containing 100MB of architectural, engineering, and presentation animation.

Sony and the Optical Market

Sony's success in the optical storage market is a reward for its innovation. Sony is an innovator. It invented the 3.5-inch diskette. It coinvented CD and CD-ROM. The total R&D investment for Sony is estimated at $200 million over the past 20 years. Sony's optical development work is chronicled as follows:

- 1979—Laser videodisc
- 1982—Audio compact disc (CD)
- 1984—CD-ROM
- 1985—12-inch optical WORM
- 1986—Analog direct read and write (DRAW)
- 1988—5.25-inch rewritable MO
- 1989—12-inch high-capacity WORM and CD-ROM XA
- 1990—Writable CD
- 1991—Multifunction rewritable/write-once optical
- 1992—Double-speed CD-ROM, portable CD-ROM XA player

The company pioneered the 8mm format in camcorders and followed the Walkman success with Discman and portable CD-ROM XA player. Sony invented the Beta video format, which did not succeed. Sony was the first company to ship production quantities of rewritable optical disk drives. The list could go on, but the point is that innovation is characteristic of Sony.

Sony's strong presence in the optical mass storage market is both a boon and a scourge for its competitors—a boon because Sony's commitment means continued R&D dollars in this technology and gives long-term viability to this market, but a scourge because Sony's strong presence in all aspects of the optical business makes it very hard to compete against it.

The overall market performance of Sony's optical data storage products in 1991 is shown in Table 4. Sony has a dominant position in all the market segments in which it participates.

Table 4
Sony's 1991 Worldwide Optical Data Storage Market Performance

Product Category	Shipment (Thousands of Units)	Revenue (U.S.$M)	Market Share Ranking
12-Inch WORM Drive	3.6	23.3	1
12-Inch WORM Media	36	14.4	4
5.25-Inch Rewritable Drive	58	92.8	1
5.25-Inch Rewritable Media	150	16.1	1
5.25-Inch WORM media	60	7.5	3
3.5-Inch Rewritable Drive	9.7	7.6	1
3.5-Inch Rewritable Media	10	0.4	2
CD-ROM Drives	375	77.6	1

Source: Dataquest (September 1992)

Dataquest's estimate of Sony's worldwide installed base of optical disk drives is as follows:

- CD-ROM—617,000 units
- 3.5-inch rewritable—9,700 units
- 5.25-inch rewritable—127,000 units
- 12-inch WORM—15,100 units

Future Directions

Sony Corporation is not immune from the worldwide economic downturn. For the fiscal year of 1991 ending March 31, 1992, Sony reported disappointing financial results. The company's operating income for the year dropped by 45 percent, to approximately $1.3 billion. The parent company in Tokyo also posted its first operating loss, estimated at $160 million. In its attempts at recovery, Sony plans to reinvigorate its sales with new focus on computing markets. Sony is also changing its management style and will be more cautious about its capital spending. The company will strive to obtain more profits out of its core businesses and look for alliances with other companies, especially in the computer areas.

This could be both good and bad news for Sony's CPPC. The bad news is that the parent company in Tokyo may reduce the R&D and capital spending in the optical area. The good news is that the refocus on the computer and multimedia markets may give CPPC more flexibility and resources in marketing and sales.

Sony is the leader in the worldwide optical mass storage market and offers a range of both optical media and drive products. In the future, we expect Sony to continue its commitment to optical mass storage as a " foundation technology" in the company's growth. Sony will strive to improve in the following areas:

- Developing and producing "enabling" optical technologies, including highly stable and reliable polycarbonate media substrates, optical pickup blocks, semiconductors, and servo-mechanics
- Providing constant improvements in performance, generational compatibility, and preserved investment for the users
- Becoming a major supplier of all four areas of optical technology: components, media, hardware systems, and software
- Providing the broadest range of optical products, including laser videodiscs, audio CD, CD-ROM, CD-ROM XA players, write-once optical, rewritable and multifunction optical, recordable CD, CD-I, and analog DRAW
- Providing total mass storage solution by tighter integration of optical technology into larger hierarchy of digital mass storage; becoming a solution vendor that matches user needs with product strengths and benefits
- Advancing manufacturing technologies to optimize production costs, components miniaturization, automation and robotics, and quality assurance
- Pursuing direct sales strategy via retail channels

Dataquest Perspective

As the most consistently innovative manufacturer in the consumer electronics industry, Sony will continue to strive for innovation. According to Sony, its engineers produce an average of 1,000 new products each year—200 of which are products that aim to create new markets. In its attempt to expand its computer business, Sony is applying its innovative powers to transform the design of computer-related products the way it did consumer electronics. More significantly, Sony will transfer its successful marketing experience in consumer electronics and leverage its brand name to the marketing and sales of computer products.

Optical storage products are no exception. In reviewing Sony's optical storage products programs and analyzing its strategies, it appears that Sony's grand plan is to go direct to end users. Traditionally, Sony has relied on OEMs, national and regional distributors, VARs, and SIs for moving its optical products. In 1991, Sony's resellers accounted for more than 95 percent of its total unit shipments in the United States, which is the major revenue source for its optical storage products.

Now, Sony believes that its optical products, such as 3.5-inch rewritable and CD-ROM drives, are ideal for the retail market because of the short product cycle, recognizable form factor, and low prices. Sony's argument is very compelling and has some merits. First, Sony is getting nowhere with the OEM customers in selling the 3.5-inch rewritable drives. Up to now, the demand has come from aftermarket users. Second, Sony has invested much money to create awareness and educate the market about optical technology as part of its pulling strategy, and it may as well sell to them directly. Third, Sony believes that it has all the necessary ingredients to be successful in the retail channels. And, last but not least, Sony believes that, by going direct, it will be able to control the price better and make the drives more affordable to stimulate demand.

But, what about Sony's network of "loyal resellers"? Many of Sony's existing resellers are currently selling to small dealers and end users. Sony spokespeople have said that it would protect its VARs and resellers by changing model numbers and charging higher prices. Will that promise work? Maybe it will, and maybe it will not. But, here is something that is guaranteed to happen—the biggest resellers will fight to control Sony's business by cutting deals and constricting their own margins or simply switch to the other vendors.

This scenario presents a few problems. Optical markets have not matured to a stage where an end user will go to one of the retail outlets and pick up a 3.5-inch rewritable disk drive for the computer. And, more important, the market depends on VARs and SIs to provide vertical applications and solutions. The defection of the resellers is the last thing that Sony needs.

Dataquest believes that Sony will remain a strong player in the optical market. But, its distribution strategy and implementation will need work and creative thinking.

Semiconductor Application Markets *Worldwide*

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Dataquest

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, CA 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

United Kingdom
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Nr Uxbridge,
Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

France
Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (01)48 97 34 00

Germany
Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
011 49 89 93 09 09 0
Fax: 011 49 89 930 3277

Japan
Dataquest Japan Limited
Shinkawa Sanko Building 2 Fl
1-3-17 Shinkawa
Chuo-kuTokyo 104
Japan
011-81-3-5566-0411
Telex: 781-32768
Fax: 011-81-3-5566-0425

Korea
Dataquest Korea
Dacheung Building Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-80
Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
(508) 370-5555
Fax: (508) 370-6262

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1993 Semiconductor Procurement Insights

User Wants and Needs

Semiconductor Application Markets
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Table of Contents

Table of Contents (Continued)

List of Figures

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Tables

Chapter 1
Executive Summary

Introduction

The market requirements of the semiconductor user, whether in procurement or component engineering, continue to be a moving target because of the shifting nature of the overall electronics industry. This study focuses on the what, where, when, and how of semiconductor users' main concerns, now and for the upcoming year.

How well an electronics company translates an end-user need into a finished product that meets that need often depends on how well the raw materials that comprise the finished product are sourced and then procured. The variety of electronic market segments—each of which has specific supplier requirements—at best makes the semiconductor supplier's task of meeting customer needs a challenge. But, as an industry, the electronics market also has some consensus semiconductor needs being met to varying degrees, depending on the specific industry segment. This report does the following:

- Highlights the overall electronics market's semiconductor user requirements
- Breaks the industry into eight specific segments to better understand where certain user requirements differ from the norm
- Segments the electronics market by semiconductor product category to note differences of need, by selected product type

Study Objectives

This document reports the findings of Dataquest's seventh annual Semiconductor User and Application Needs survey. This survey assesses the current status and future needs of the semiconductor user community and is presented in an impartial, third-party format that allows both users and suppliers of semiconductors to gain better insight into respective competitor and customer needs in the upcoming months.

The survey was designed to gather detailed information on the current status of semiconductor users and of their needs for 1993. The specific objectives were as follows:

- Highlight both the top user issues needing focus, along with areas now being met but that if neglected would cause supplier review/removal

- Provide a 1992 benchmark of key indexes for eight key electronic industry segments
- Provide a succinct list of supplier selection criteria, down to the semiconductor product level

Methodology

The overall goal of the project was to gain an understanding of semiconductor procurement logistics, service and product requirements, and issues for OEMs headquartered in North America. To this end, in October we surveyed 95 separate companies out of the sample population of the *Electronic Business Magazine* top 200 electronic companies (also known as the EB 200).

We were successful at accounting for $3.7 billion in semiconductor purchasing power, which represents 6 percent of the worldwide and 18 percent of North American semiconductor markets. A survey of about 50 questions was used in telephone and face-to-face contacts with predominantly senior procurement management officials with corporate overview.

Key Findings of This Study

Top User Issues and Supplier "Cardinal Sins"

According to the study, the three main issues that will receive top attention in the upcoming months are price, availability, and lead time. Areas now being done well (primarily high quality and on-time delivery) need to be maintained by suppliers in order to keep existing customers. Table 1-1 shows how top issues have changed (remain unchanged?) over the past six years. Tangible issues such as price, quality, and lead time generally take top priority, but it is often the intangibles, if neglected, that can rapidly turn into visible tangible costs (good supplier relations and supplier flexibility, among others). Quality levels now meet market requirements, and the next hurdle to face is lowering a tangible (and very visible) cost variable as much as practically possible. The current systems market is forcing semiconductor users to require the highest level of quality yet simultaneously cut and control costs. It is up to prudent management to decide what the total cost level must be for a system (integrating quality, price, and delivery, among others) and work toward that goal, rather than solely focus on isolated issues of price, lead time, and the like.

Semiconductor User Future Needs, by Industry

As a result of this survey, the respondents noted that the U.S. electronics industry designs and assembles the majority of its own circuit boards and predominantly assembles them in the United States, with the Far East as the runner-up for assembly location. It was found that the "latest" trend to use contract manufacturers or "outsource" is not new at all to the respondents of this survey. The vast majority of the respondents have a formal quality program in place and for the most part see the results at worst as being beneficial; many see the programs as critical to their ongoing

Table 1-1
Historical Procurement Issues

Issue	1993	1992	1991	1990	1989	1988
Pricing	1	1		2	2	2
Availability/Allocation	2	4	2	4	1	1
Lead Times	3	-	-	-	-	-
Quality/Reliability	4	2	5	6	4	6
On-Time Delivery	5	3	6	1	3	3
Cost Control	6	6	3	3	7	4
Flexibility/Service	7	-	-	-	-	-
JIT/Inventory Control	8	7	4	5	6	9
Developing Supplier Relations	9	10	-	-	-	-
New/Obsolete Products	10	5	7	7	8	8

Source: Dataquest (December 1992)

business. The small difference in average parts per million of rejected incoming semiconductors by product family and the overall low level of rejects attest to the effectiveness of these programs (see Figure 1-1). It appears that strategic supplier programs have gotten much attention and many companies have programs under way. It was found that the definition of "on-time delivery" had almost as many ranges as the number of respondents, with the most common delivery schedule being +0,-5 days to delivery date (see Figure 1-2). Although the 15.2 percent average electronics 1993 growth forecast given by our respondents is a bit aggressive, based on our research (Dataquest's 1993 U.S. electronics market forecast is 4.4 percent), it does reflect the positive outlook for next year of the economy pulling itself out of the current slowdown.

Semiconductor Supplier Selection Criteria

On average, quality and delivery performance remain the most stringently employed supplier selection criteria. Microcomponents (MPUs, among others) was the only product category where pricing was a serious contender as a selection criteria. This perception is probably because of the relative higher prices of these parts and the limiting sourcing options in some cases.

Quality performance across-the-board was clearly a prerequisite to doing business. All four surveyed product areas had average minimum acceptable quality levels of about 60 parts per million (ppm). The higher-volume businesses such as PCs required even more restrictive quality performance.

The high ranking of delivery performance, especially in ASICs, seemed to underscore the importance of timing in today's global market. With product life cycles running under two years in some volume segments, even a week slippage can hurt an OEM's market positioning.

Approved supplier lists are slated to shrink next year for almost all industries and for all semiconductor products. OEMs on average maintained eight microcomponent, six standard logic and analog, five ASIC, and five memory suppliers during 1992. High-volume users tended to keep the number smaller, whereas military/aerospace users had nearly double the amount in some cases.

Structure of the Report

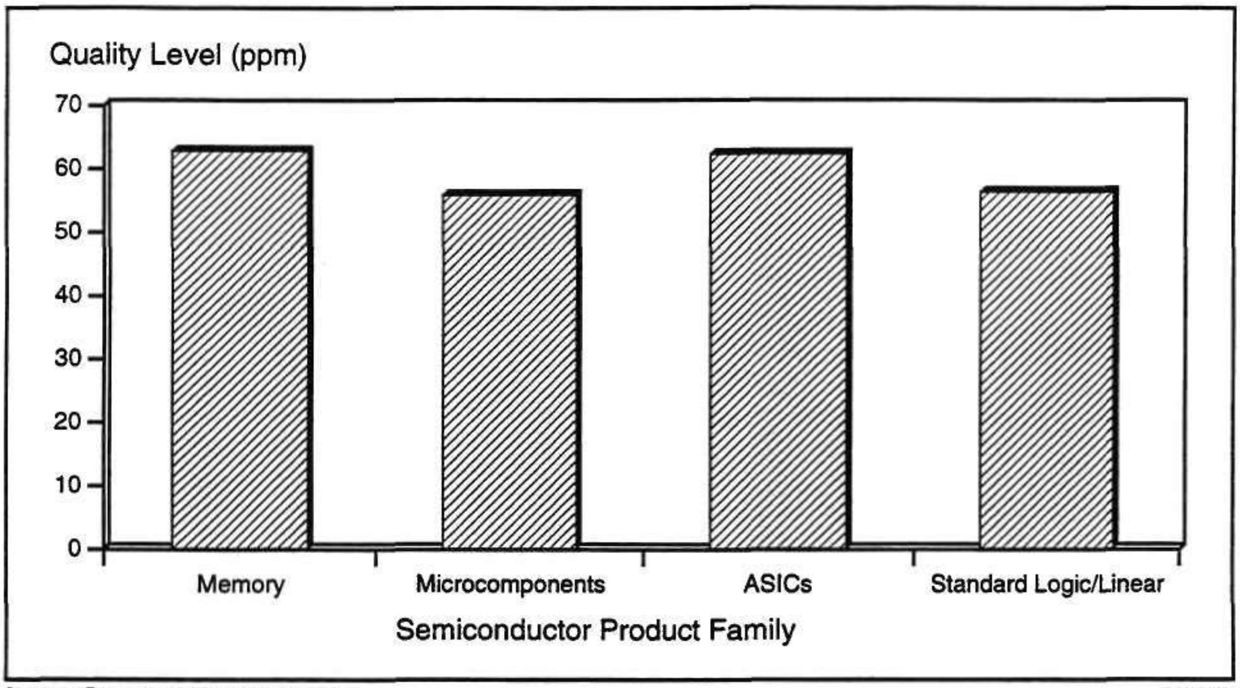
The remainder of this report is divided into five sections, deriving detail on procurement data, logistics, and issues by electronic industry (data processing, for example) and by semiconductor product category (memory ICs, for example). The report relies heavily on graphical analysis, facilitating quick assessment by the reader. The other chapters of the report include the following:

- Respondent Demographics—This chapter assesses the type of companies and decision makers surveyed for this report.
- 1993 Semiconductor User Issues and Supplier Cardinal Sins—This chapter addresses questions about what is most important to semiconductor users in various industries. The supplier "cardinal sins" or disqualification factors are brought to the surface and analyzed as well.
- Semiconductor User Status and Future Needs, by Industry—Key logistical and procurement information is spotlighted in this chapter. Information about regional board assembly, contract manufacturing, on-time delivery definitions (±days), and the usage of quality and supplier partnering programs is highlighted as well.
- Semiconductor User Needs, by Product Category—Organized by semiconductor product category, this chapter of the report assesses the supplier selection criteria used by OEMs. Criteria such as pricing consistency, delivery and quality performance, market flexibility, and product portfolio and plans are ranked by respondents. OEM definitions of quality on a ppm basis are uncovered, along with plans for reducing qualified supplier lists.
- Recommendations—This chapter provides twin assessments about how OEMs and chip companies can work with each other profitably in the competitive 1990s.

Project analysts: Mark Giudici and Gregory Sheppard

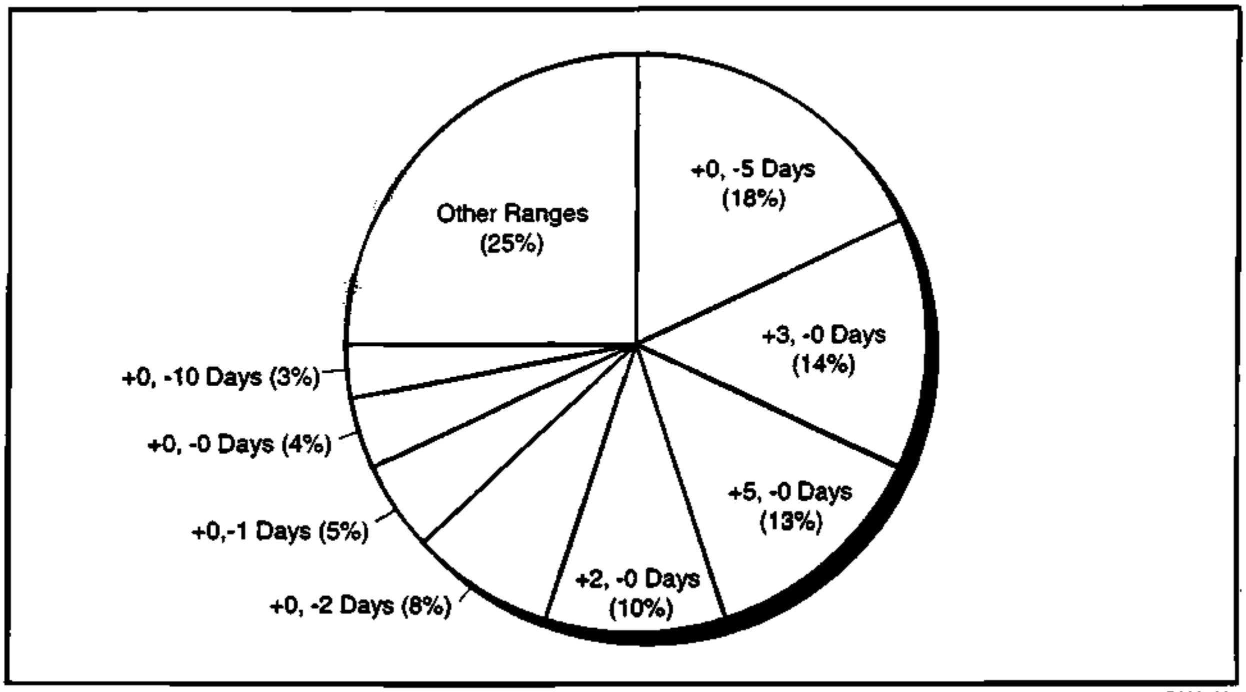
Research support: Mario Morales and Rick Shigemoto

Figure 1-1
Electronics Industry Average Quality Level, by Semiconductor Product Family (ppm)



Source: Dataquest (December 1992)
G2001282

Figure 1-2
Electronics Industry On-Time Delivery Definitions (Delta to Delivery Date)



Source: Dataquest (December 1992)

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Chapter 2
Respondent Demographics

Introduction

The survey population was *Electronic Business Magazine's* top 200 North American electronic companies. Of these 200, 168 were contacted for this survey. The remainder were deemed ineligible because they were not system/subsystem OEMs. One goal of this survey was to capture responses from decision makers responsible for at least 10 percent of the North American market for semiconductors. The surveyed purchase value more than exceeded that, accounting for almost 18 percent of the North American market and 6 percent of the worldwide market. Another goal was to capture a valid sample of the market with representation from the various industries proportional to their mix of the market. Likewise, a substantial number of small companies were surveyed as well to give balance to their viewpoints.

Respondents' Role

Figure 2-1 presents the type of people we surveyed, by organizational title. About a third were of managerial status and another 40 percent were senior buyers.

Purchasing Power

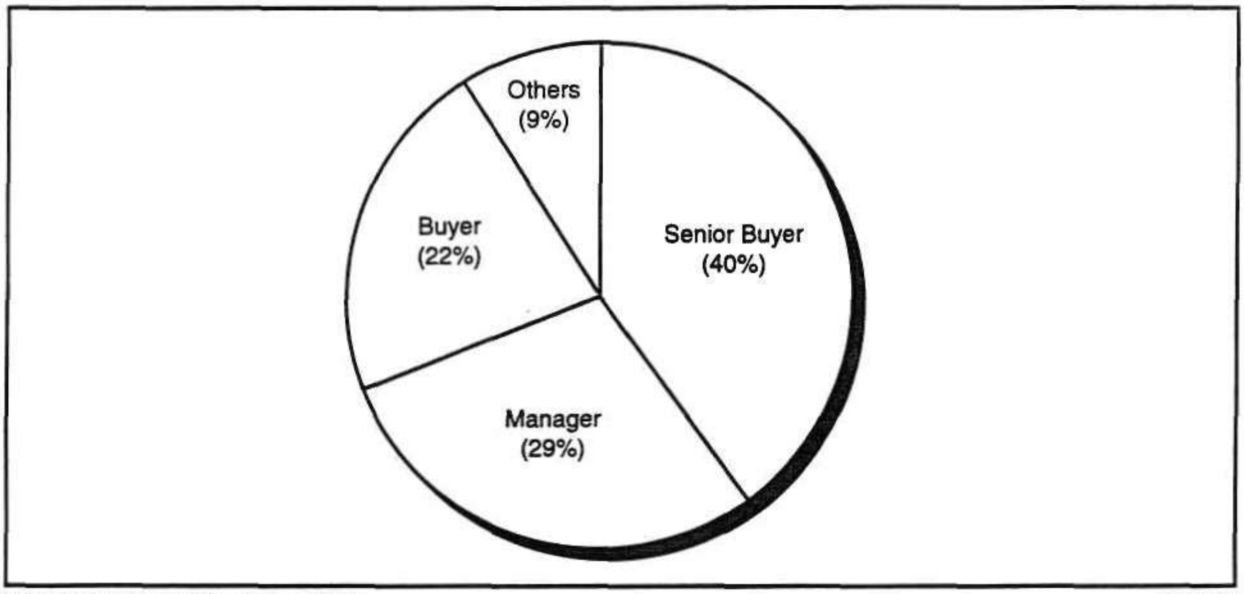
The overall semiconductor purchasing value of the respondents was $3.7 billion in 1992. This was spread among about 95 companies and 101 separate interviews. The intent was to approximate the actual distribution of the market. Figure 2-2 presents the weighted average distribution of semiconductor purchasing value covered in the survey. Data processing comprises more than 60 percent of the value, about 15 percent higher than what Dataquest estimates as the actual percentage it represents of the whole market.

Figure 2-3 indicates the purchasing power distribution captured in the survey. As happens in the marketplace, the predominant number of OEMs surveyed (including some divisions of large OEMs) purchase less than $10 million of semiconductors per year. The larger OEMs, however, account for a significant percentage of the overall market.

Summary

We believe that the survey demographics were representative of the market mix. Nearly 60 percent of the eligible EB 200 companies were surveyed by phone, and they accounted for 6 percent of the worldwide semiconductor market. Furthermore, surveys were conducted with primarily high-level decision makers knowledgeable of procurement practices and plans.

Figure 2-1
Respondents' Title



Source: Dataquest (December 1992)

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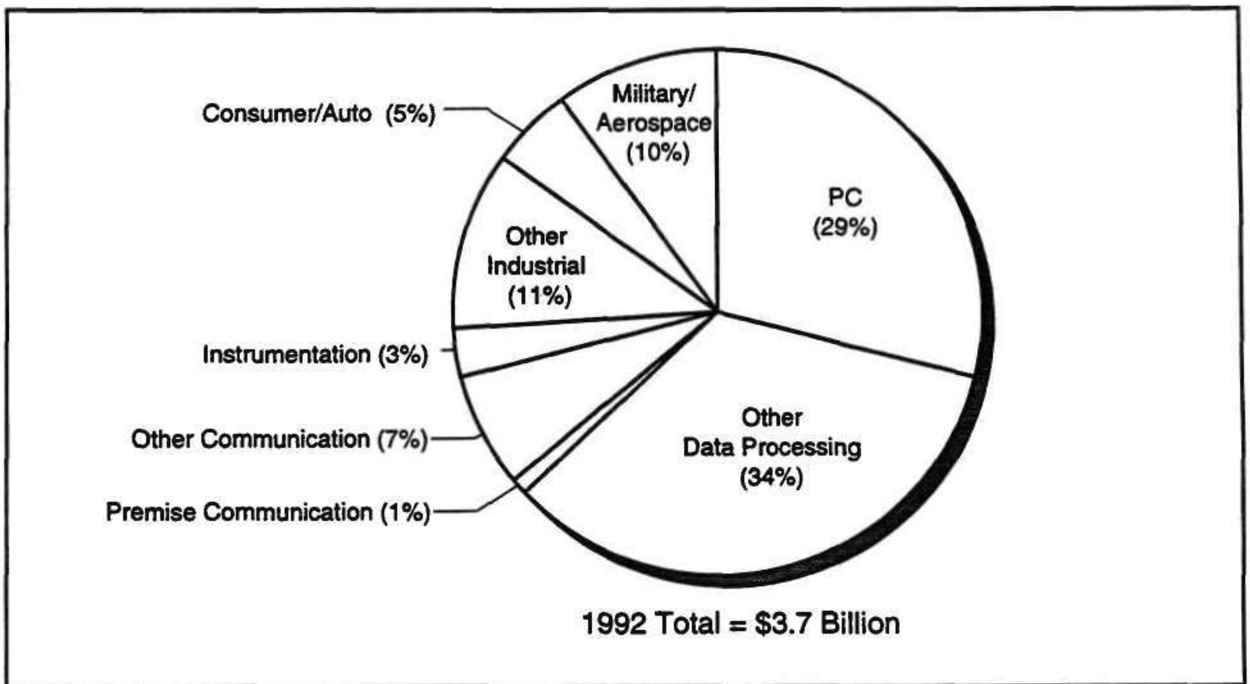
Figure 2-2
Respondents' Semiconductor Purchasing Power, by Industry



Source: Dataquest (December 1992)

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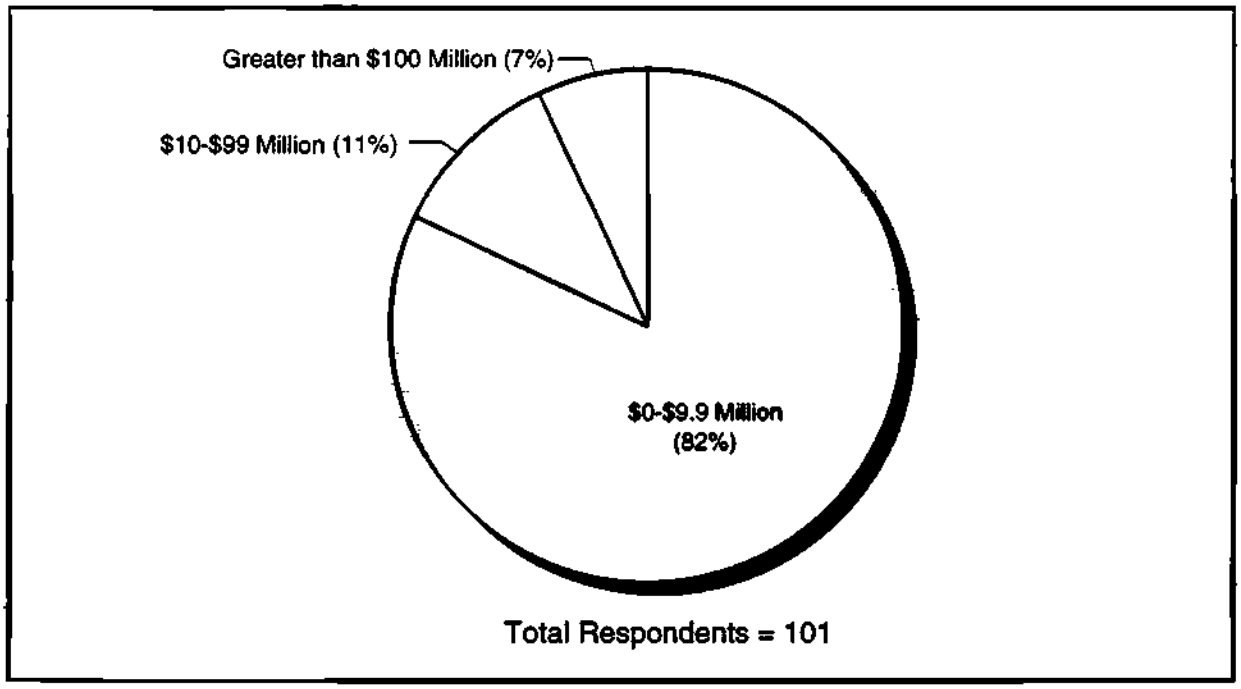
Figure 2-3
Respondents' Purchasing Power Segmentation



Source: Dataquest (December 1992)

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Chapter 3
1993 Semiconductor User Issues and Supplier Cardinal Sins

This chapter focuses on the key issues that need attention in 1993 (supplier opportunity) and, on a more negative note, on behavior by a semiconductor supplier that warrants review and its potential dropping (supplier cardinal sins). The overall sample clearly noted that price, availability, and lead time are the three key issues for 1993 (see Figures 3-1 and 3-2). Concern over semiconductor capacity levels and overall costs remain in the forefront.

The current business environment in general is growing at a moderate rate, with some companies in the data processing segment being constrained by lack of capacity. Behind all this growth, a top concern of most electronics companies remains overall cost control, often gauged in the most tangible of ways—price and inventory levels. Although these areas can be easily measured and benchmarked, the other variables of adherence to delivery schedules, world class quality, and market flexibility came out in this survey as other key areas that require attention in the upcoming months. The following paragraphs summarize each industry's key issues. Figures detail each grouping.

Key Issues

Data Processing

Availability and price appear to be the data processing market's key concerns, while poor quality ranks No. 1 as a reason to review or drop a supplier for this segment (see Figures 3-3 through 3-6).

Telecommunications

Figures 3-7 through 3-10 highlight that price and lead time are the telecommunications industry's key 1993 concerns. Continual missed delivery schedules, followed by poor quality, will warrant supplier review or removal in this industry.

Industrial Equipment

In the industrial equipment market, the instrumentation segment has distinct differences regarding key issues of price and availability. The rest of the industrial segment's focuses is on-time delivery and quality as key issues in the upcoming year (see Figures 3-11 through 3-14). There is concurrence in the industrial equipment industry that poor quality and missed delivery schedules warrant supplier review or removal.

Consumer/Automotive

Figures 3-15 and 3-16 show that the combined consumer and automotive industry category notes lead time and price as key 1993 issues, and that poor quality will cause immediate supplier review.

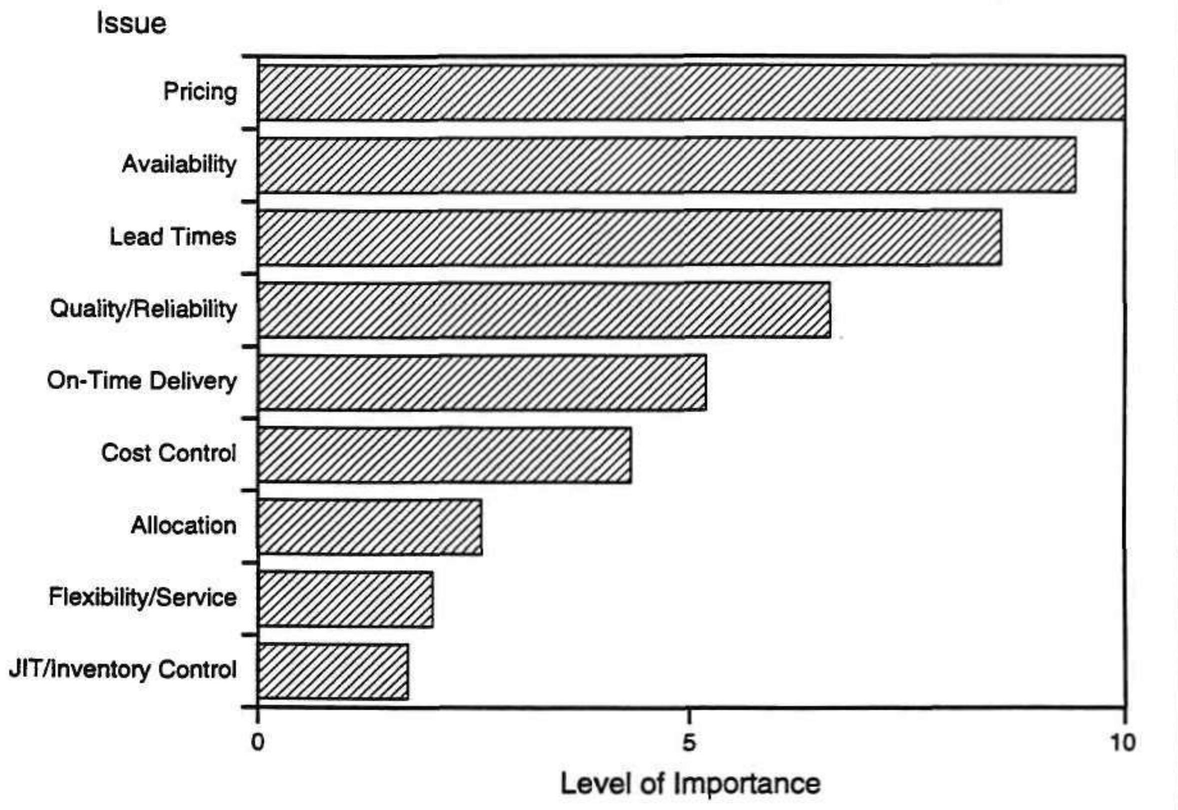
Military/Aerospace

The military/aerospace industry will focus on availability and a combination of quality and price in 1993. Missed delivery schedules and quality that is not up to specifications are reasons to drop a supplier (see Figures 3-17 and 3-18).

Summary

The three main issues that surfaced in this study were that price, availability, and lead time will receive top attention in the upcoming months. Areas now done well (primarily high quality and on-time delivery) need to be maintained by suppliers in order to keep existing customers. On the surface, the paradox of quality ranking as the overall reason for dropping a supplier and of price being the No. 1 cost-cutting issue for next year appears at odds with the concept of total cost management. Quality levels now meet market requirements and the next hurdle to face is lowering a tangible (and very visible) cost variable as much as practically possible. The current systems market is forcing semiconductor users to require the highest level of quality, yet simultaneously cut and control costs. To some extent this can be achieved, but generally only for a limited time. It is up to prudent management to decide what the total cost level must be for a system (integrating quality, price, and delivery, among others) and work toward that goal, rather than solely focus on isolated issues of price, lead time, and the like.

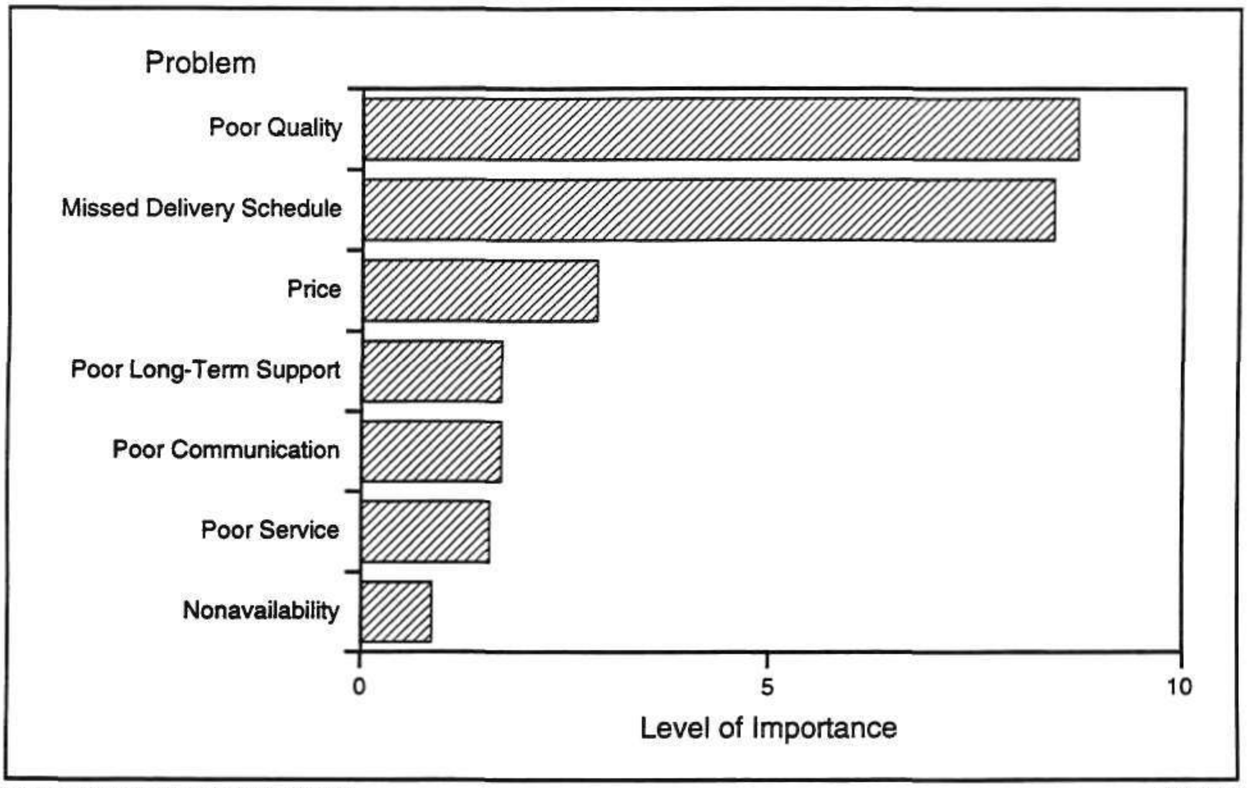
Figure 3-1
Electronics Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992) G2001287

- *Concerns over semiconductor availability, lead time, allocation, and the like are again being raised as suppliers stretch existing capacity to meet demand growth.*
- *Quality and on-time delivery are significant issues, but are considered prerequisites for suppliers today.*

Figure 3-2
Electronics Industry Ranking of Supplier Cardinal Sins



Source: Dataquest (December 1992)

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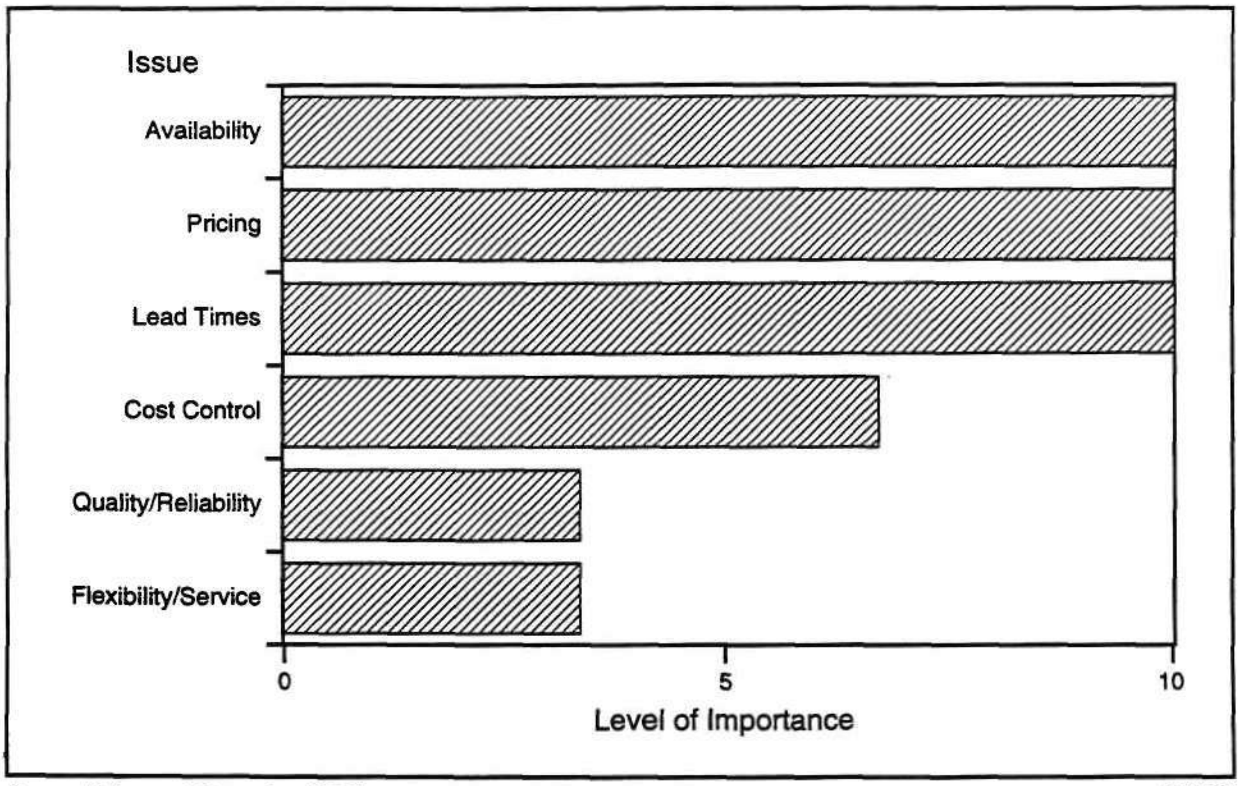
The top two actions/conditions that warrant supplier review or removal tie in directly with the total cost concept that relies on top quality and on-time delivery.

Figure 3-3
PC Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)

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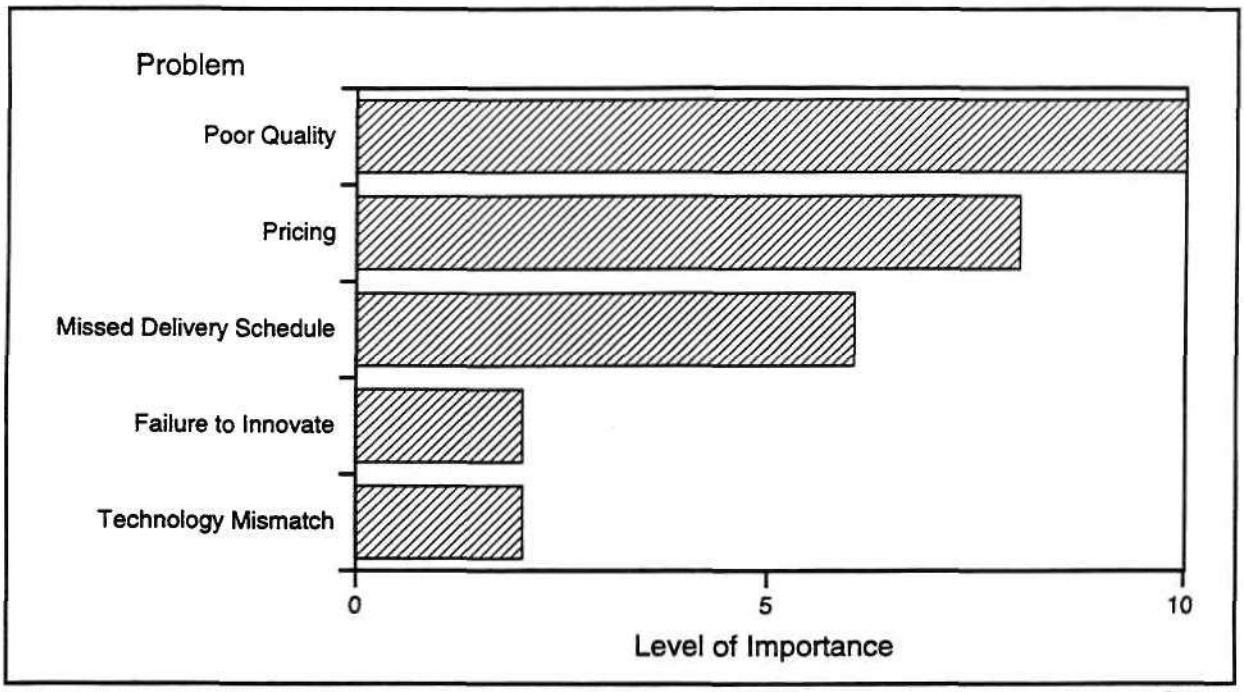
Three issues tie for the top spot in this segment, and all are interrelated. As capacity levels of suppliers fill, availability often takes precedence over price.

Figure 3-4
PC Industry Ranking of Supplier Cardinal Sins



Source: Dataquest (December 1992)

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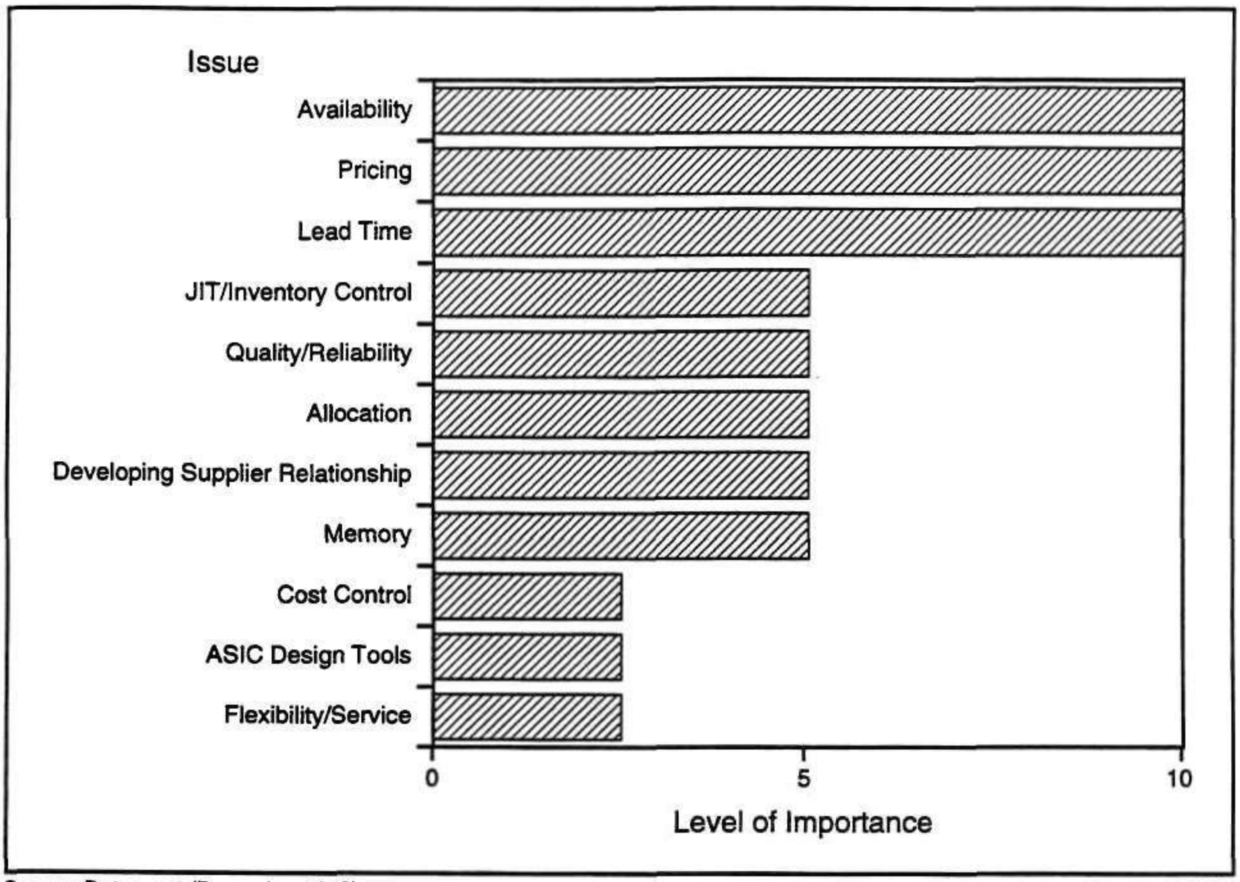
Suppliers that want to avoid review by their personal computer customers should provide top quality, competitively priced parts, and on-time delivery.

Figure 3-5
Other Data Processing Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)

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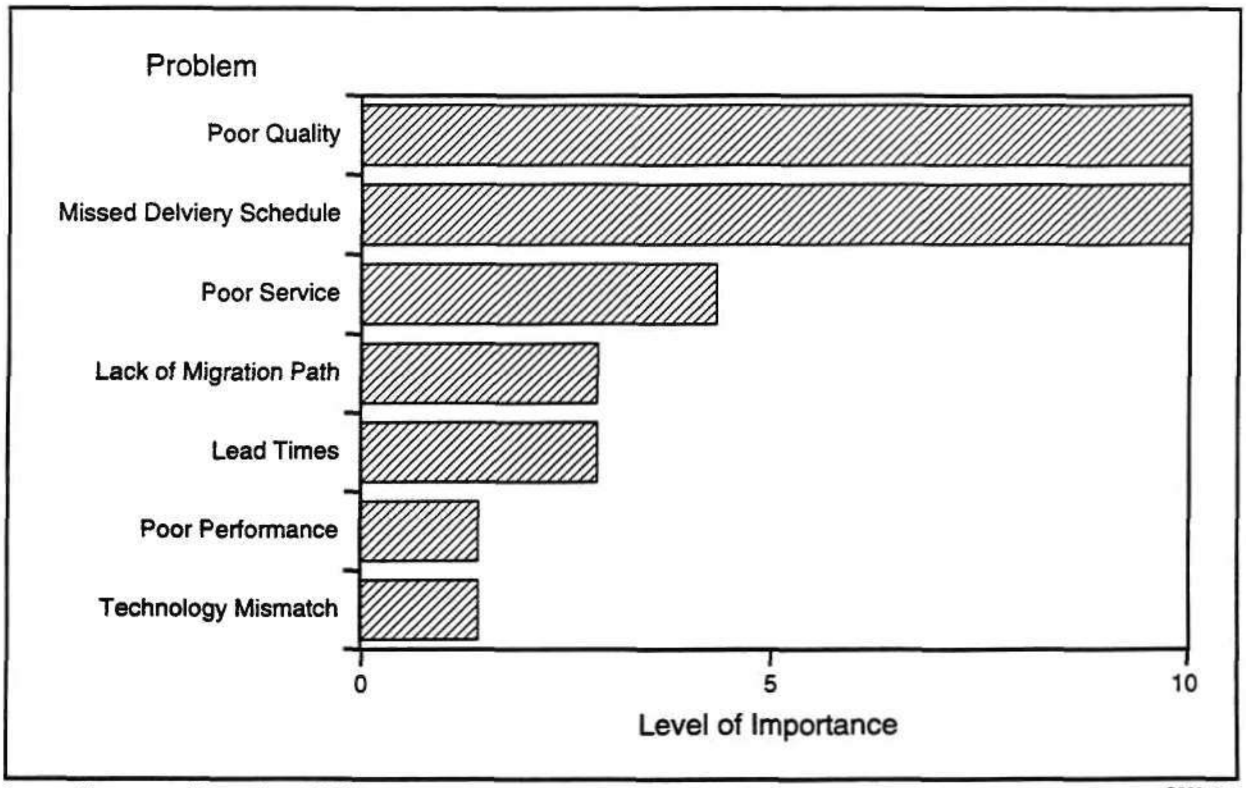
For the rest of the data processing companies, availability, pricing, and lead time tie as the key issues needing attention in 1993.

Figure 3-6
Other Data Processing Industry Ranking of Supplier Cardinal Sins



Source: Dataquest (December 1992)

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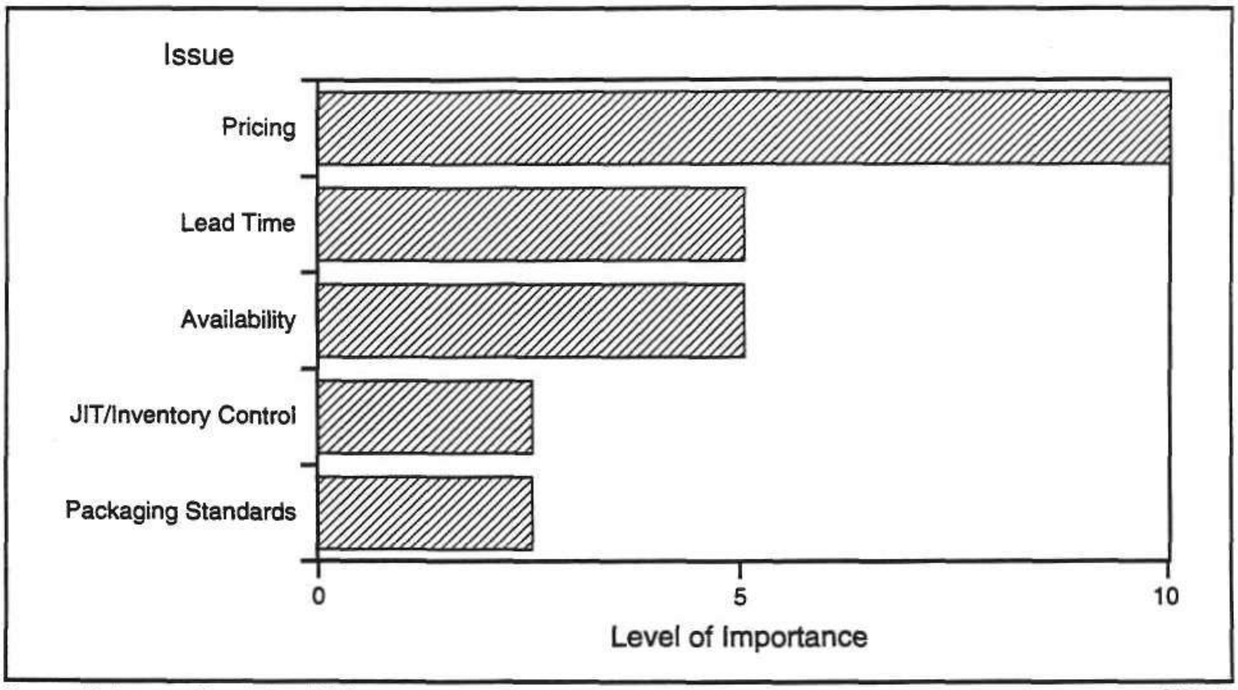
The two main taboos for semiconductor suppliers—poor quality and missed delivery windows—rank as the top problems that would warrant supplier review.

Figure 3-7
Premise Communications Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)

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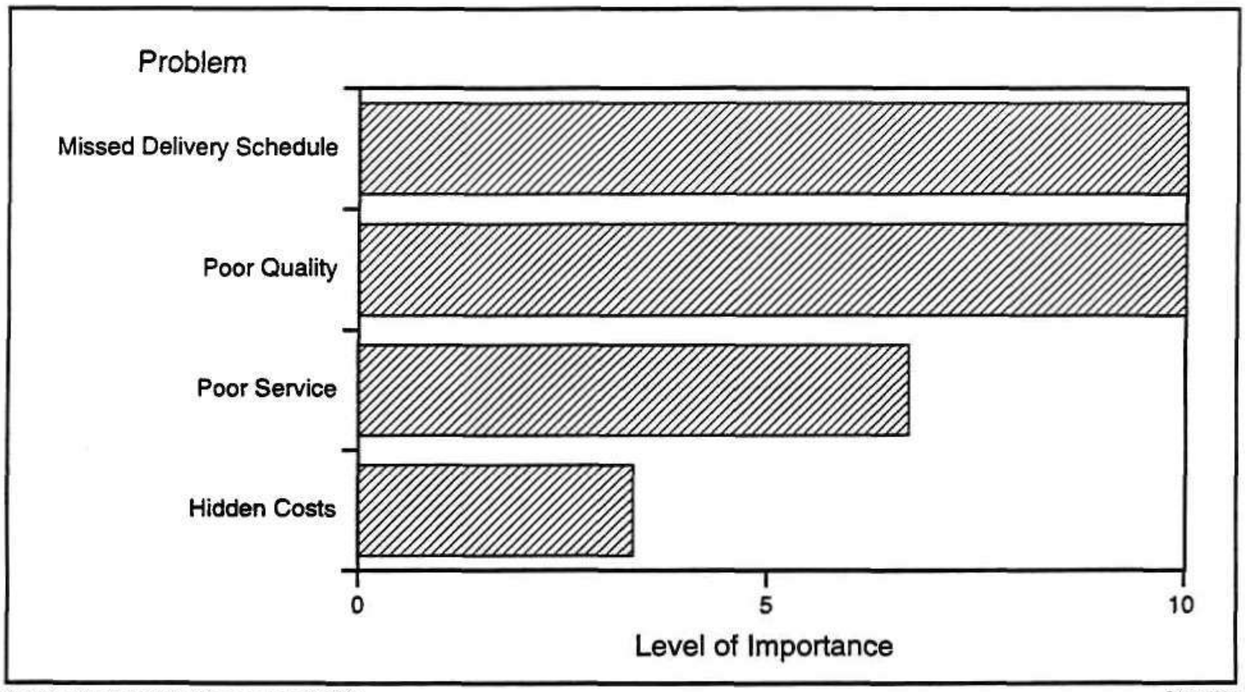
For the premise communications segment, pricing is the most important issue for next year, followed by concern over lead time and availability.

Figure 3-8
Premise Communications Industry Ranking of Supplier Cardinal Sins



Source: Dataquest (December 1992)

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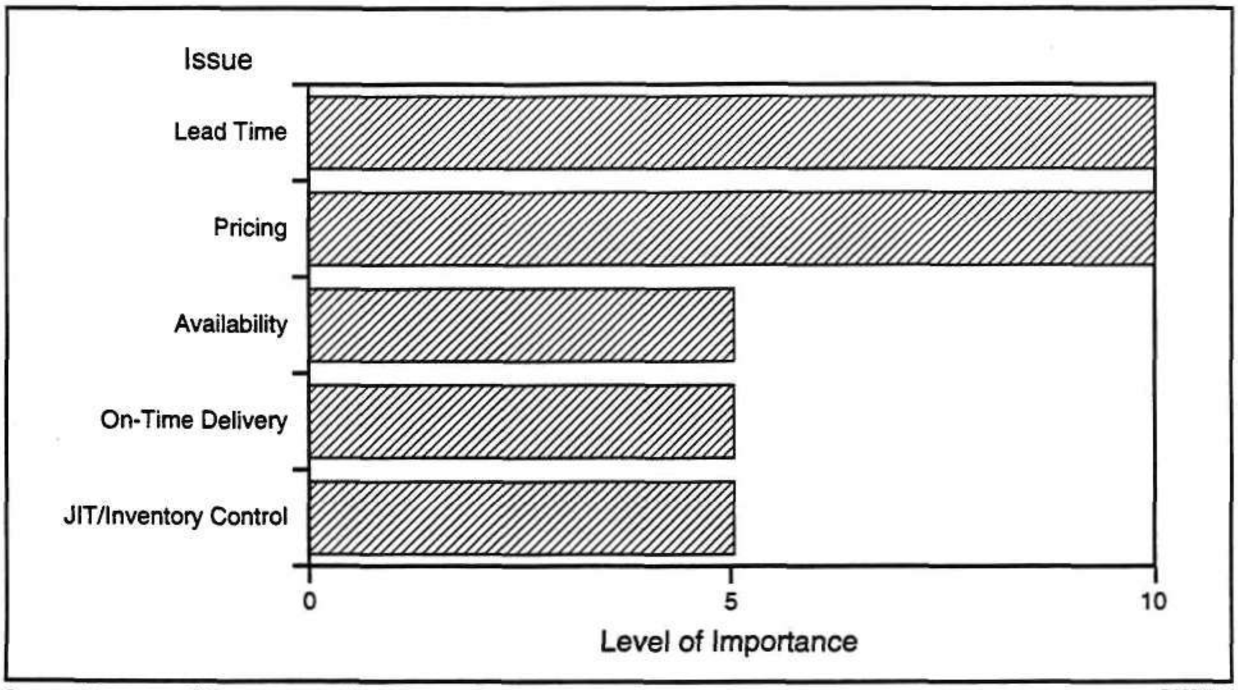
The big two problem areas—poor quality and missed delivery schedule—tie for the top of what suppliers should not do for this segment of customers.

Figure 3-9
Other Communications Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)

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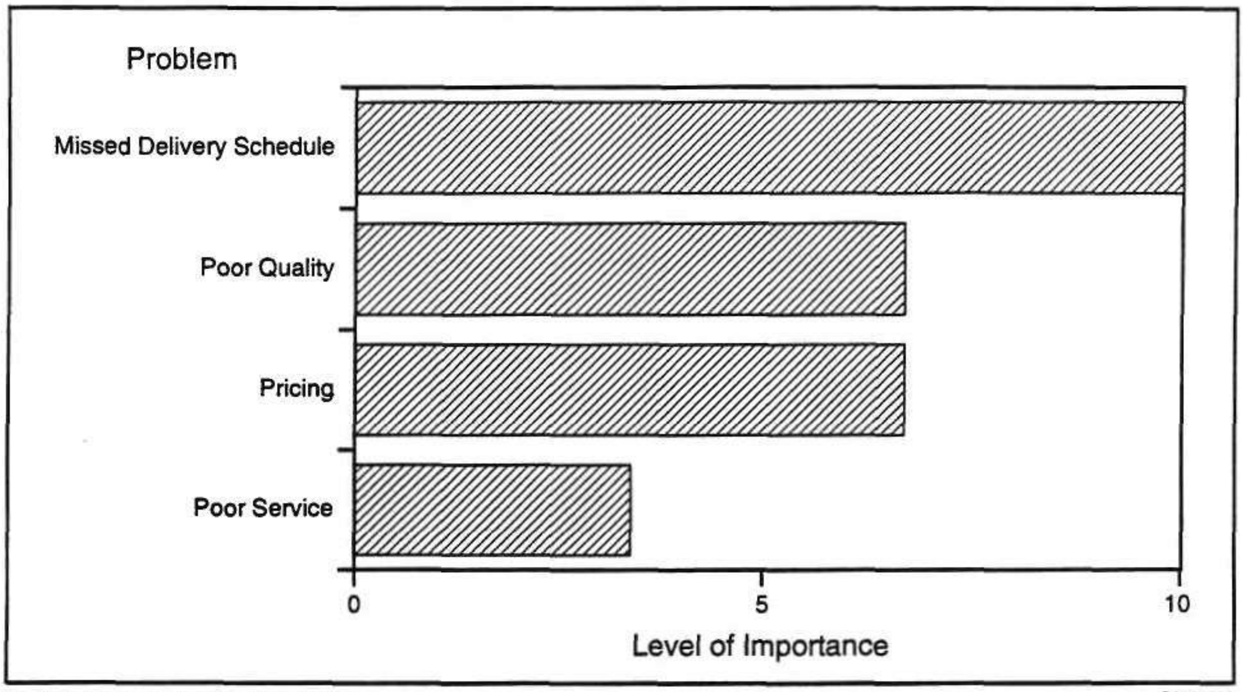
For this segment of the communications industry, lead time and pricing both take top honors as the key concerns for 1993.

Figure 3-10
Other Communications Industry Ranking of Supplier Cardinal Sins

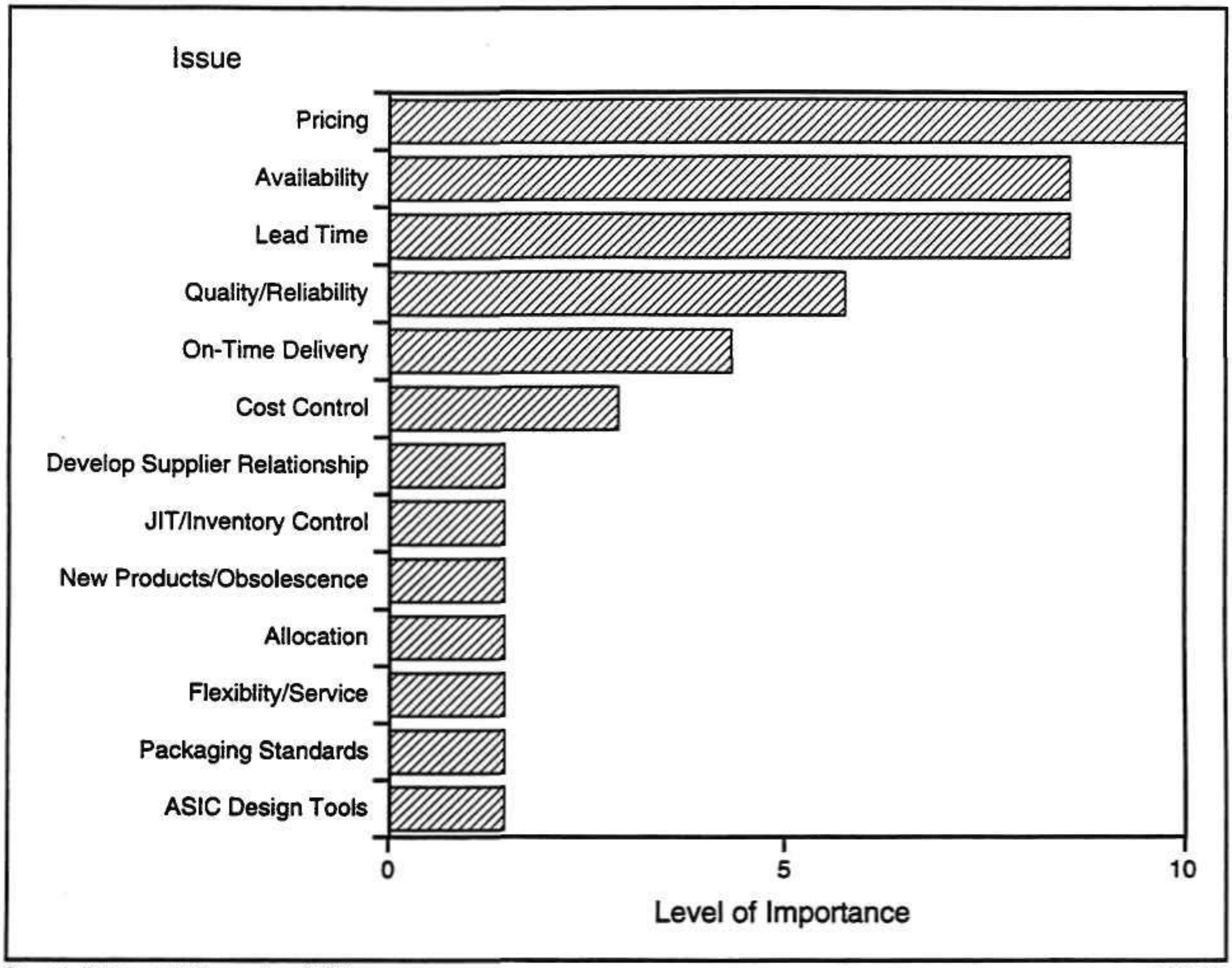


Source: Dataquest (December 1992)

G2001296

Missed delivery schedules is the top area warranting supplier review as inventory levels now remain at target levels (see Chapter 4).

Figure 3-11
Instrumentation Industry 1993 Top Procurement Issues

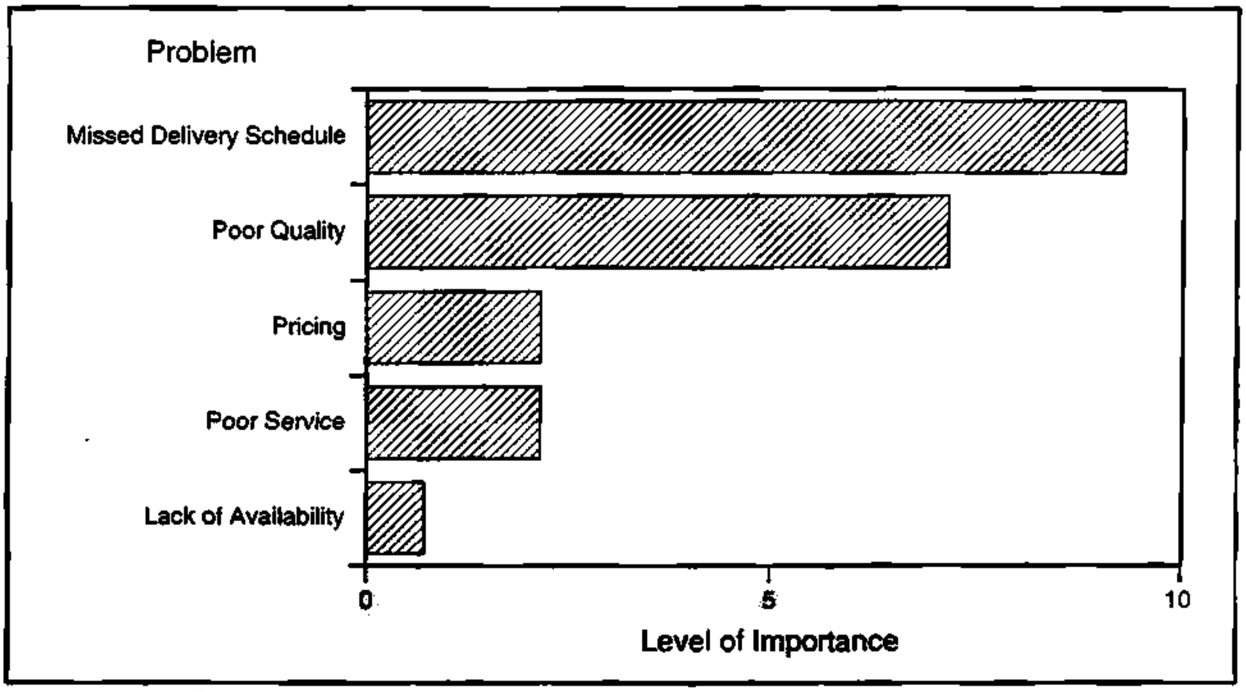


Source: Dataquest (December 1992)

G2001297

This segment sees pricing, availability, and lead time as the top three issues needing focus next year.

Figure 3-12
Instrumentation Industry Ranking of Supplier Cardinal Sins

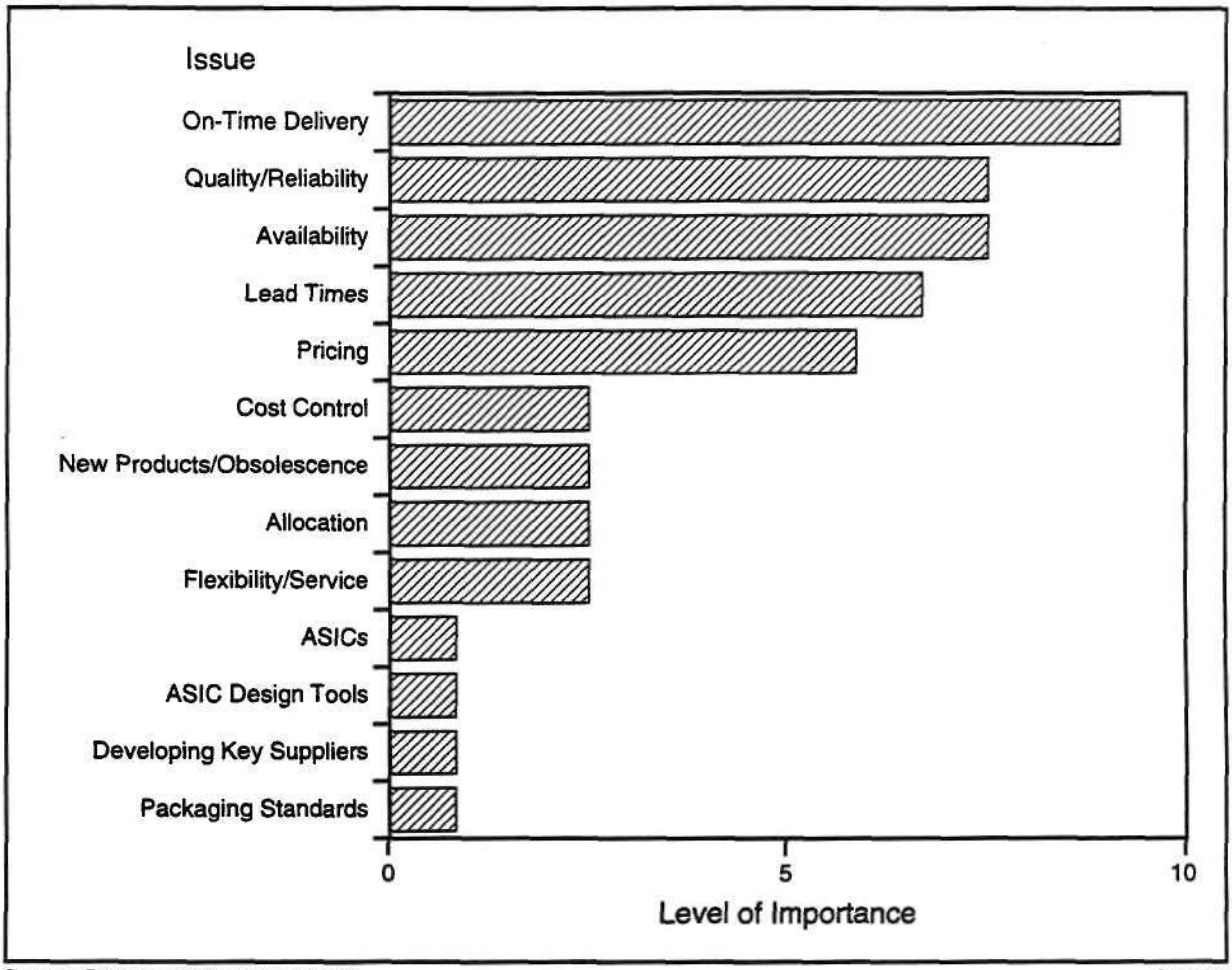


Source: Dataquest (December 1992)

G2001298

Missed delivery windows, followed by poor quality, far and away are the top two areas that warrant supplier review or removal for this segment of the market.

Figure 3-13
Other Industrial Companies' 1993 Top Procurement Issues

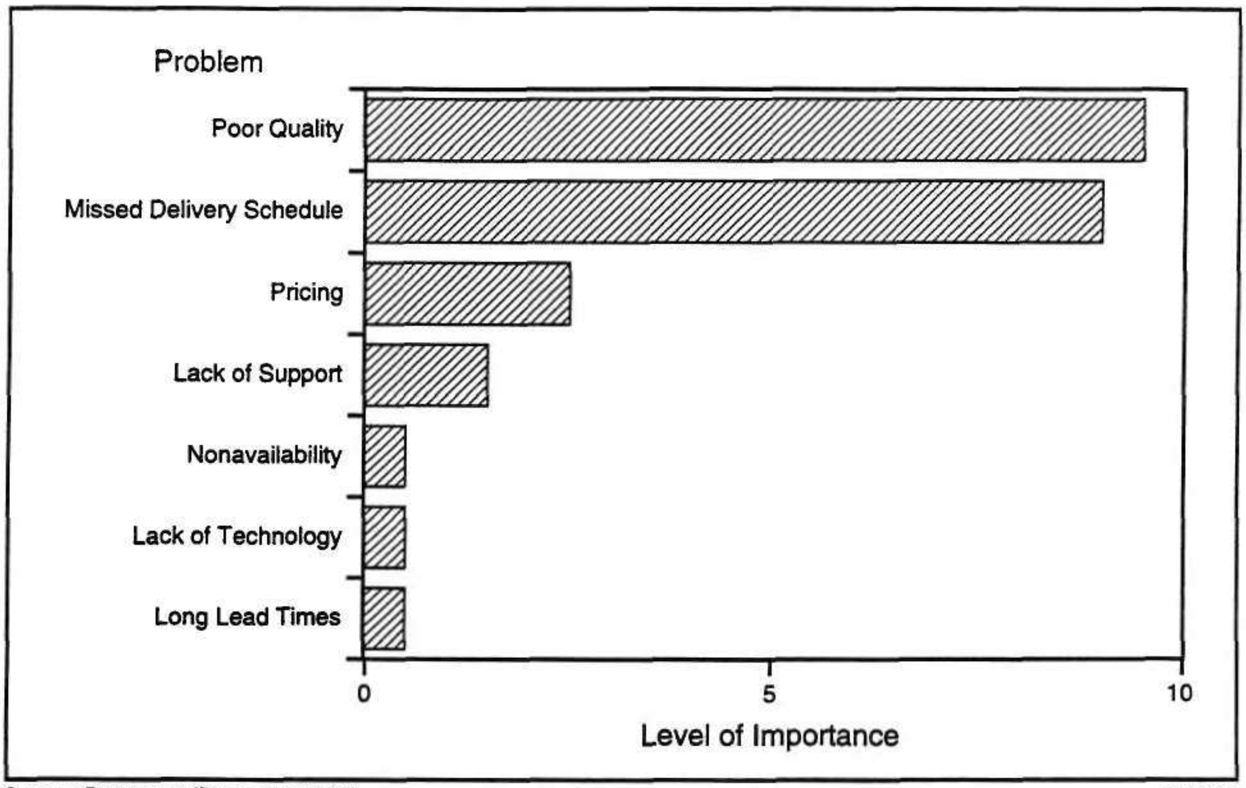


Source: Dataquest (December 1992)

G2001299

- *For the rest of the industrial respondents, on-time delivery is seen as the top issue for 1993.*
- *The top five issues for this group cover the key variables of total cost and all are considered important issues in the upcoming year.*

Figure 3-14
Other Industrial Companies' Ranking of Supplier Cardinal Sins

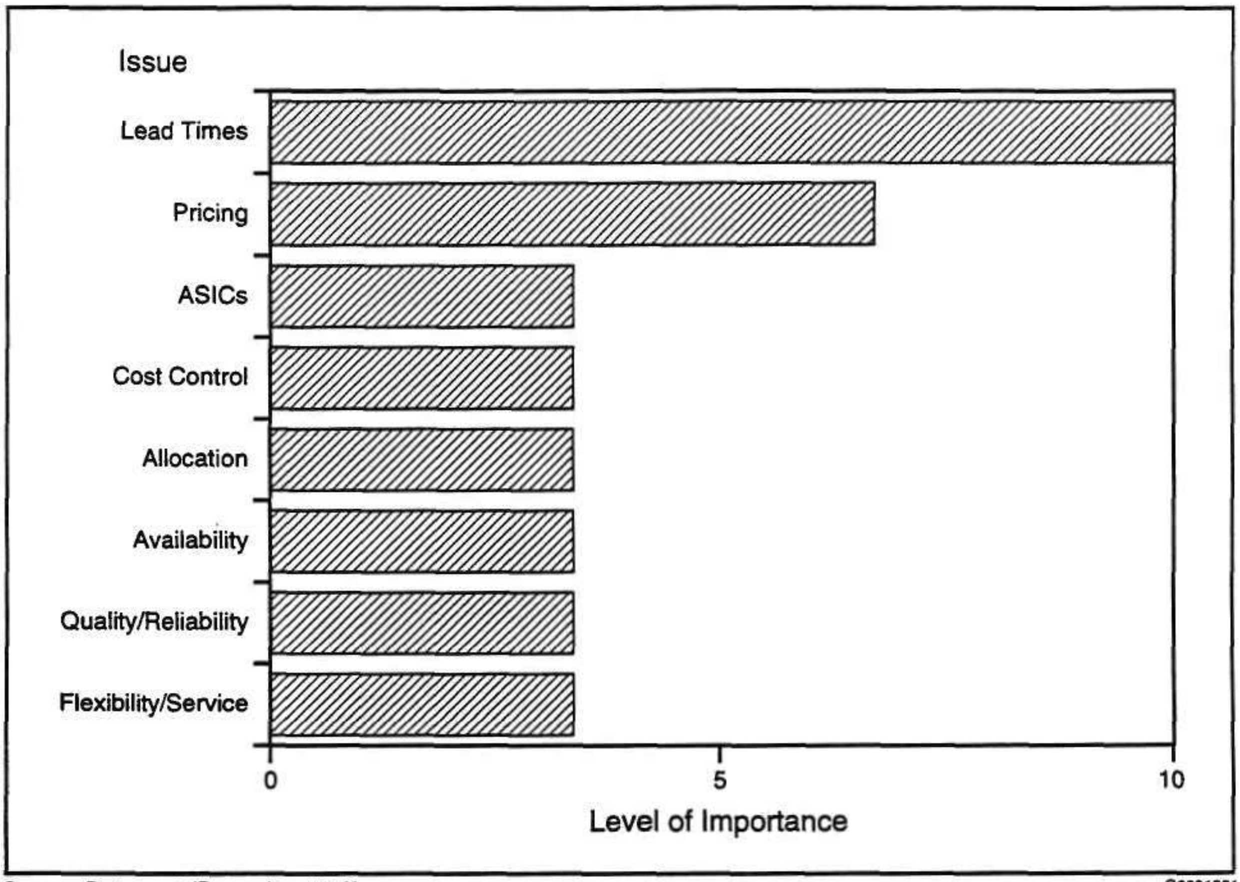


Source: Dataquest (December 1992)

G2001300

The big two user issues—poor quality, followed closely by poor delivery performance—are the main areas that companies in this market segment cannot condone.

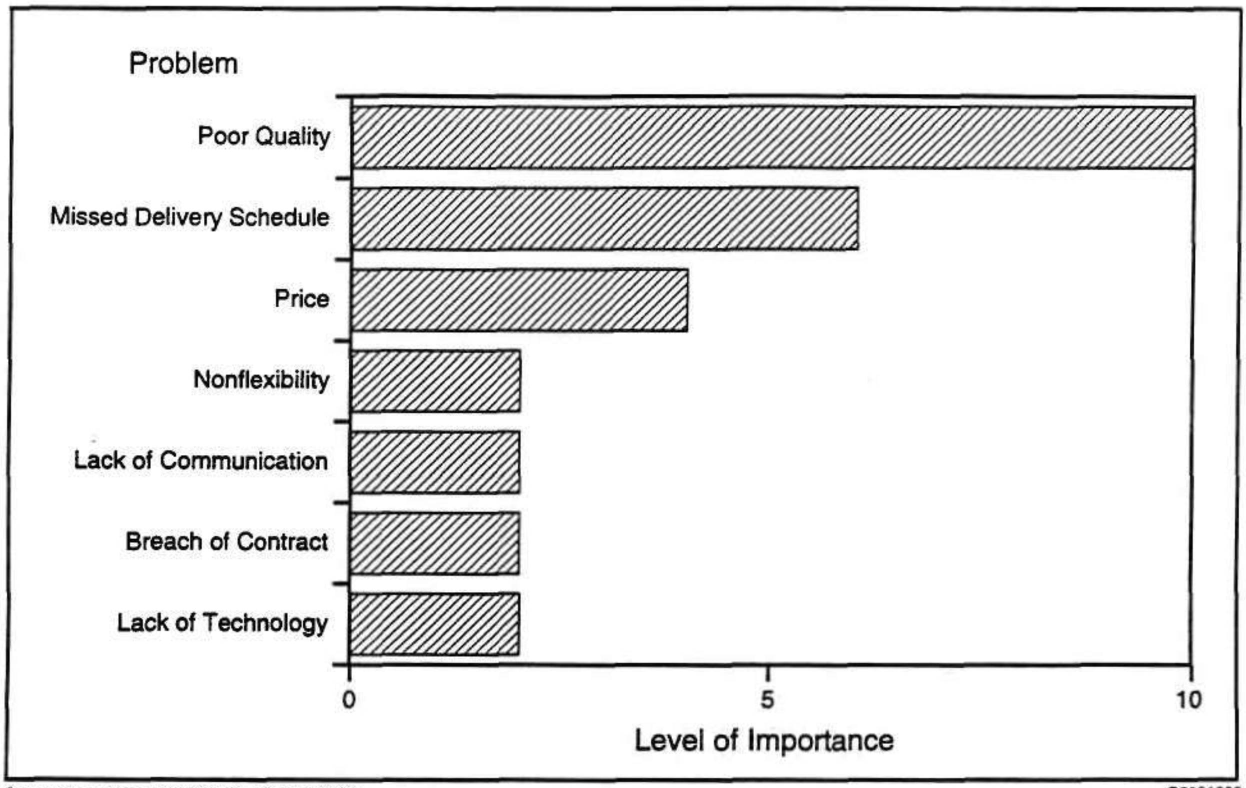
Figure 3-15
Consumer/Automotive Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)
G2001301

Lead time and pricing are the two main issues arising for this segment in 1993.

Figure 3-16
Consumer/Automotive Industry Ranking of Supplier Cardinal Sins

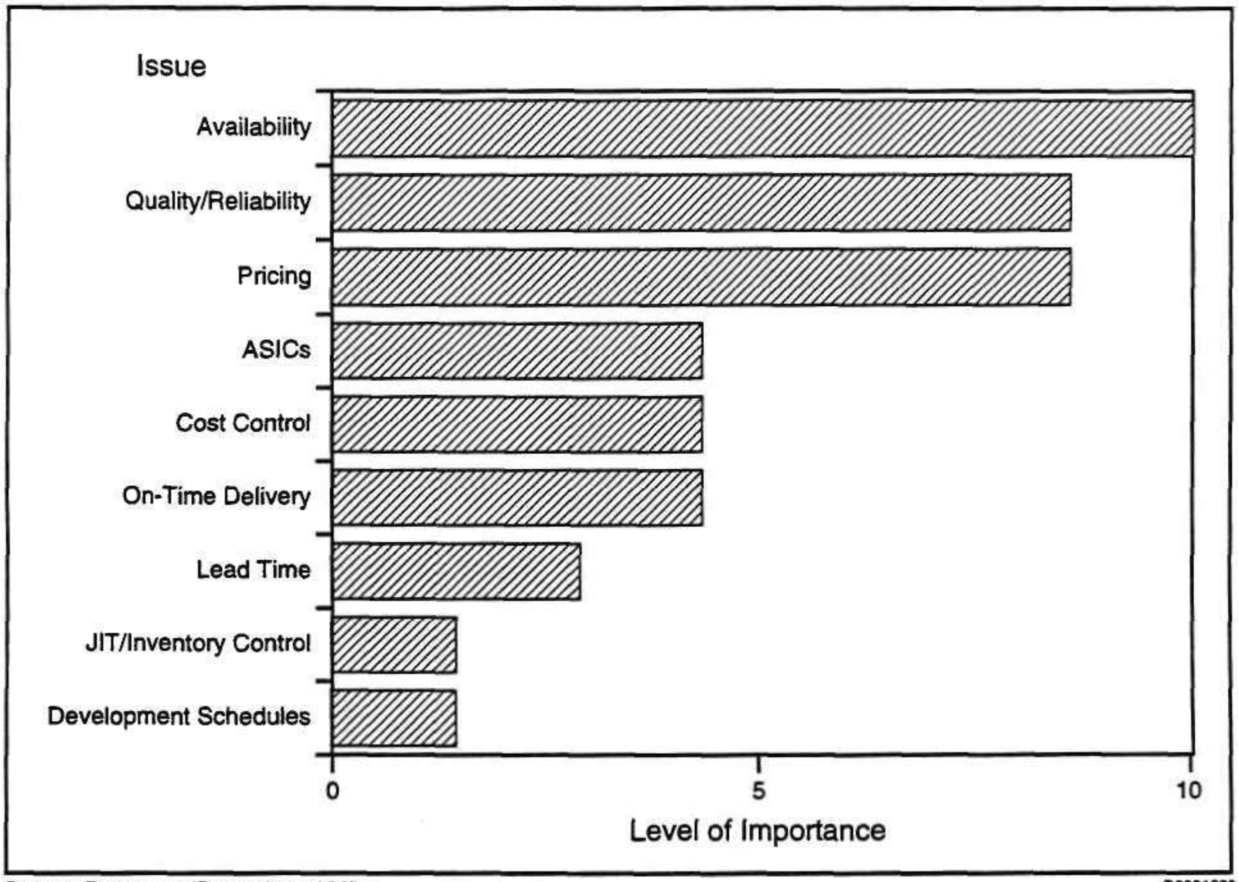


Source: Dataquest (December 1992)

G2001302

Because of the high reliability requirements of the automotive industry, poor quality is deemed the top issue warranting supplier review or disqualification.

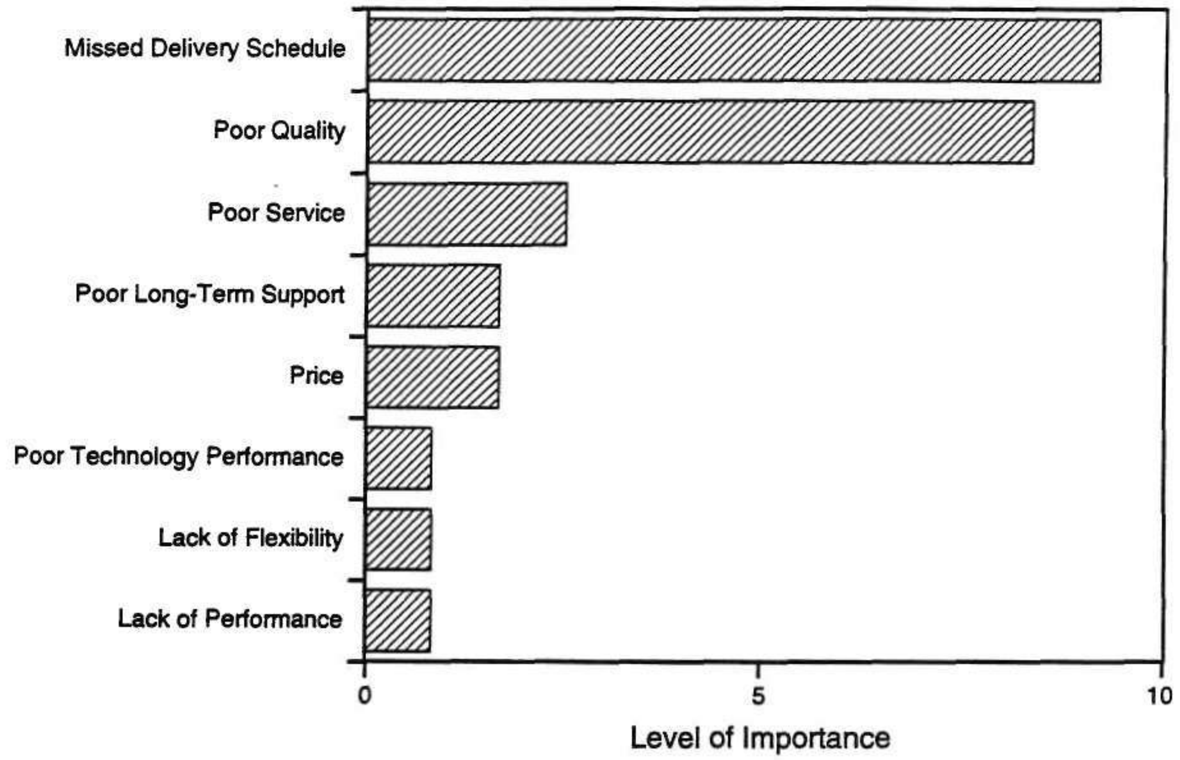
Figure 3-17
Military/Aerospace Industry 1993 Top Procurement Issues



Source: Dataquest (December 1992)
G2001303

The top three concerns for this segment—availability, quality, and price—all will take center stage in 1993 as more cost-effective ways to procure semiconductors continue to be explored.

Figure 3-18
Military/Aerospace Industry Ranking of Supplier Cardinal Sins



Source: Dataquest (December 1992)

G2001304

Missed deliveries and poor quality are anathema for this group, because government contracts often mandate parameters. Suppliers to this market generally are well aware of these requirements.

Chapter 4
Semiconductor User Status and Future Needs, by Industry

This chapter focuses on what the overall electronics industry and each electronic industry subcategory is now doing and what is needed to remain competitive. Areas covered are the type of semiconductor family used by the industry grouping, the percentage of the industry that manufactures its own semiconductors, the extent each industry designs and assembles its own circuit boards, and where those circuit boards are assembled. Next reviewed are the status and plans for the number of semiconductor suppliers, and the level of contract manufacturing and semiconductor distributors used. Then we provide a spot check on semiconductor inventory levels by industry and analysis on the status of industry quality and strategic supplier programs, followed by a 1993 survey forecast for each industry. An analysis of average semiconductor quality levels (by ppm) by major product family and on-time-delivery definitions for the overall electronics industry is also presented. After each industry group summary, reference is made to figures that support the analysis.

Overall Electronics Industry

For the overall electronics industry sample, 93.1 percent designed their own circuit boards, but a third (33 percent) of this aggregate did not assemble them because of contract manufacturing use. Of the overall grouping, 84.4 percent physically assembled their products in the United States, but as noted later in this report, some industries were more homebound than others. The overall trend to reduce the supply base has been achieved, with minor reshuffling of the remaining key supply base of the respondents. As a whole, 61 percent of the respondents used contract manufacturing and were outsourcing an average of 9.6 years. An overall electronics industry definition for on-time delivery ranged from the highest response of +0,-5 days to schedule to the third highest response of +5,-0 days, highlighting the need yet not showing a consensus for one standard definition at this time. Although 14.9 percent of the respondents noted no formal quality program in place at their company, close to two-thirds (58.4 percent) did have a strategic supplier program in place, confirming a trend to lower overall costs via preventative measures. On average, a standard quality-level benchmark ranged from a low of 55.9 ppm (microprocessors/ASSPs), to a high of 69.2 ppm (memory products) for this sample. Based on the aggregate survey results, the overall electronics industry was expected to grow by 15.2 percent in 1993 (see Figures 4-1 through 4-14).

Personal Computer Industry

Three-quarters (75 percent) of the PC industry sample designed its own circuit boards and more than 80 percent (83.3 percent) continued to assemble them in-house. Although 71.4 percent of the sample assembled its boards in the United States, more than a quarter (25.7 percent) utilized offshore assembly in the Far East. The supply base for the PC industry appeared relatively stable, compared with other electronics industry subsets. Nearly two-thirds (62.5 percent) of the PC group used contract manufacturing, on average for 4.8 years. Although all respondents had a strategic supplier program in place, only 75 percent had a formal quality program utilized. Of those with a quality program, 16.7 percent found it only "nice to have." Per this sample, the PC market for 1993 was expected to grow by 10 percent (see Figures 4-15 through 4-25).

Other Data Processing Industries

A full 100 percent of this response segment both designed and assembled its own circuit boards, and 85.4 percent were assembled in the United States. Aside from memory suppliers, the other supply bases were expected to shrink in 1993 relative to this year for this subset. Although slightly more than half (53.8 percent) of the sample used contract manufacturing, the average use was for nearly 10 (9.9) years, highlighting that this "new" trend has been tried and tested for some time. Although 23.1 percent of the respondents' companies did not have a formal quality program in place, 60 percent of those companies that did found it "critical" in their cost-cutting goals. Nearly half (46.2 percent) of this group did not have a strategic supplier program in place. The 1993 outlook per this market sample was expected to grow by 15 percent (see Figures 4-26 through 4-36).

Premise Communications Industry

Although 100 percent of the respondents designed their own circuit boards, a solid 40 percent outsourced their assembly. More than three-fourths (78 percent) of the boards were physically assembled in the United States, with the large majority of the rest (21 percent) assembled in the Far East. The overall semiconductor supply base for this segment was expected to remain static next year. This subset is another strong user of contract manufacturing: 60 percent used outside contractors and had been for an average of 10.7 years. For the 60 percent of the sample that has a formal quality program in place all found the program "critical" to their ongoing operations. Although all respondents had a strategic supplier program in place, 20 percent noted that it was only "nice to have," highlighting an area that may need attention to maximize the return on this investment in time and money (see Figures 4-37 through 4-44).

Other Communications Industries

This segment of the industry wholly (100 percent) designed and assembled its own circuit boards; 97.5 percent of this sample physically assembled them in the United States. Aside from the ASIC supply base, all other semiconductor supplier levels were expected to shrink in 1993, per this group's response. Half (50 percent) of the sample used contract manufacturers, yet the average usage was only 3.0 years, the lowest average noted in this survey. Three-fourths (75 percent) of the respondents have a quality program in place, and all (100 percent) noted that it is "critical" to their operation. Likewise, 75 percent of the group had a strategic supplier program, and all (100 percent) of these participants found the program "critical" in sourcing components. The survey response industry outlook for 1993 was for an average 15.0 percent growth (see Figures 4-45 through 4-55).

Instrumentation Industry

About four-fifths (83.3 percent) of the respondents of this segment of the industrial equipment industry designed their own circuit boards, yet a third (33 percent) outsourced their assembly. This grouping is another strong user of domestic assemblers; 94 percent physically assembled their boards in the United States. Aside from the general-purpose microprocessor/ASSP supply base, all other supplier levels were expected to be marginally trimmed in 1993. Comparing closely with the overall electronics industry, 61.1 percent of this sample used contract manufacturers and had done so on average for 7.2 years. Nearly 90 percent (88.9 percent) of the respondents had a formal quality program in place, of whom 62.5 percent found the program "critical" to operations. Nearly 40 percent (38.9 percent) did not have a strategic supplier program formulated. This area of the industrial market was expected, per this sample, to grow an aggressive 25 percent in 1993 (see Figures 4-56 through 4-66).

All Other Industrial Companies

For all of the other industrial companies in our sample, 96.3 percent designed their own circuit boards and outsourced an average 36 percent of them for assembly by contract manufacturers. More than three-fourths (79.8 percent) of the boards are physically assembled in the United States, with 13.2 percent assembled in the Far East. Like the public/radio communications segment, this grouping was expected to marginally reduce its semiconductor supply base in the next year, except for the ASIC area. Contract manufacturers were used by 74.1 percent of the respondents and had been used an average 9.7 years, again highlighting the long usage of this extension of manufacturing. More than 90 percent (92.6 percent) of this sample had a formal quality program in place, with more than half (56 percent) noting it was "critical" to their business' success. Although 51.9 percent of this group had a strategic supplier program working, those participating generally were positive with the results thus far. On average, the survey respondents expected 1993 growth for this segment to be 11.5 percent (see Figures 4-67 through 4-77).

Consumer/Automotive Industries

All (100 percent) of this market segment designed its own circuit boards and 42.9 percent outsourced its assembly. Nearly two-thirds

(64.3 percent) physically assembled their boards in the United States, with the remainder assembled either in Japan or other areas in the Far East. The supply base level for this subset was expected to change, with memory and ASIC suppliers expected to rise, and the microprocessor/ASSP and logic supply base expected to shrink. Although more than half (57.1 percent) of the sample did not use a contract manufacturer, those that had on average used one (or more) for 7.3 years. More than 85 percent (85.7 percent) of the respondents had a formal quality program in place, and 83.3 percent saw it as a "critical" aspect of their business. A similar 85.7 percent of the sample had a strategic supplier program, of which a minority (16.7 percent) saw it as only "nice to have." Per these respondents' outlook, this segment of the industry was expected to grow 7.5 percent in 1993 (see Figures 4-78 through 4-88).

Military/Aerospace Industries

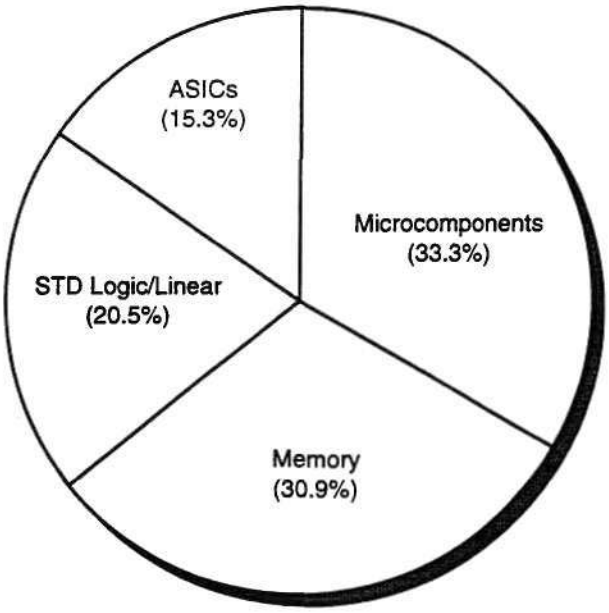
A strong majority of 94.4 percent of the respondents in this market designed their own circuit boards, and a like majority of 62.5 percent outsourced their assembly. Again the majority (93.4 percent) assembled their boards in the United States, with the balance spread evenly between Japan and the rest of Asia. As a result of restructuring in the defense industry, the overall supply base for this segment was expected to decline in 1993. This segment was by far the longest users of contract manufacturing; 55.6 percent of the respondents used outside contractors and had done so for an average of 16 years. Although quality specifications are often written into military contracts, the strong showing of 88.9 percent of the respondents having a formal quality program in place was not surprising. What was interesting was that only 37.5 percent of the respondents saw the program as "critical" to ongoing business. Although only 33.3 percent of the respondents had a strategic supplier program in place, 83.3 percent saw the program being either "beneficial" or "critical" to their companies (see Figures 4-89 through 4-99).

Summary

Based on our survey results, the U.S. electronics industry designs and assembles the majority of its own circuit boards and predominantly assembles them in the United States, with the Far East as the runner-up for assembly location. Although the majority of supplier reductions have occurred over the past few years, some fine-tuning remains where users continue to improve the balance of what they need/require versus what their supply base can deliver. The "latest" trend to use contract manufacturers or "outsource" is not new at all to the respondents of this survey. There is a positive correlation, however, to the amount of contract manufacturing used relative to the amount of time a company has used outside contractors. This bodes well for the contract manufacturing industry and for user companies weighing the pros and cons of whether to use outside contractors.

The vast majority of the respondents have a formal quality program in place and for the most part see the results at worst beneficial; many see the programs as critical to their ongoing business. It appears that, although strategic supplier programs have gotten much lip service and many companies have programs under way, more of the response was that the program is nice to have rather than critical or beneficial to business. This is an area where suppliers have an opportunity to differentiate themselves or solidify an ongoing program by addressing user requirements noted in Chapters 3 and 5. The 15.2 percent average electronics 1993 growth forecast given by our respondents is a bit aggressive, based on our research (Dataquest's 1993 U.S. electronics market forecast is 4.4 percent), but it does reflect positive outlook for next year as the economy pulls itself out of the current slowdown.

Figure 4-1
Electronics Industry Survey IC Purchases

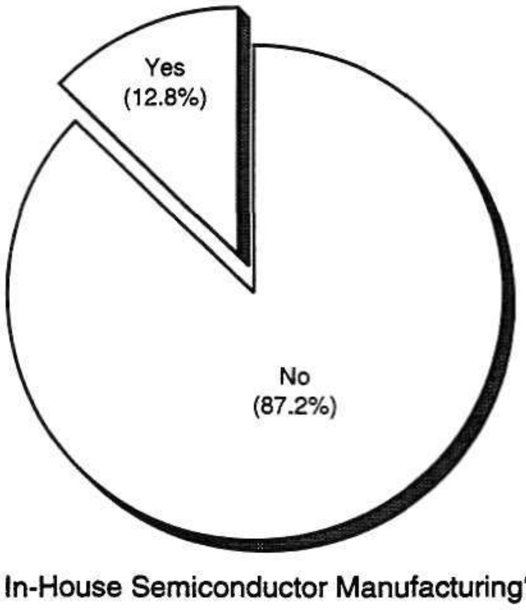


Source: Dataquest (December 1992)

G2001305

Nearly two-thirds (63.2 percent) of the overall electronics industry's IC purchases go to memory or microcomponent products.

Figure 4-2
Electronics Industry Captive Semiconductor Production

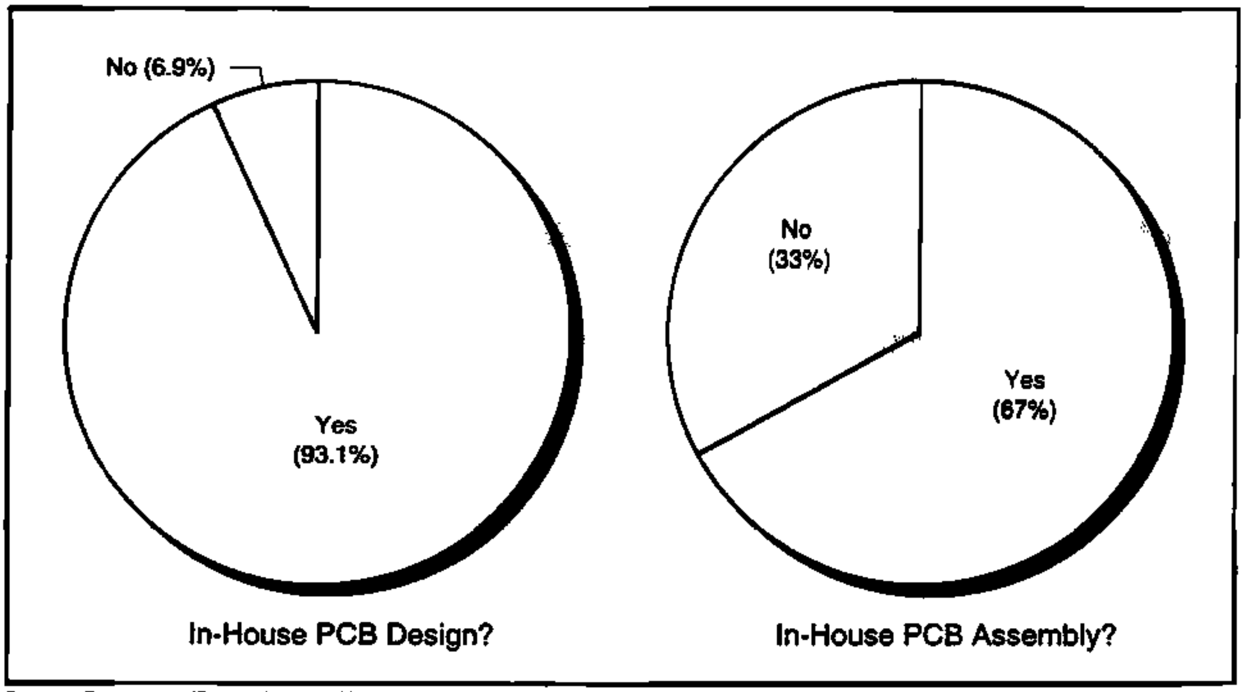


Source: Dataquest (December 1992)

G2001306

A minority of overall respondents (12.8 percent) have internal semiconductor production capability.

Figure 4-3
Electronics Industry Circuit Board Design and Assembly

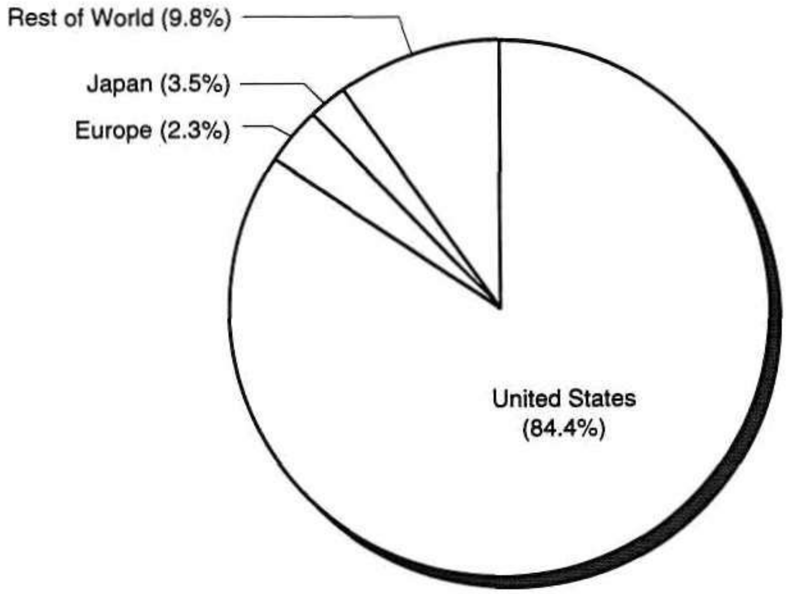


Source: Dataquest (December 1992)

G2001307

Although the majority of the electronics industry designs its own circuit boards, a full one-third of the respondents subcontract their board assembly.

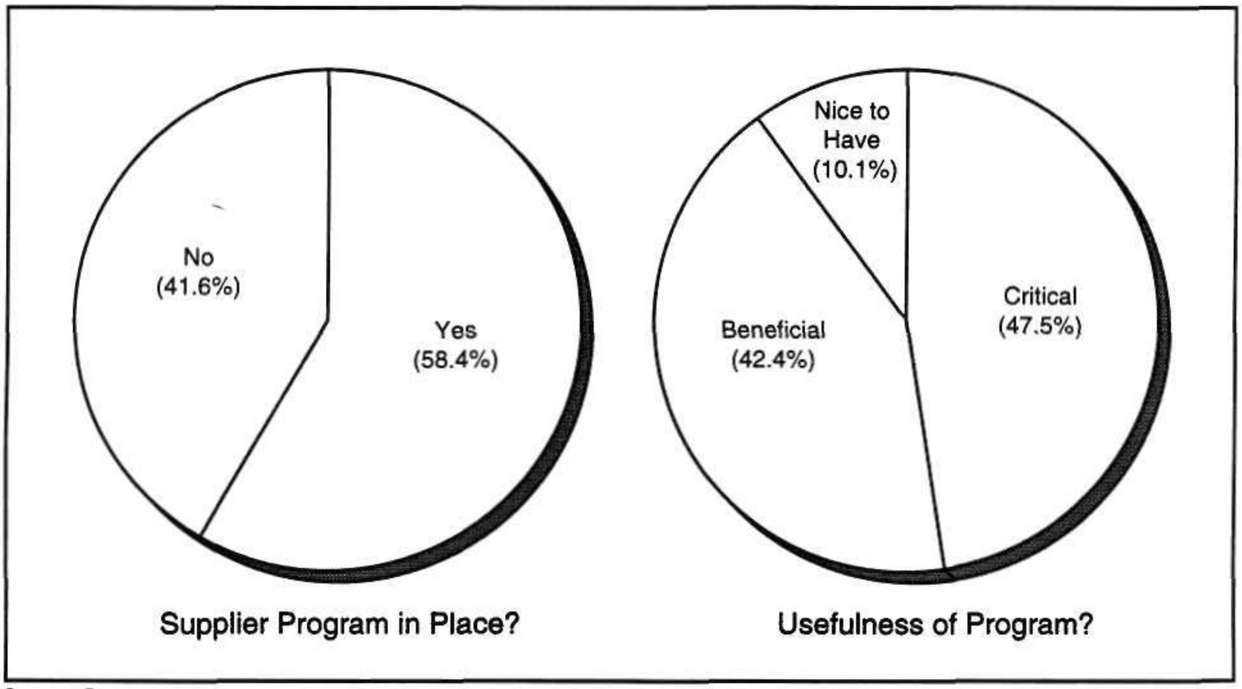
Figure 4-4
Electronics Industry Physical Circuit Board Assembly Region



Source: Dataquest (December 1992)
G2001308

More than 80 percent of all circuit boards assembled are in the physical United States, with nearly 10 percent in Asia outside of Japan.

Figure 4-5
Electronics Industry Strategic Supplier Status

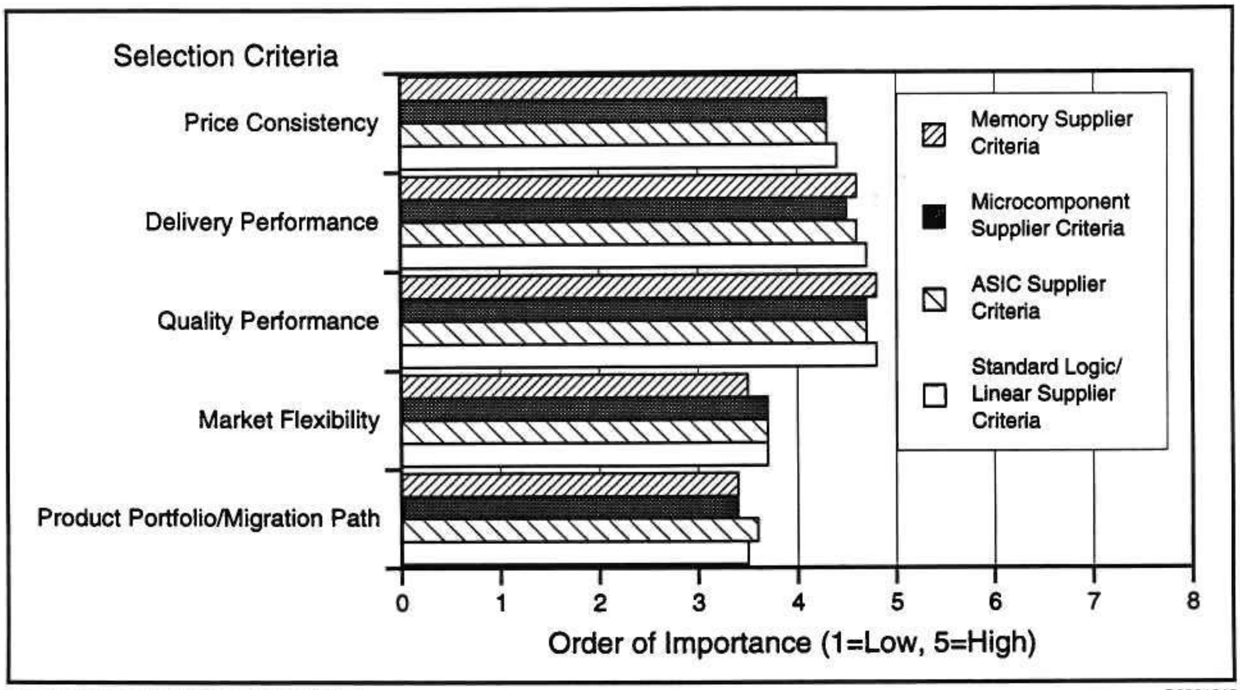


Source: Dataquest (December 1992)

G2001309

Although more than half the respondents have a strategic supplier program in place, less than half see it as critical to their business; 10.1 percent see such programs as merely "nice to have."

Figure 4-6
Electronics Industry Semiconductor Supplier Selection Criteria

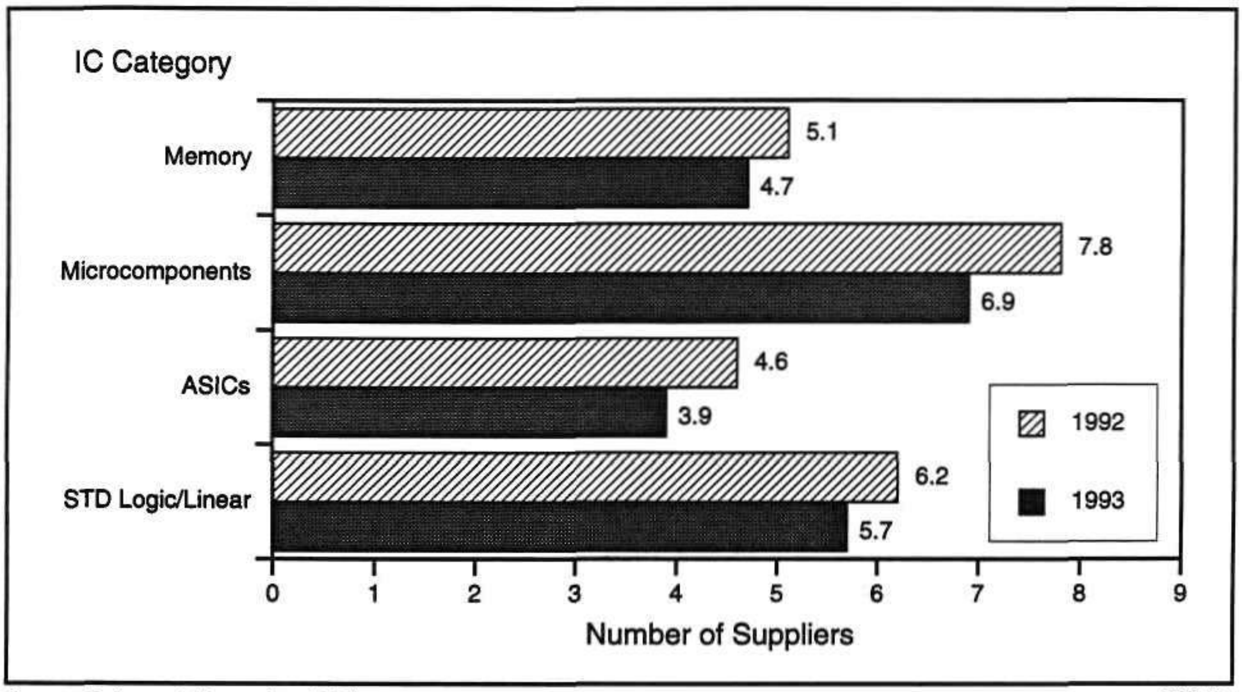


Source: Dataquest (December 1992)

G2001310

The top criteria used by the aggregate sample in selecting prospective semiconductor suppliers are quality and meeting delivery schedules.

Figure 4-7
Electronics Industry Supply Base Trend

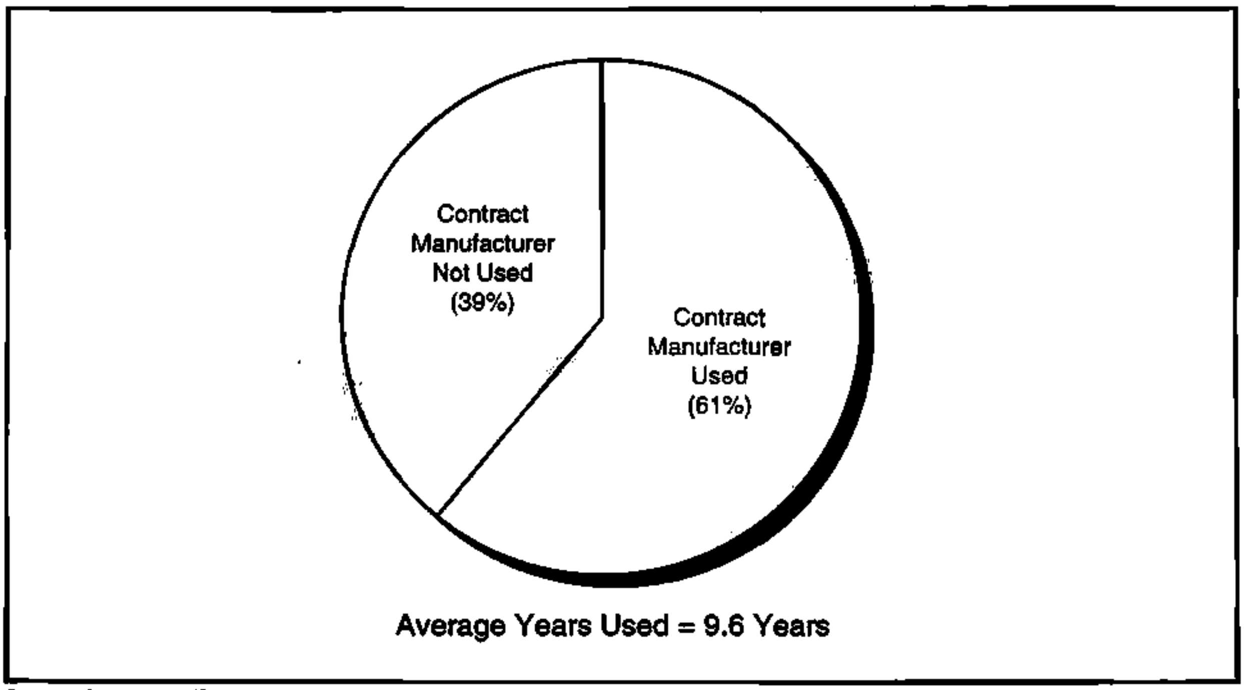


Source: Dataquest (December 1992)

G2001311

The overall trend is to reduce the number of suppliers, but for the most part the survey respondents are fine-tuning existing low supply base levels.

Figure 4-8
Electronics Industry Contract Manufacturer Use

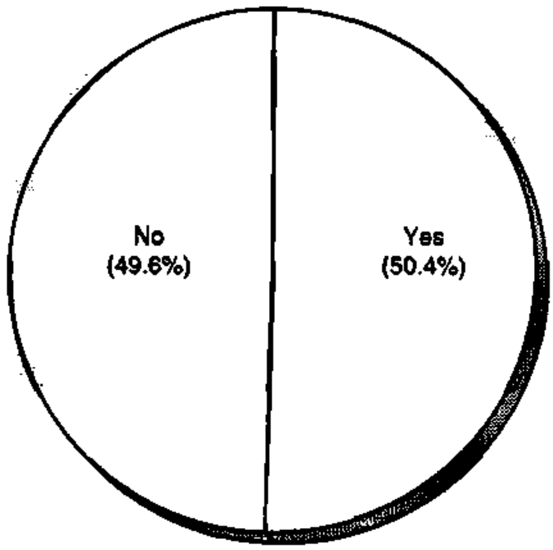


Source: Dataquest (December 1992)

G2001312

- *More than 60 percent of respondents use contract manufacturers and have used them an average of more than nine years.*
- *The growing contract manufacturing market has long been a resource used by these large companies.*

Figure 4-9
Electronics Industry Semiconductor Distributor Use

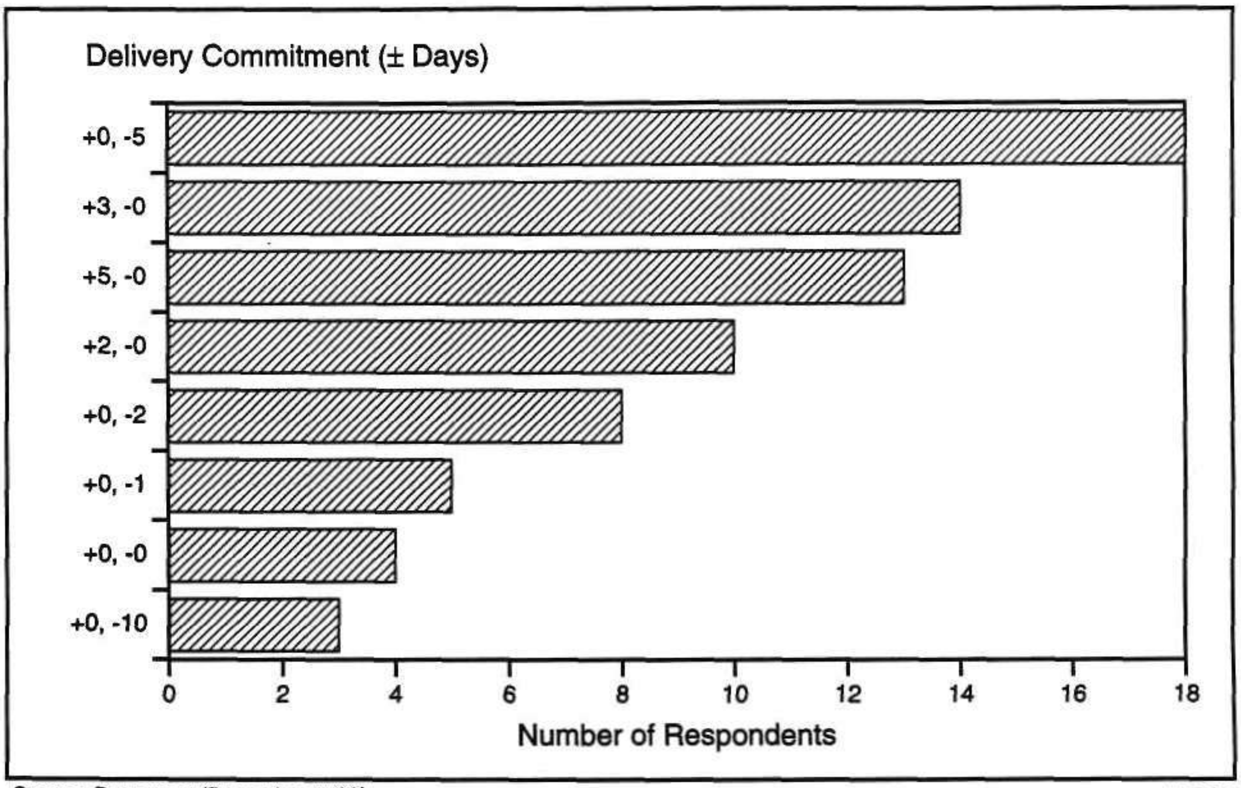


Source: Dataquest (December 1992)

G2001313

- *Slightly more than half of the sample uses semiconductor distribution.*
- *Distribution is not being used just by small to midsize semiconductor users.*

Figure 4-10
Electronics Industry On-Time Delivery Definitions

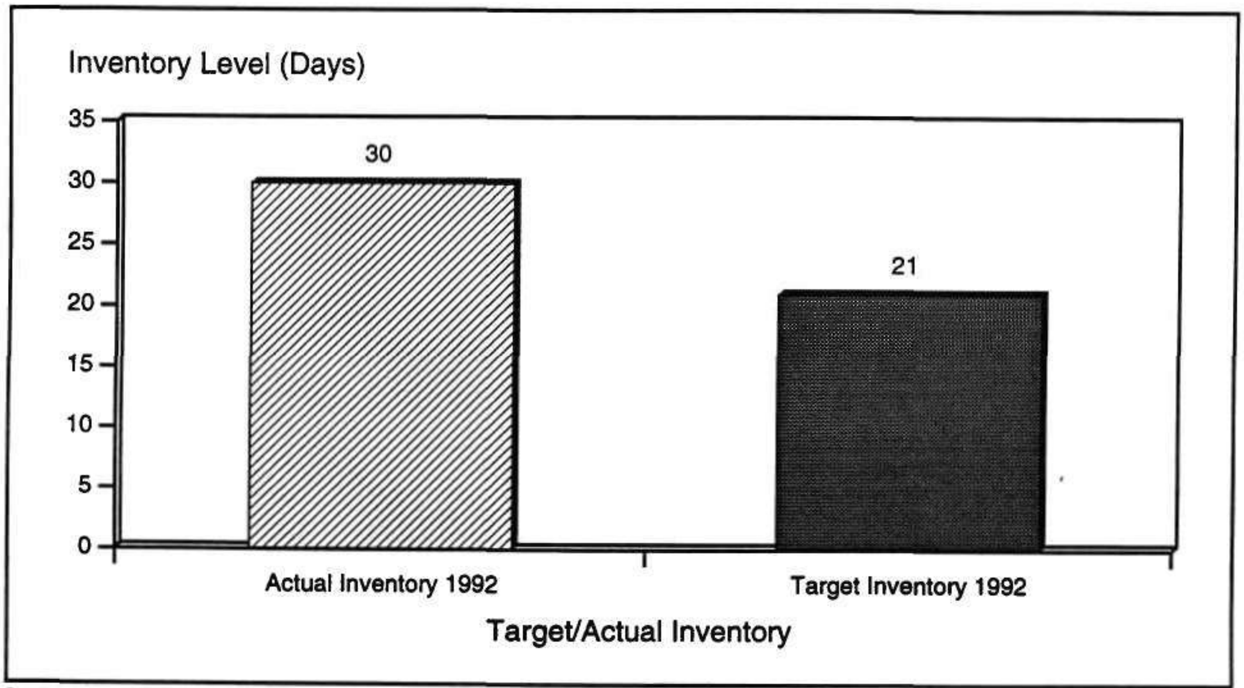


Source: Dataquest (December 1992)

G2001314

- *Nearly half (45 percent) of the respondents favor between +0,-5 days; +3,-0 days; or +5,-0 days as a standard on-time delivery window.*
- *Taken together, this 10-day (+5,-0 and -0,+5) window has room for improvement.*

Figure 4-11
Electronics Industry Semiconductor Inventory Status

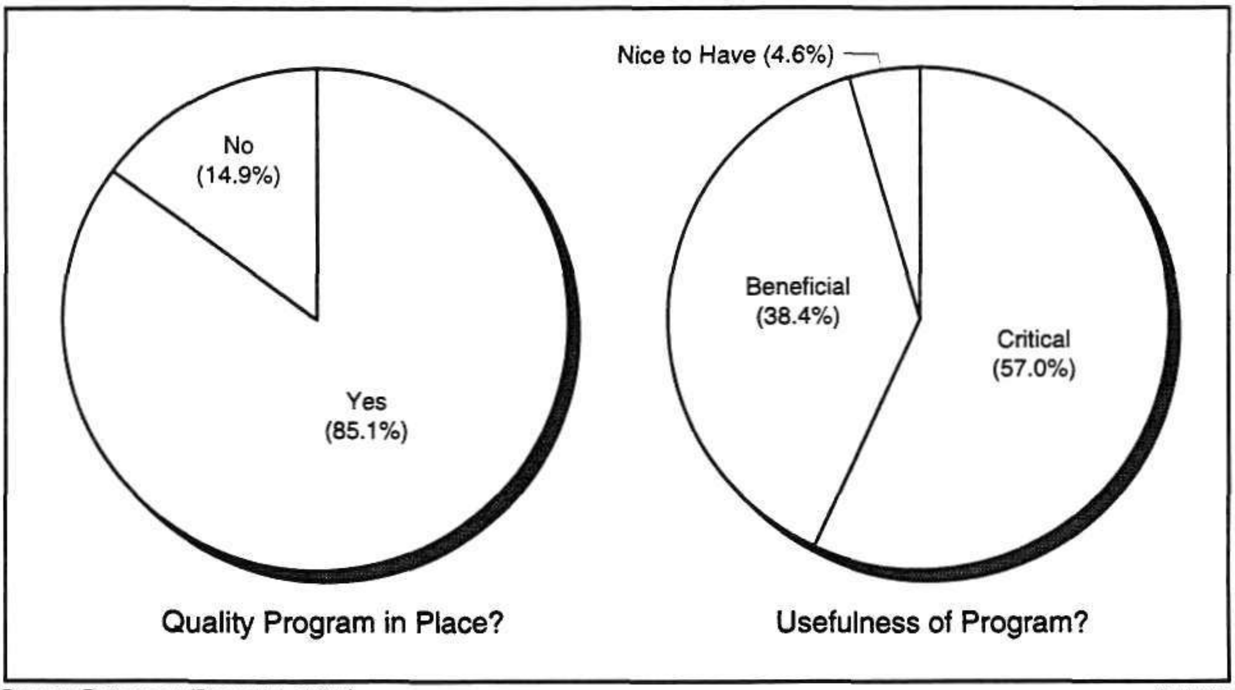


Source: Dataquest (December 1992)

G2001315

Actual semiconductor inventory levels of 30 days for the overall electronics industry highlights that cost control is being focused on in this very tangible area.

Figure 4-12
Electronics Industry Quality Improvement Program Status

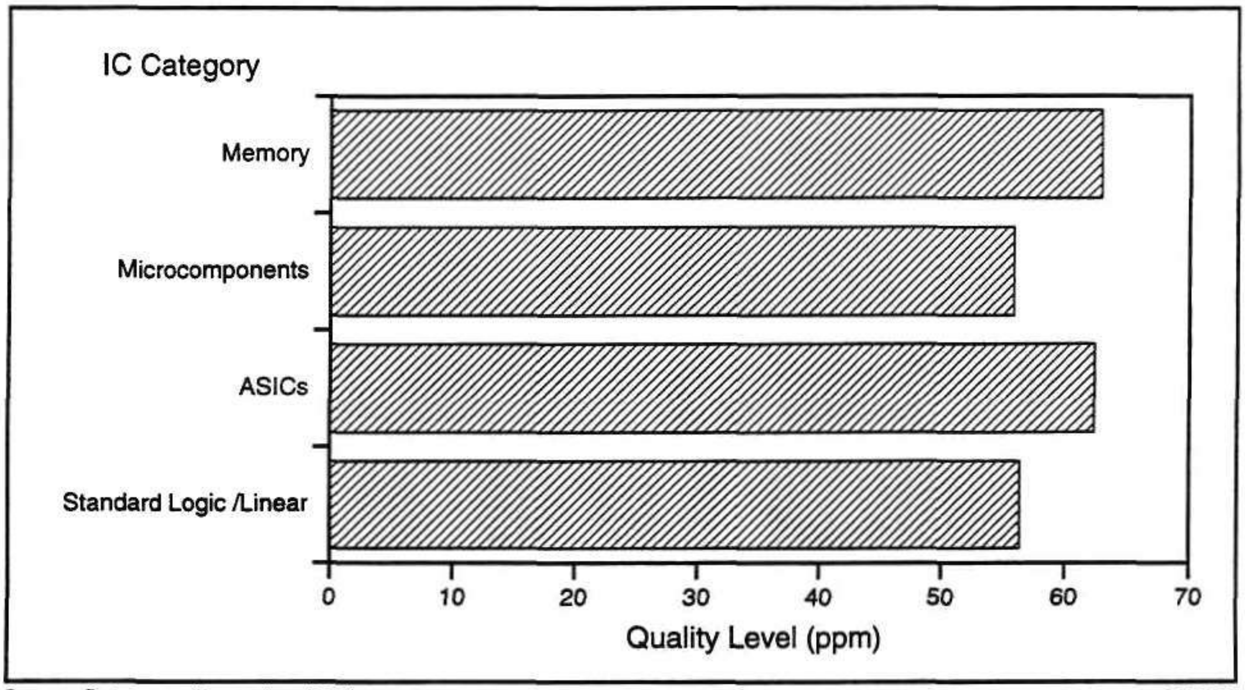


Source: Dataquest (December 1992)

G2001316

More than 85 percent of the respondents have a formal quality program in place; 95.3 percent of those that have one find the program either critical or beneficial to their business.

Figure 4-13
Electronics Industry Average Quality Level, by Major Semiconductor Product Family (ppm)

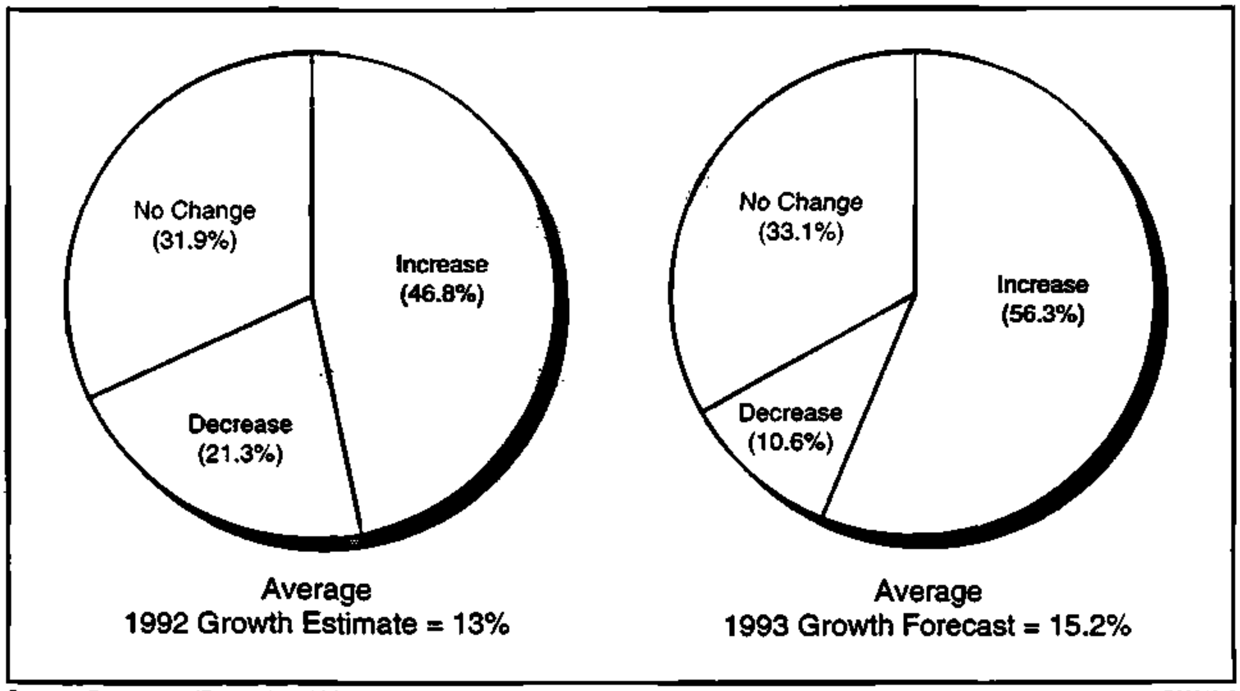


Source: Dataquest (December 1992)

G2001317

- *Quality improvement programs are reflected in the high overall average quality standard, ranging from 55 to 69 ppm.*
- *Improvements in quality programs should continue to result in lower ppm levels.*

Figure 4-14
Electronics Industry Surveyed Growth Outlook

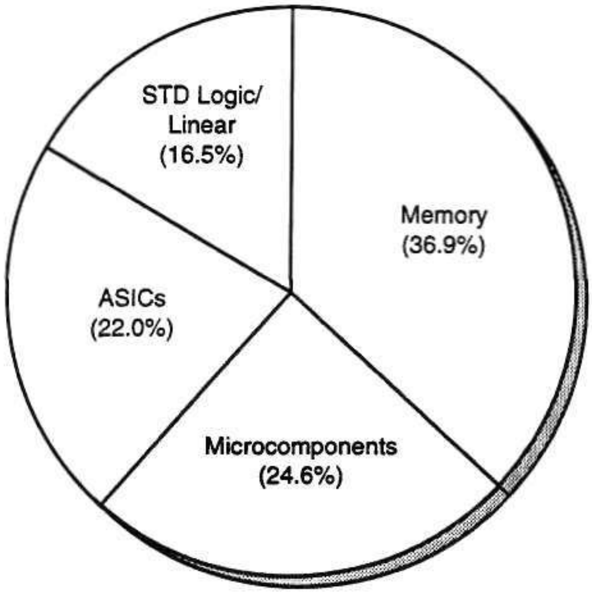


Source: Dataquest (December 1992)

G2001318

- *The percentage of respondents expecting business to improve rose from less than half to more than half.*
- *Those expecting business to decline went from 21.3 percent in 1992 to 10.6 percent in 1993.*
- *This level of optimism, though a bit aggressive, underlies the overall trend for a positive growth year in 1993.*

Figure 4-15
PC Industry Survey IC Purchases

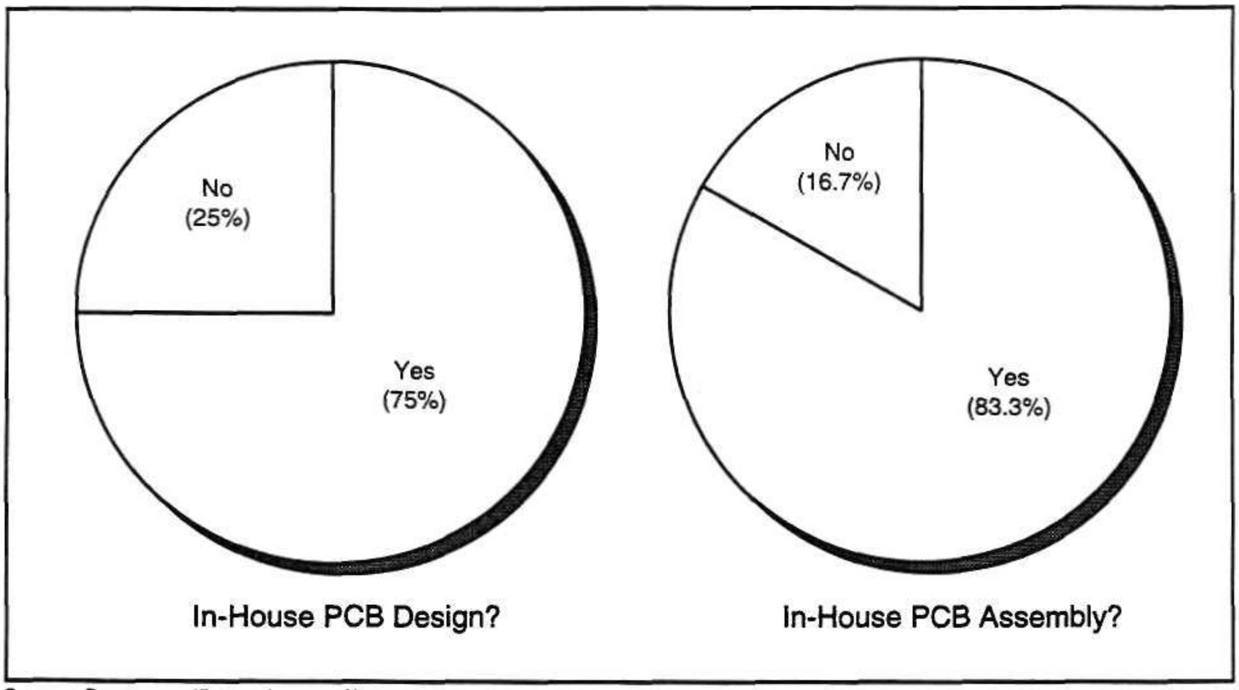


Source: Dataquest (December 1992)

G2001319

- *Because of the high memory content of PC systems, it is not surprising to see more than 36 percent of all semiconductor purchases going to memory.*
- *Combined with microprocessing purchases, more than 60 percent (61.5 percent) of semiconductor buys for this PC industry sample go to microprocessor and memory products.*

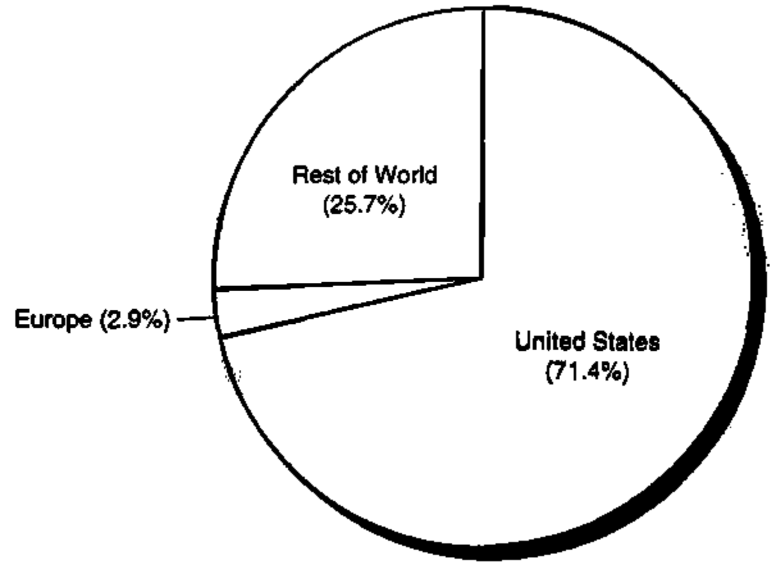
Figure 4-16
PC Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992)
G2001320

As the PC market continues to become commoditized, it is interesting to note the percentages of respondents that do not design or assemble their own circuit boards.

Figure 4-17
PC Industry Physical Circuit Board Assembly Region

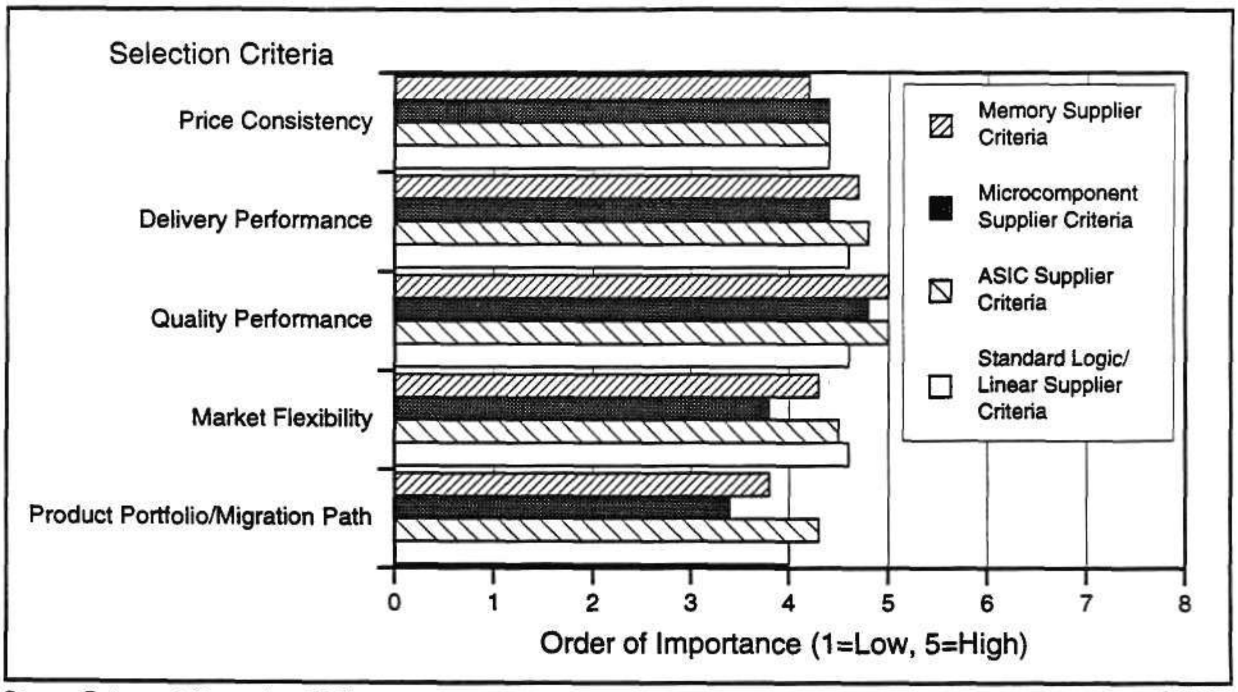


Source: Dataquest (December 1992)

G2001321

Although a great majority of U.S. company PC assembly is still done onshore, more than 25 percent of it is done in Asia outside of Japan.

Figure 4-18
PC Industry Semiconductor Supplier Selection Criteria

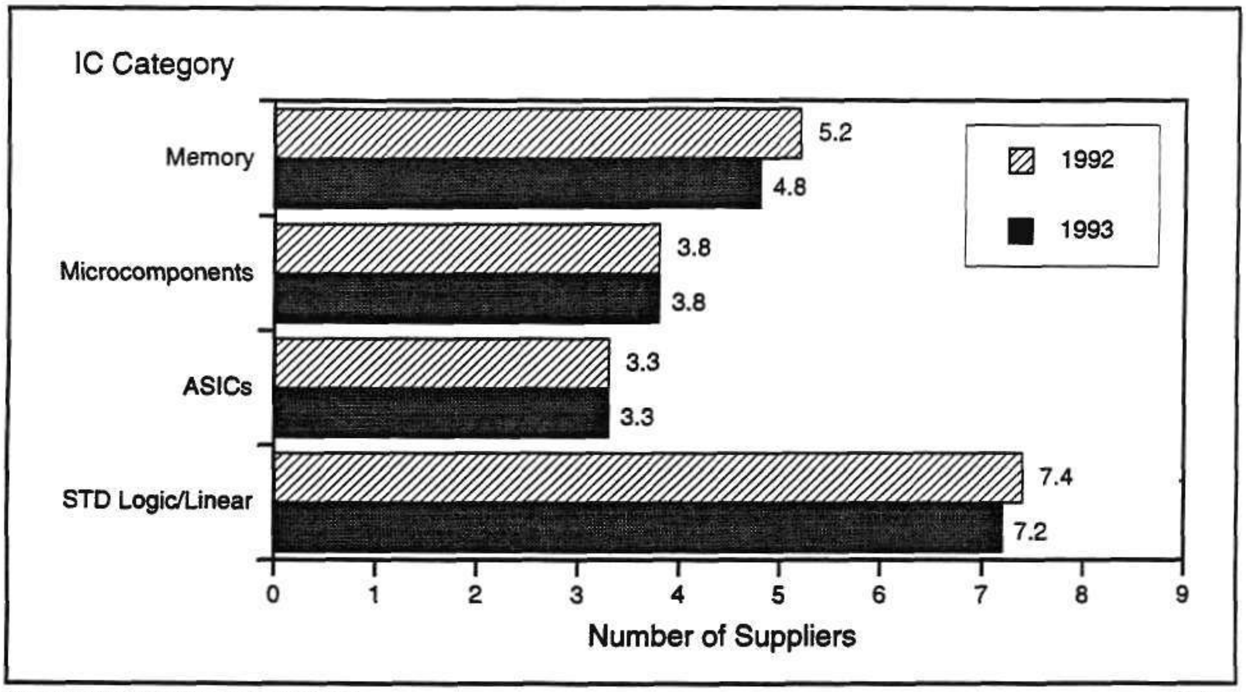


Source: Dataquest (December 1992)

G2001322

The PC industry requires absolute quality adherence when selecting memory and ASIC suppliers.

Figure 4-19
PC Industry Supply Base Trend

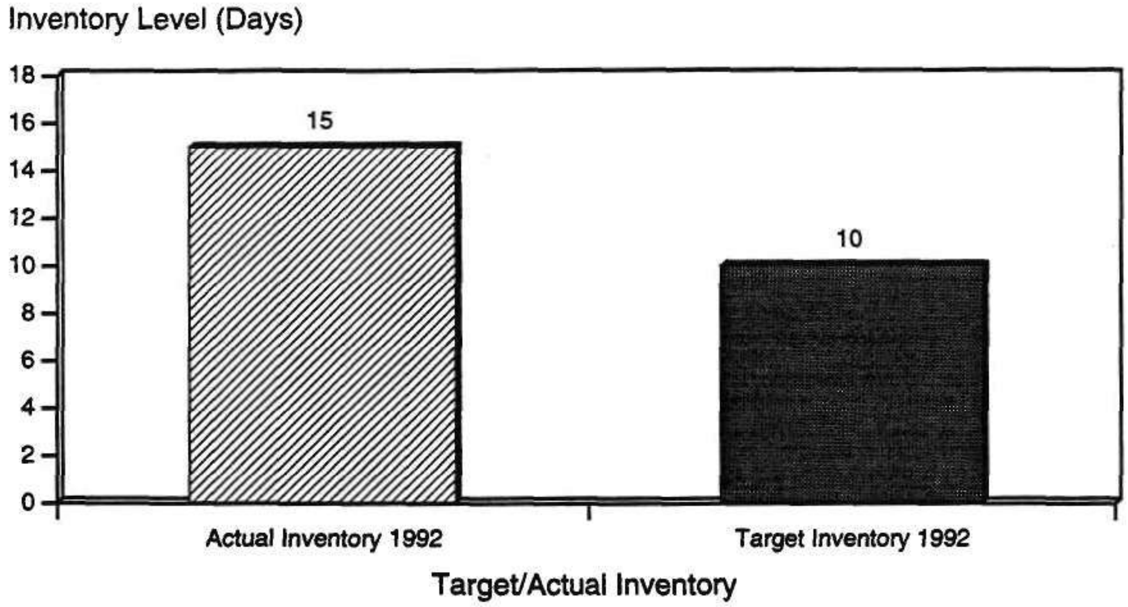


Source: Dataquest (December 1992)

G2001323

The PC semiconductor supply base is being well managed, as evidenced by the small amount of proposed change and the current low level of suppliers.

Figure 4-20
PC Industry Semiconductor Inventory Status

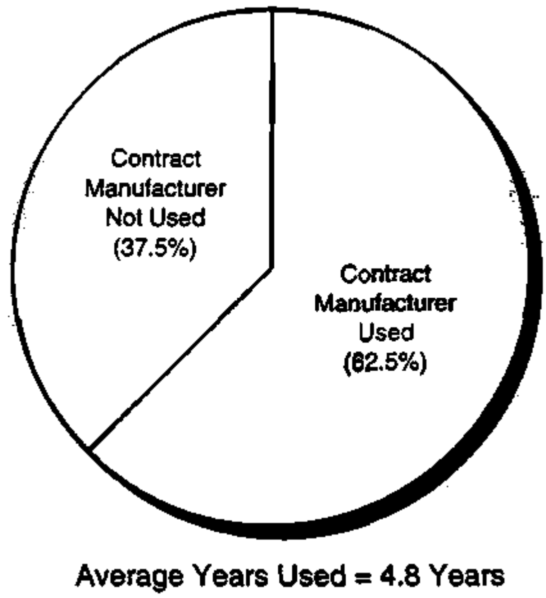


Source: Dataquest (December 1992)

G2001324

Because of the ultracompetitive PC market, targeted actual semiconductor inventory levels are half that of the overall electronics industry.

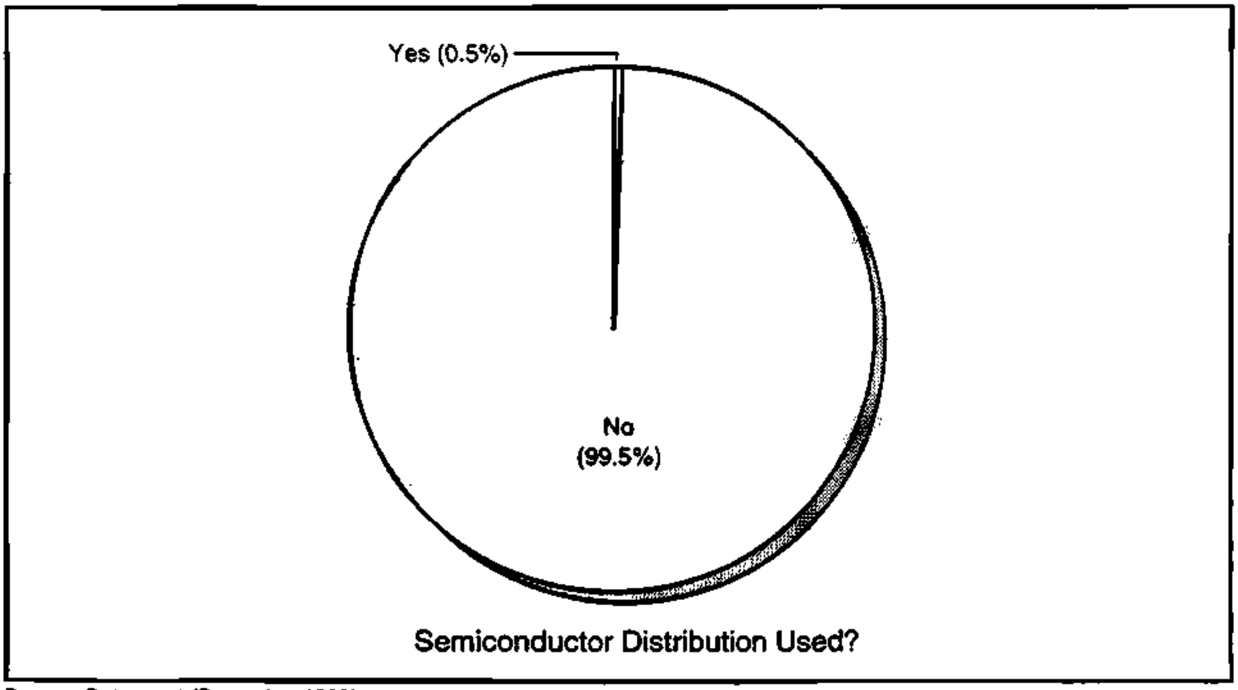
Figure 4-21
PC Industry Contract Manufacturer Use



Source: Dataquest (December 1992)
G2001325

Although 62.5 percent of the respondents use contract manufacturing, it has not been until recently that they have been strategically used. This reflects the relatively short 4.8-year average time contract manufacturers have been used.

Figure 4-22
PC Industry Semiconductor Distributor Use

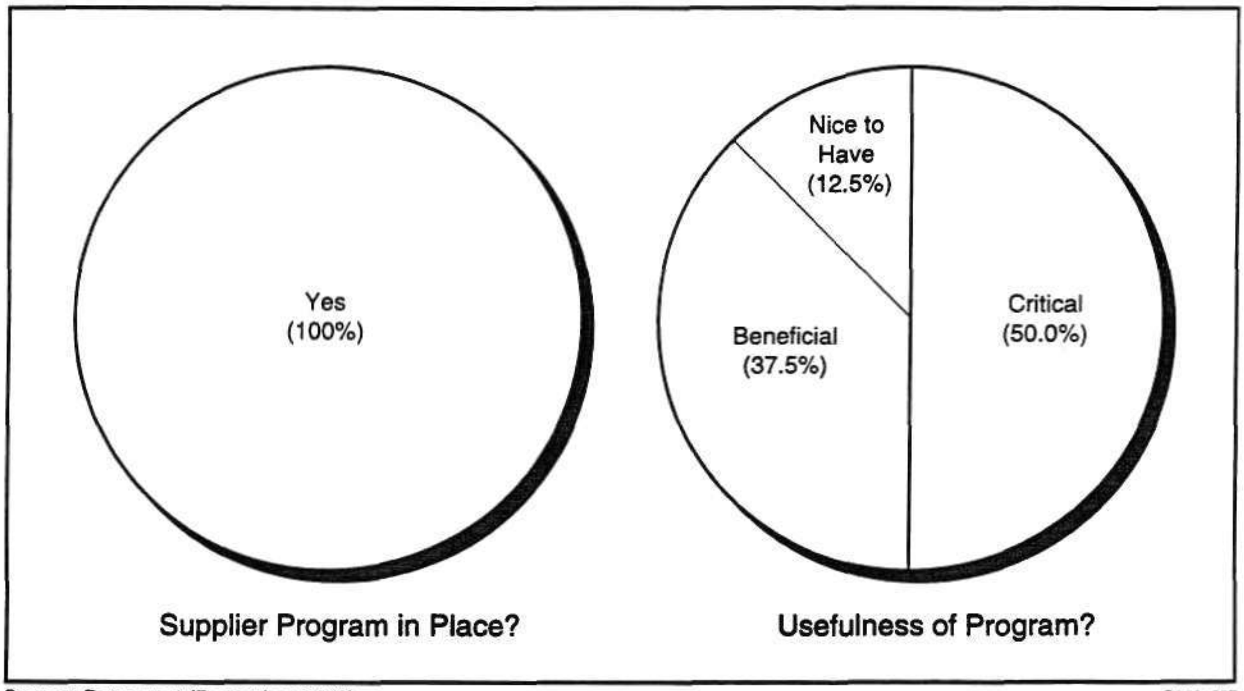


Source: Dataquest (December 1992)

G2001326

- *Less than 1 percent of this sample of PC companies use semiconductor distributors.*
- *Because of the large volumes and required low prices, most large PC manufacturers work directly with OEM semiconductor suppliers.*

Figure 4-23
PC Industry Strategic Supplier Status

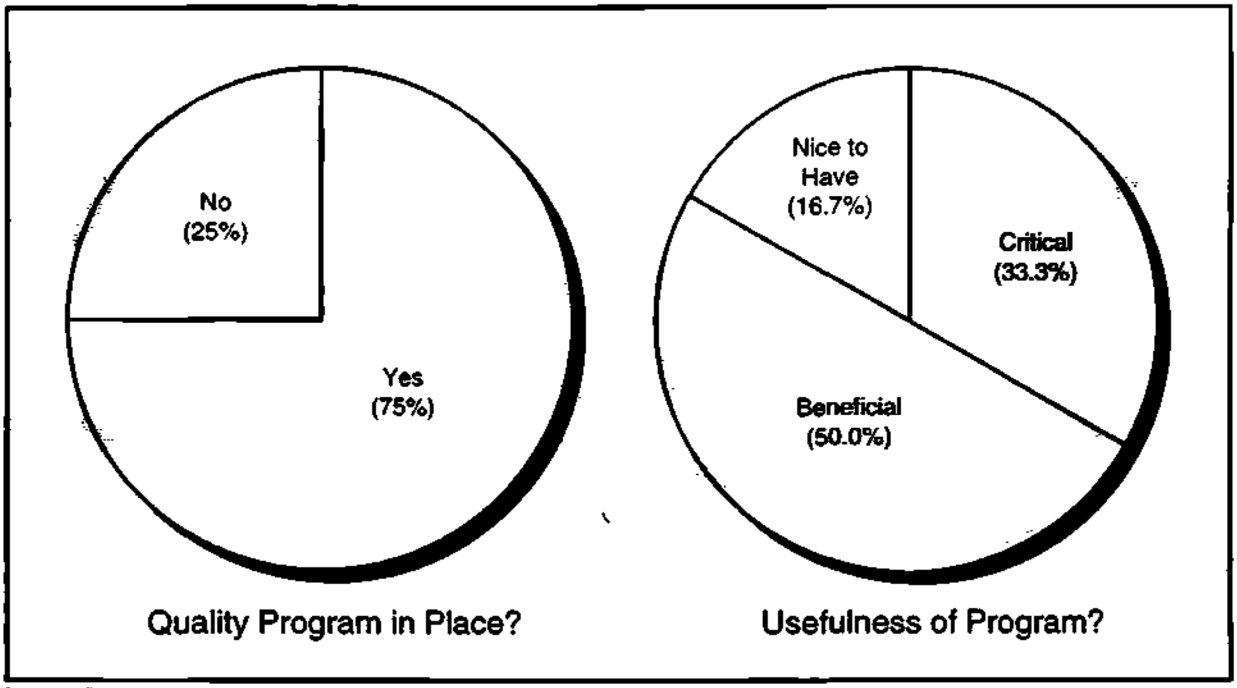


Source: Dataquest (December 1992)

G2001327

- *Tied in with the low use of semiconductor distributors, 100 percent of the respondents have strategic supplier programs in place.*
- *Nearly 90 percent of the respondents find the supplier programs either beneficial or critical for their business.*

Figure 4-24
PC Industry Quality Improvement Program Status

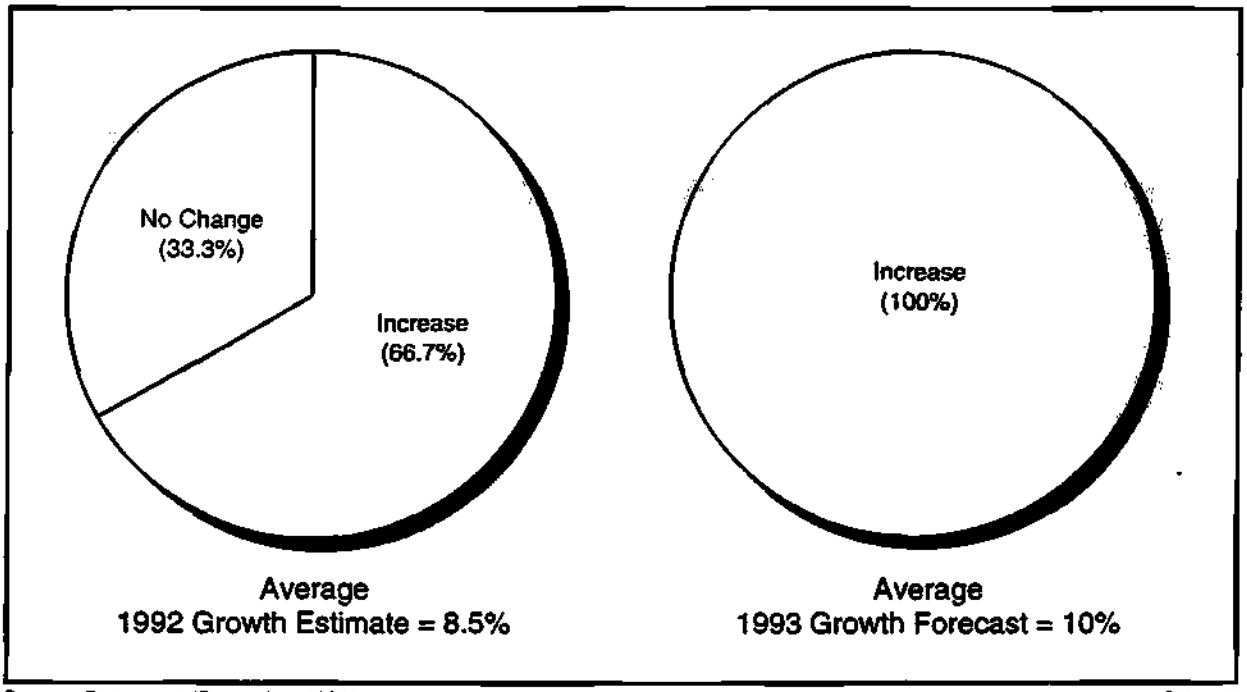


Source: Dataquest (December 1992)

G2001328

With 75 percent of the PC industry respondents utilizing quality improvement programs, more than 80 percent find them beneficial or critical to their business.

Figure 4-25
PC Industry Surveyed Growth Outlook

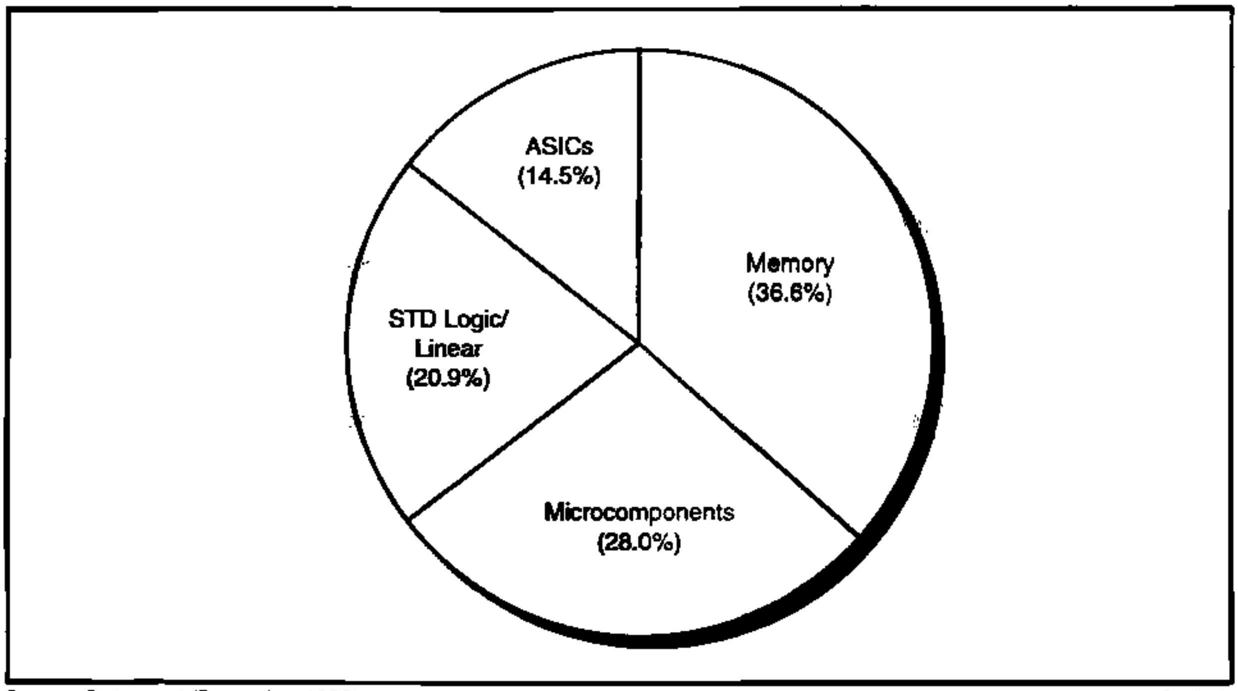


Source: Dataquest (December 1992)

G2001329

- *Despite the PC price wars, two-thirds of the respondents expect to see growth in 1992 averaging 8.5 percent.*
- *An optimistic sample, all expect to see business expand in 1993 an average 10 percent.*

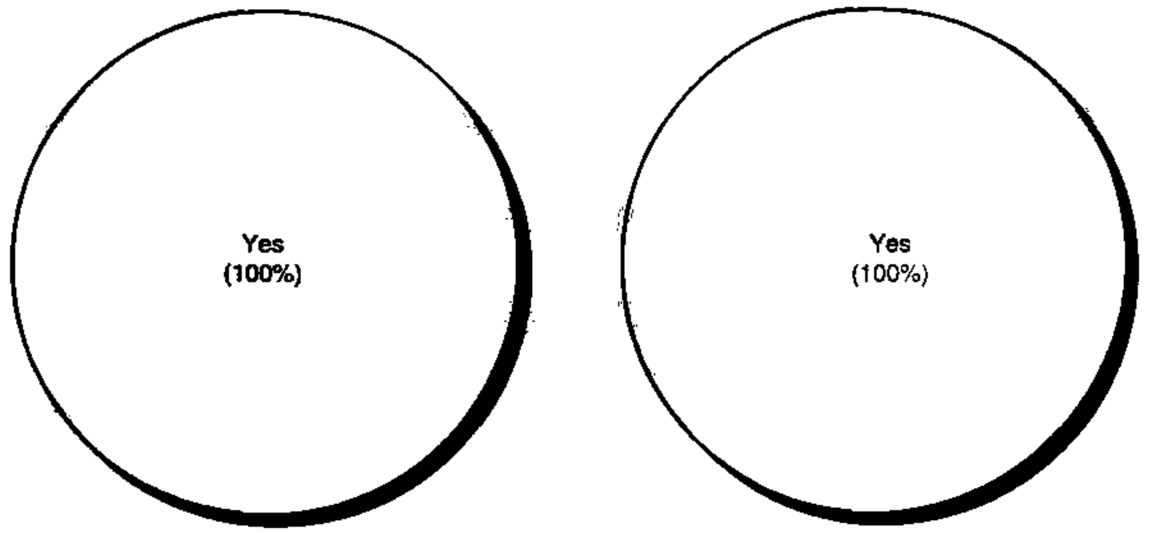
Figure 4-26
Other Data Processing Industry Survey IC Purchases



Source: Dataquest (December 1992) G2001330

Nearly 65 percent of all the data processing (except PC) respondents' semiconductor dollar goes to memory and microcomponent devices.

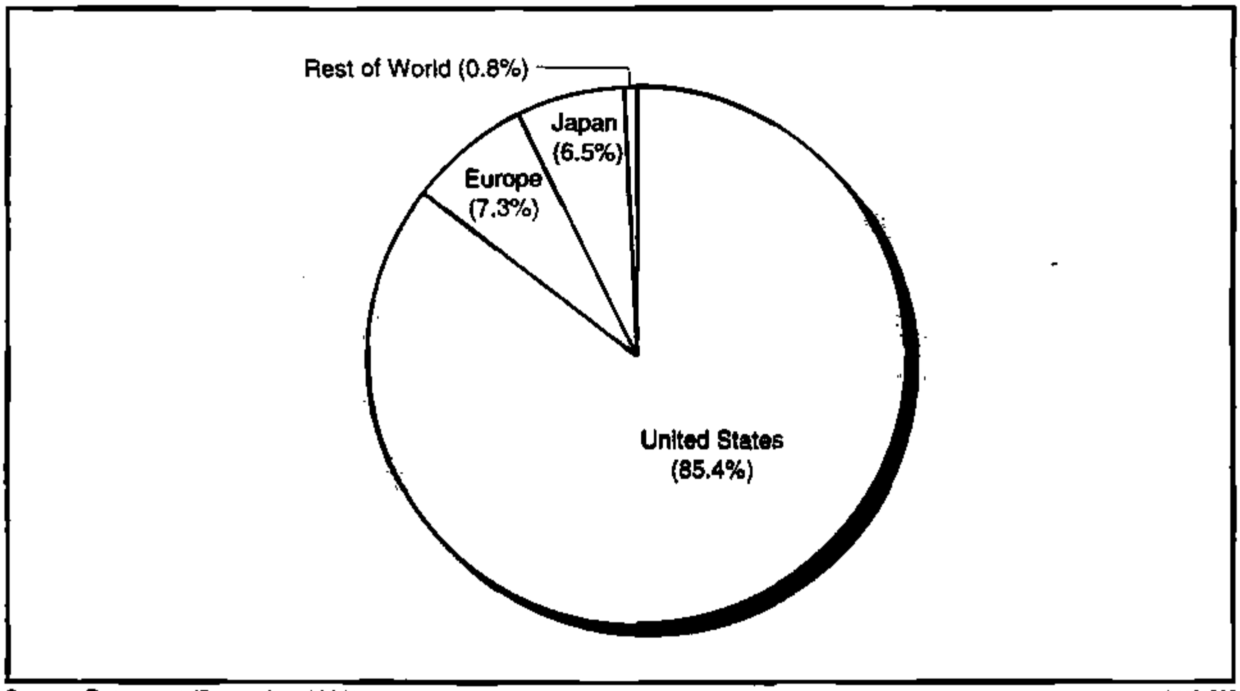
Figure 4-27
Other Data Processing Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992) G2001331

The nature of this market segment requires proprietary designs, which is a main reason all the respondents both design and assemble all of their circuit boards.

Figure 4-28
Other Data Processing Industry Physical Circuit Board Assembly Region

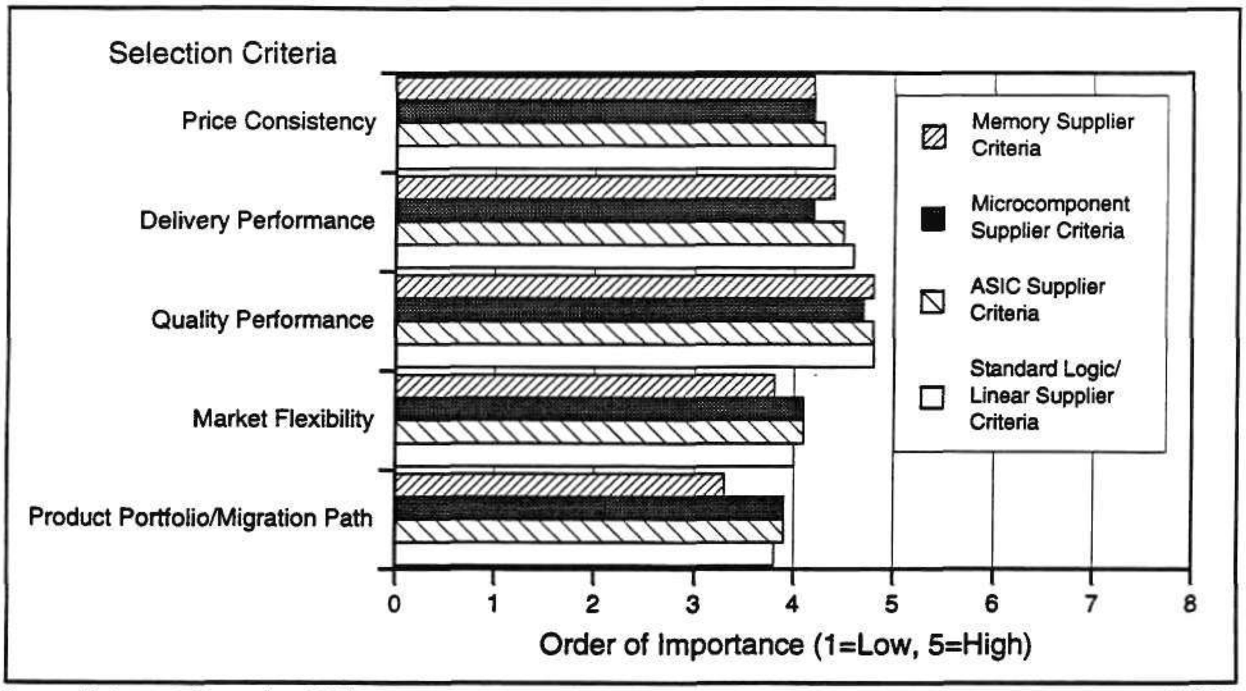


Source: Dataquest (December 1992)

G2001332

- *The United States remains the region where most assembly is done, followed by Europe, Japan, and the rest of Asia a distant fourth.*
- *Proprietary designs and local market content heavily influence assembly region decisions for this market.*

Figure 4-29
Other Data Processing Industry Semiconductor Supplier Selection Criteria

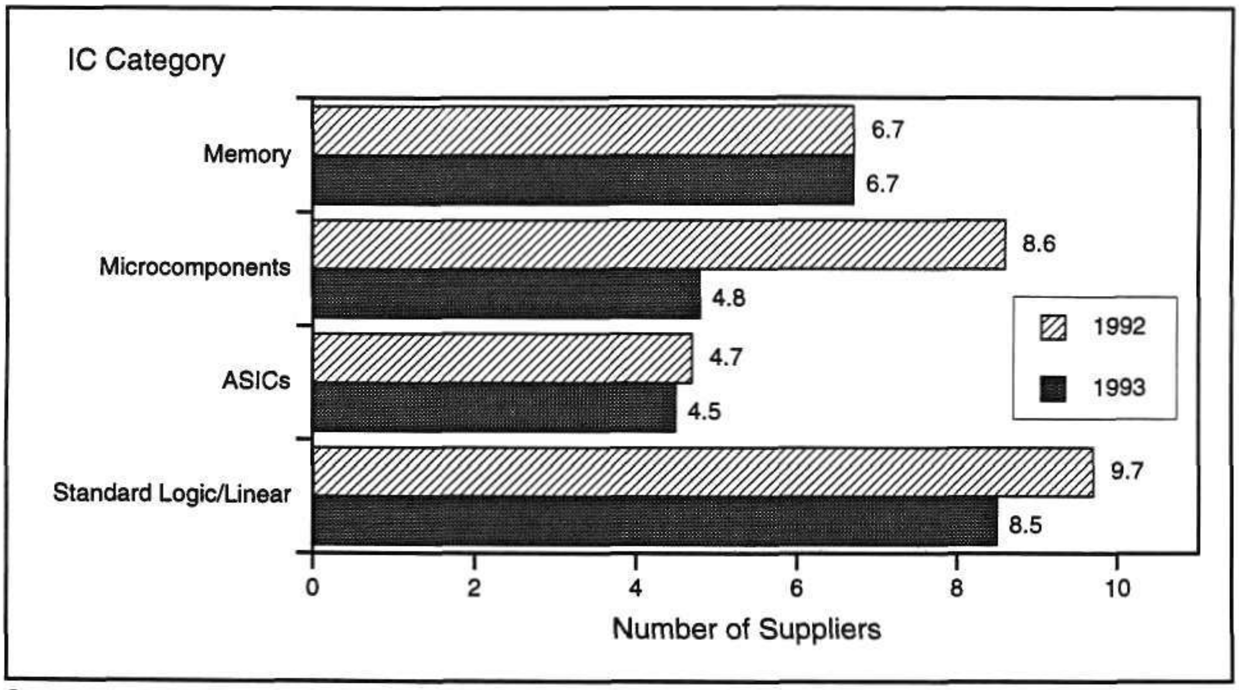


Source: Dataquest (December 1992)

G2001333

- *Across the supplier categories, quality performance is the key criterion for selecting a semiconductor supplier.*
- *The breadth and plans of a supplier universally was seen as not as important.*

Figure 4-30
Other Data Processing Industry Supply Base Trend

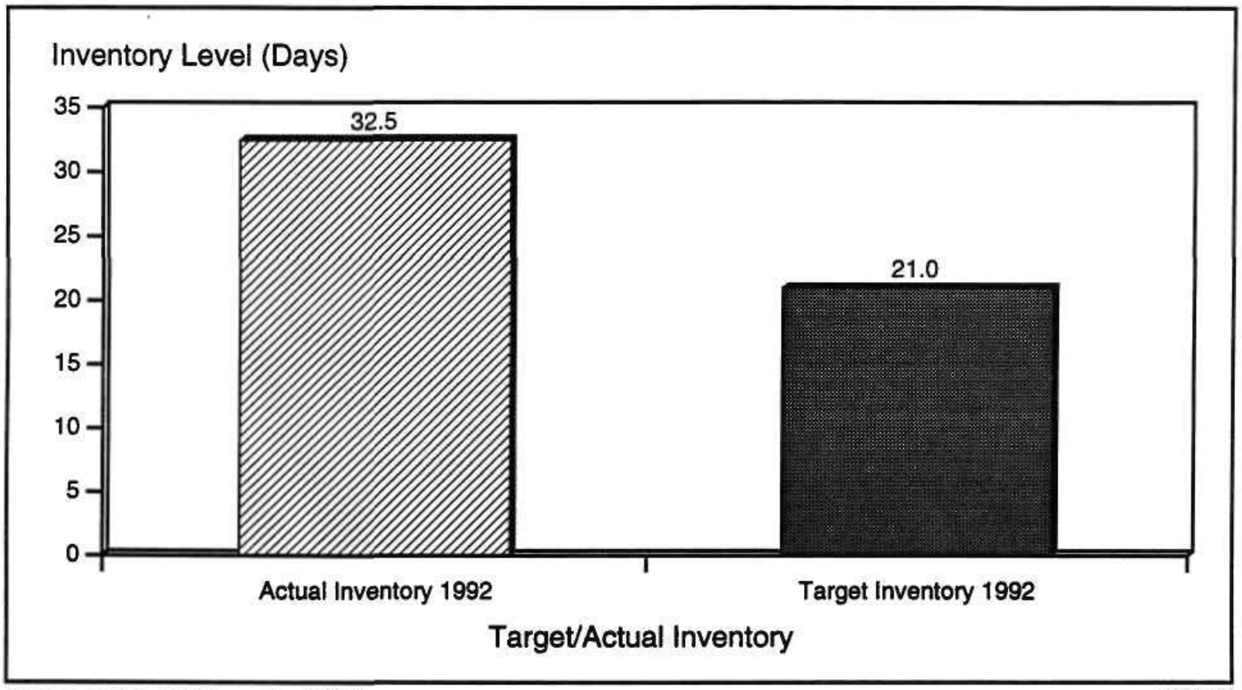


Source: Dataquest (December 1992)

G2001334

- *Aside from the microcomponent supply base, most supplier levels are expected to remain the same.*
- *Because of extreme competition in the ASSP market, respondents are consolidating their supplier list, focusing on long-term viable companies.*

Figure 4-31
Other Data Processing Industry Semiconductor Inventory Status

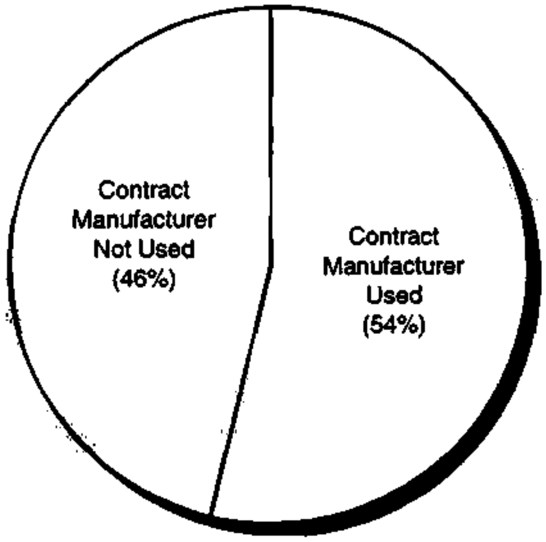


Source: Dataquest (December 1992)

G2001335

- *This segment of the industry closely tracks the overall electronics market in average target and actual semiconductor inventory levels.*
- *Despite the higher use of contract manufacturing and distribution, higher levels of inventory are kept relative to the PC market because of the diverse needs of the other segments of data processing.*

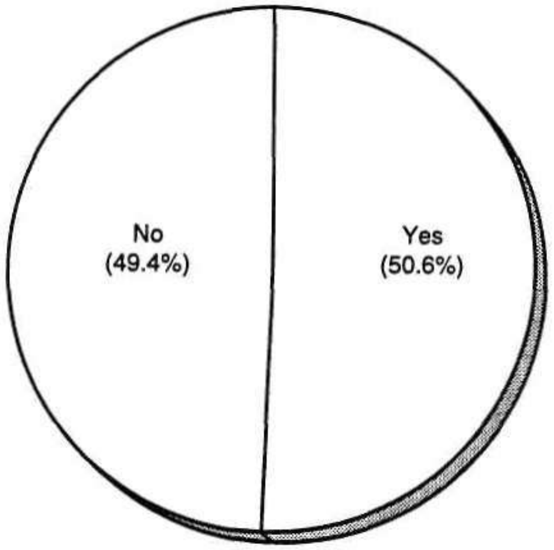
Figure 4-32
Other Data Processing Industry Contract Manufacturer Use



Source: Dataquest (December 1992) G2001336

More than half the respondents use contract manufacturers, with the length of time a contract manufacturer was used averaging nearly 10 years.

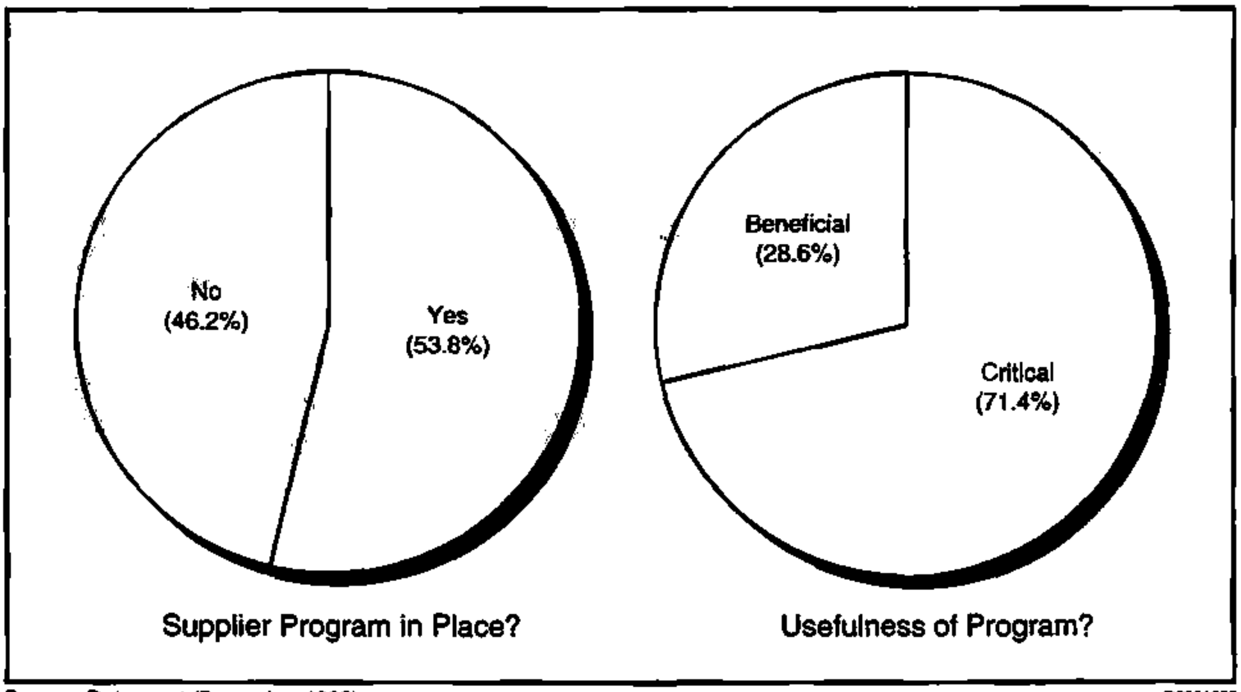
Figure 4-33
Other Data Processing Industry Semiconductor Distributor Use



Source: Dataquest (December 1992) G2001337

- *Slightly more than half the data processing respondents use semiconductor distributors.*
- *Distribution often is used to lower overhead costs of low-usage components or high-service-level items such as subassembly kits.*

Figure 4-34
Other Data Processing Industry Strategic Supplier Status

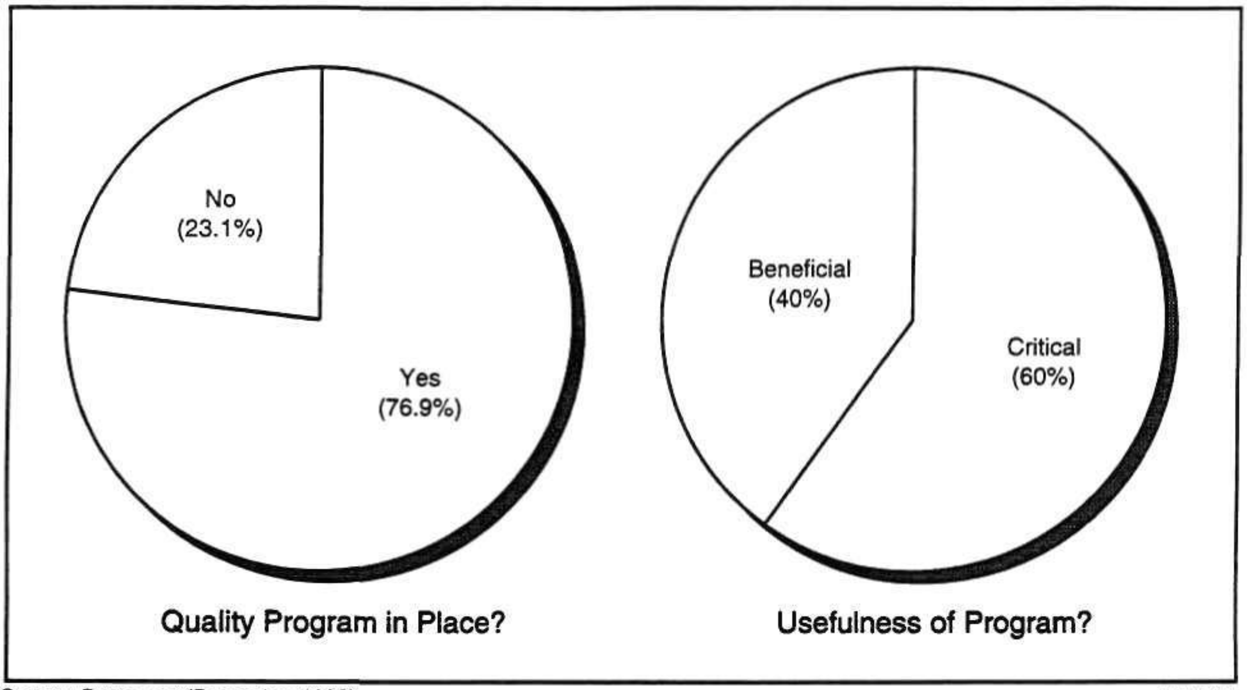


Source: Dataquest (December 1992)

G2001336

For the 54 percent of respondents using a strategic supplier program, more than 70 percent found the program critical to their operation.

Figure 4-35
Other Data Processing Industry Quality Improvement Program Status

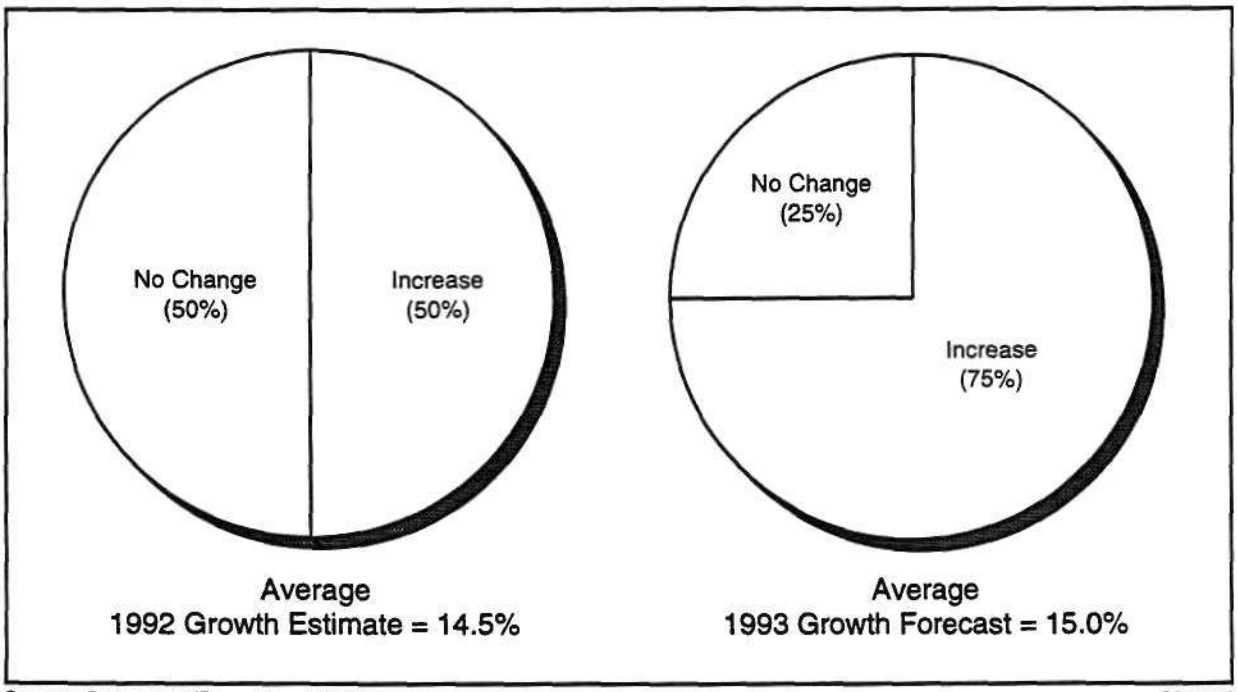


Source: Dataquest (December 1992)

G2001339

More than three-fourths (76.9 percent) of the sample has a formal quality improvement program in place, and 60 percent of the users find the program critical to their business.

Figure 4-36
Other Data Processing Industry Surveyed Growth Outlook

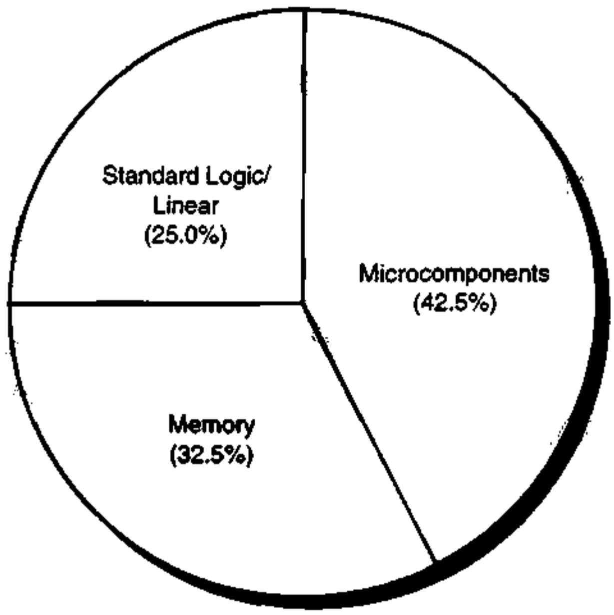


Source: Dataquest (December 1992)

G2001340

- *Although none of the respondents expects to see a decline in system sales, the results are evenly mixed on a flat to growing market for 1992.*
- *Seventy-five percent of the respondents expect growth to be an average 15 percent in 1993.*

Figure 4-37
Premise Communications Industry Survey IC Purchases

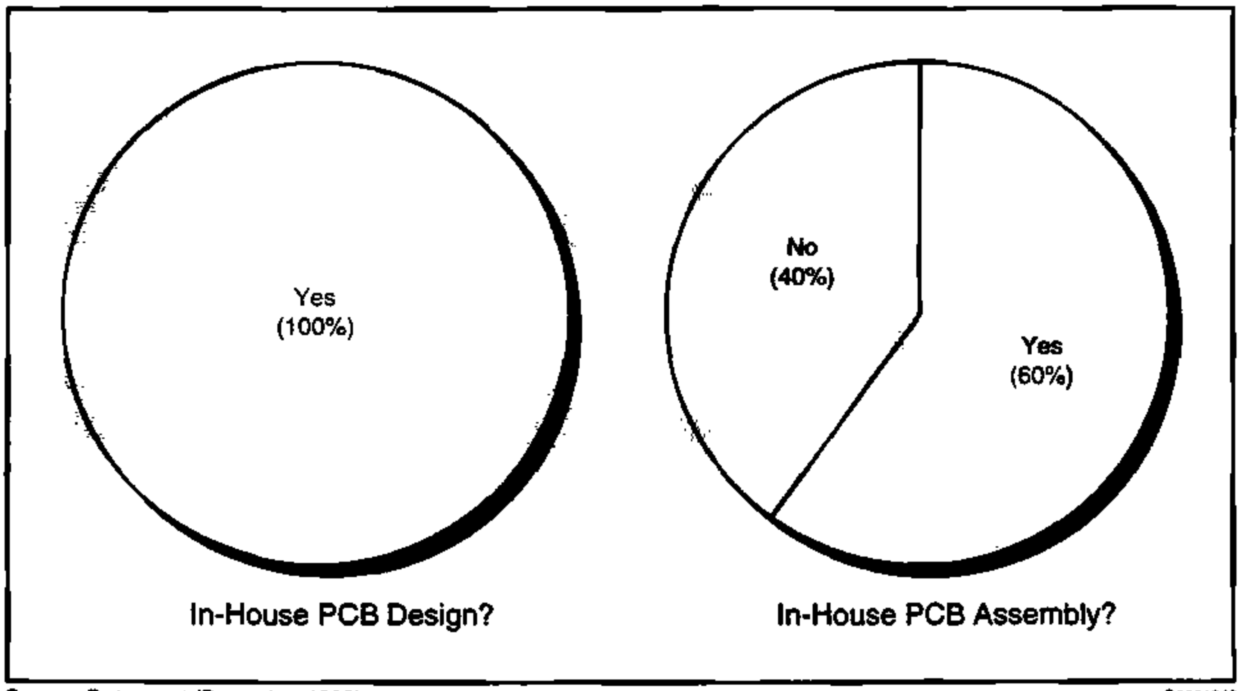


Source: Dataquest (December 1992)

G2001341

The respondents in this market segment spend 75 percent of their semiconductor procurement dollar on microcomponent devices.

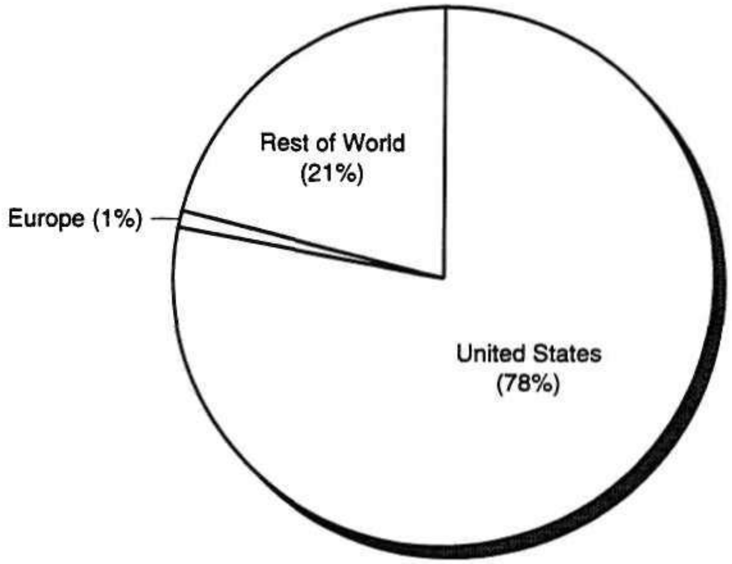
Figure 4-38
Premise Communications Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992) G2001342

Although all respondents design their own circuit boards, 40 percent outsource their assembly.

Figure 4-39
Premise Communications Industry Physical Circuit Board Assembly Region

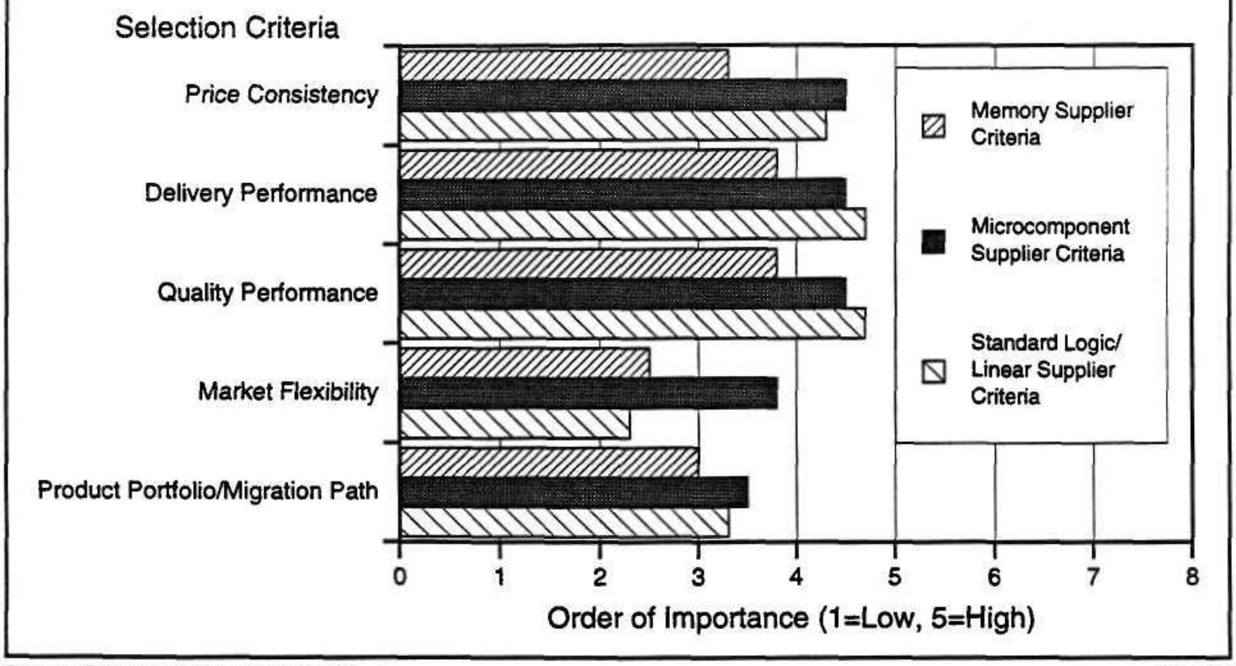


Source: Dataquest (December 1992)

G2001343

Assembly is predominantly done in the United States, followed by the Asian region outside Japan.

Figure 4-40
Premise Communications Industry Semiconductor Supplier Selection Criteria

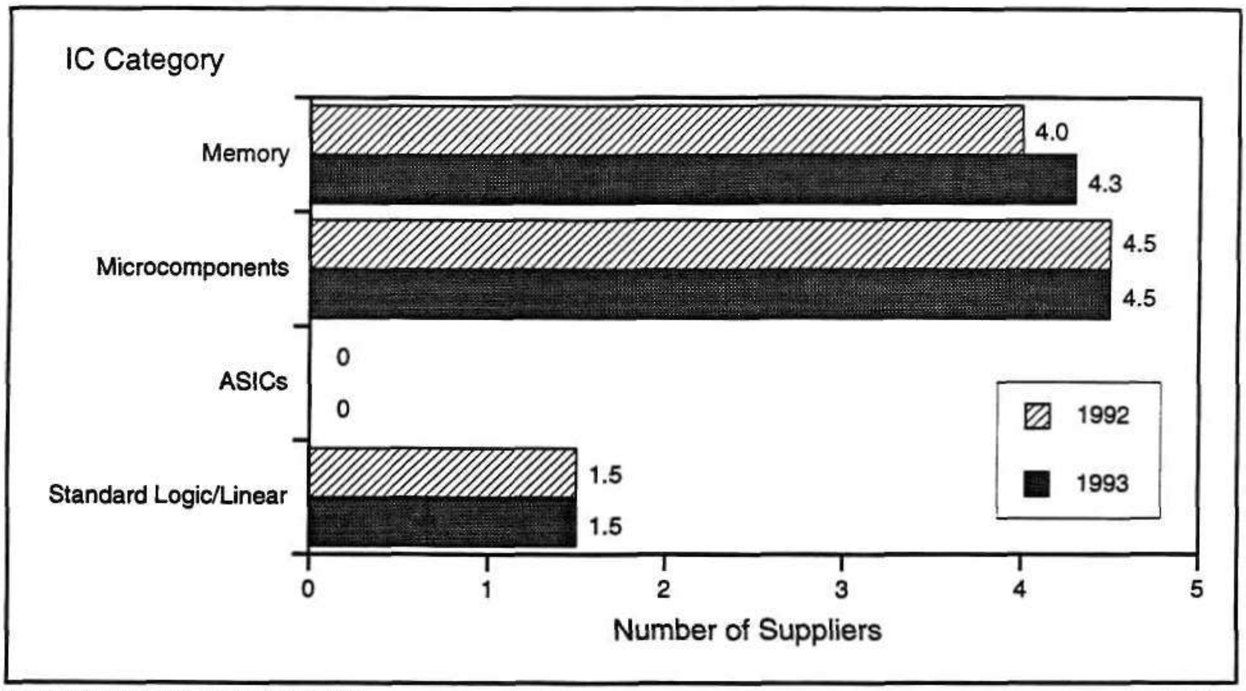


Source: Dataquest (December 1992)

G2001344

Because of the larger level of microcomponents consumed, this segment has higher criteria set for these suppliers, when compared to the rest of the industry.

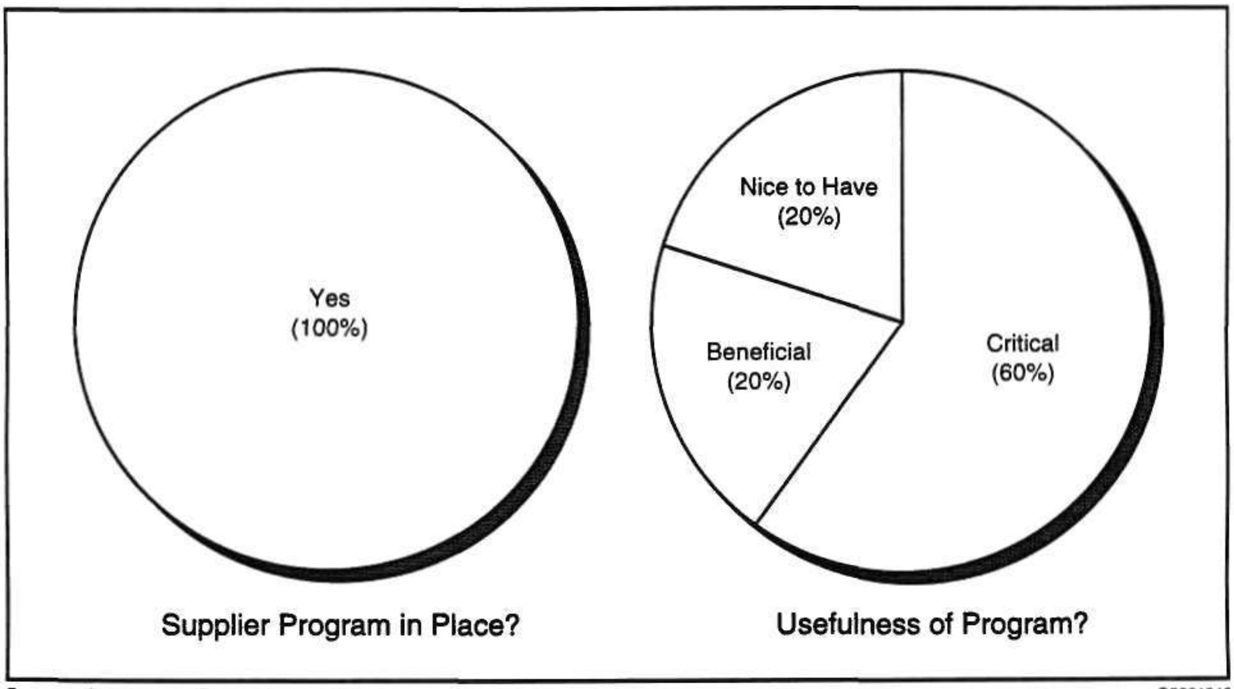
Figure 4-41
Premise Communications Industry Supply Base Trend



Source: Dataquest (December 1992) G2001345

Aside from a slight adjustment in memory supply, all other suppliers are expected to remain the same.

Figure 4-42
Premise Communications Industry Strategic Supplier Status

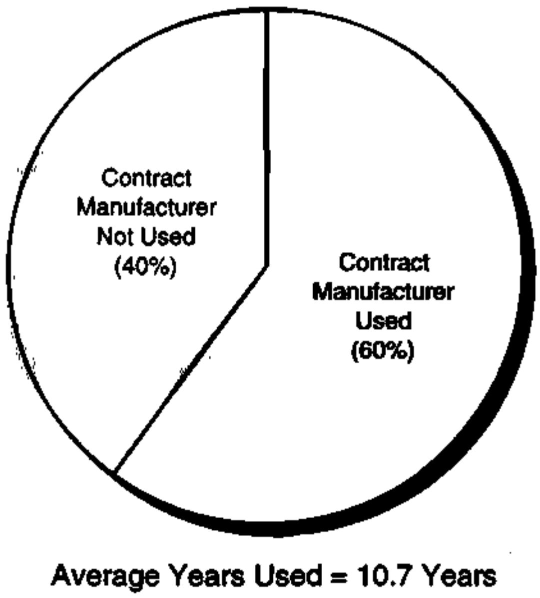


Source: Dataquest (December 1992)

G2001346

All respondents have strategic supplier programs in place. Although 80 percent of the sample found the program beneficial to critical for their business, 20 percent saw the program as merely "nice to have."

Figure 4-43
Premise Communications Industry Contract Manufacturer Use

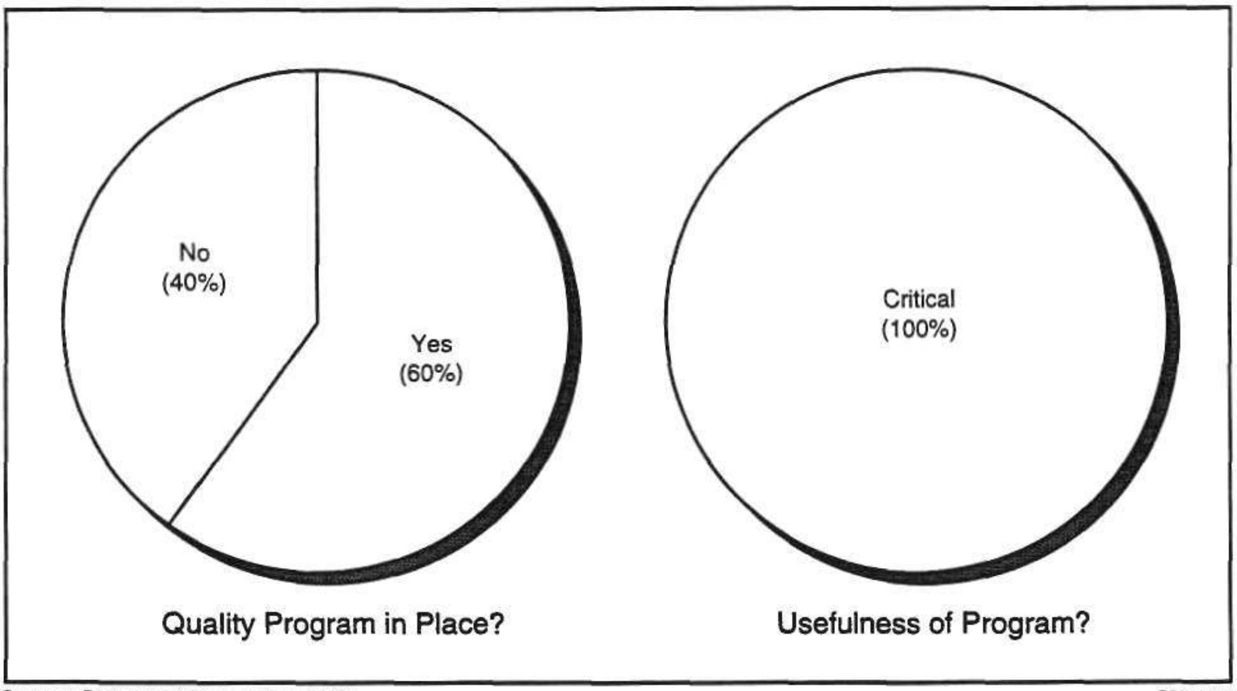


Source: Dataquest (December 1992)

G2001347

Contract manufacturers are used by 60 percent of this sample, with the length of time a contractor was used averaging more than 10 years.

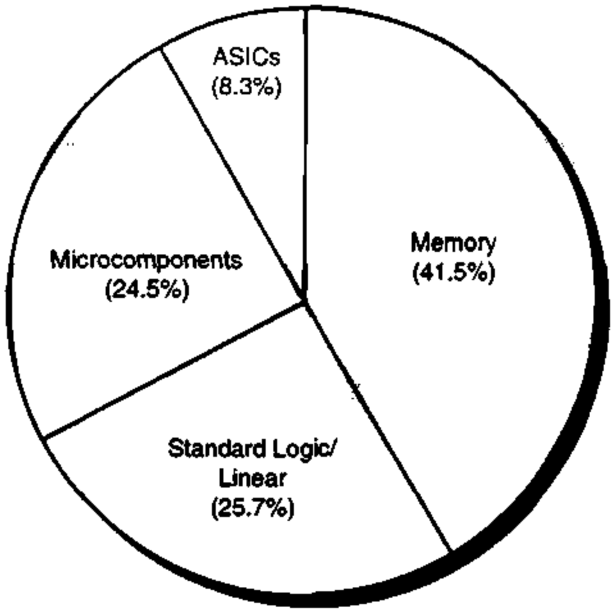
Figure 4-44
Premise Communications Industry Quality Improvement Program Status



Source: Dataquest (December 1992)
G2001348

The 60 percent of the respondents with a formal quality program in place all find the exercise critical for doing business.

Figure 4-45
Other Communications Industry Survey IC Purchases

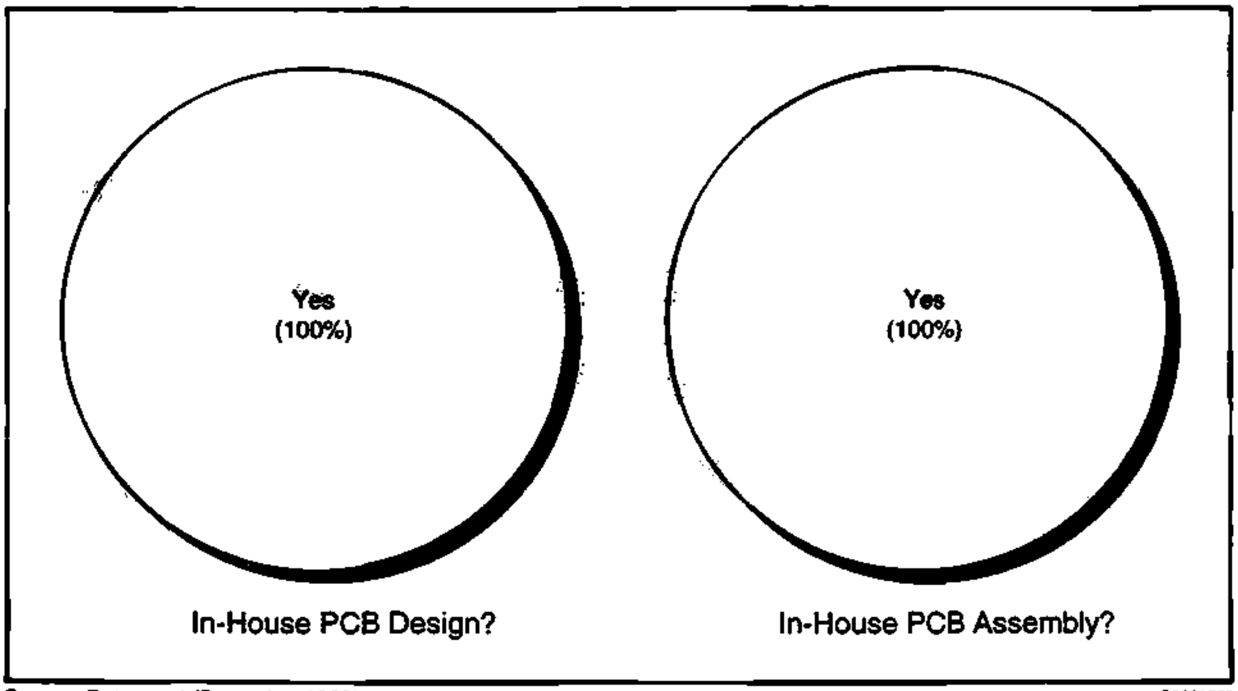


Source: Dataquest (December 1992)

G2001349

- *Sixty-six percent of the semiconductor purchase of this market segment goes to memory and microcomponent products.*
- *ASIC devices are expected to erode the usage of standard logic for this market because of space and voltage requirements.*

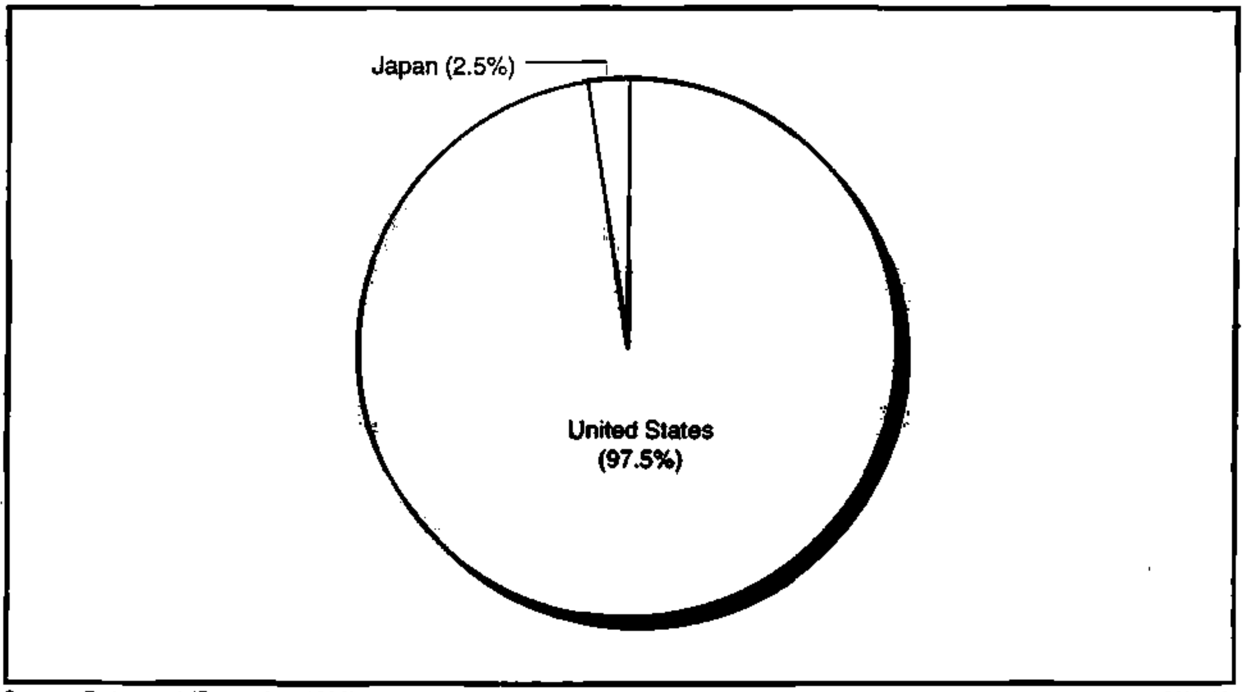
Figure 4-46
Other Communications Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992) G2001360

Because of the emerging/proprietary nature of this market, all circuit design and assembly is done in-house.

Figure 4-47
Other Communications Industry Physical Circuit Board Assembly Region

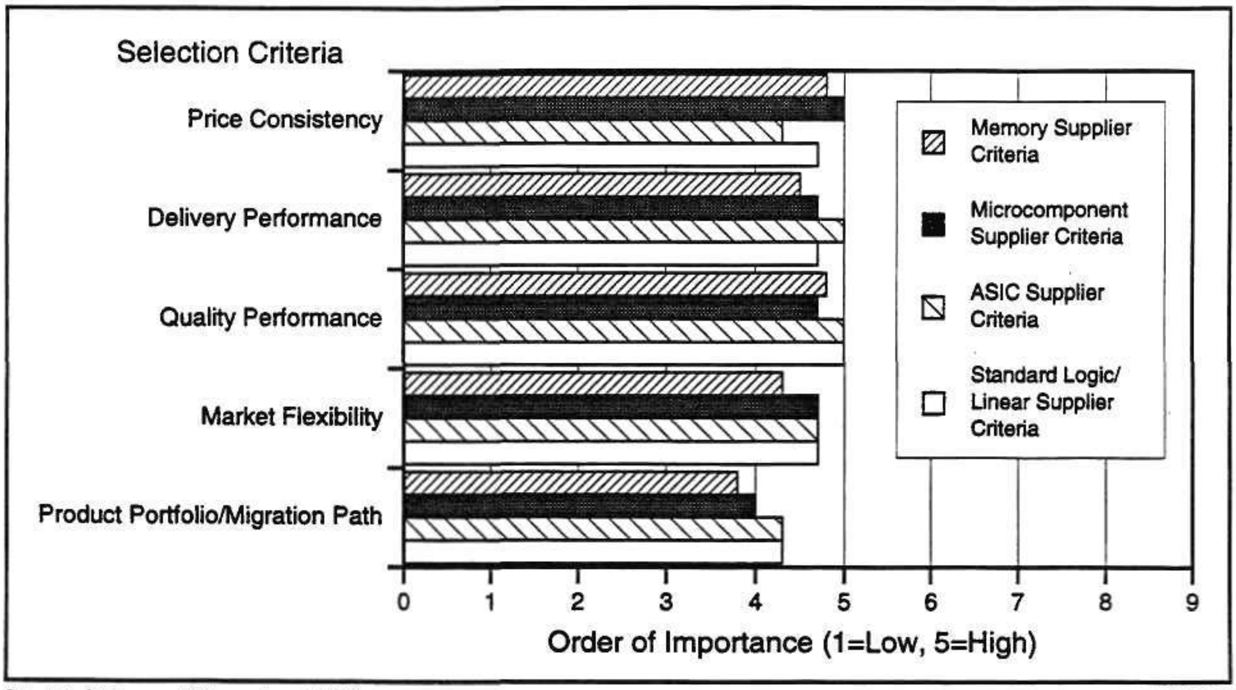


Source: Dataquest (December 1992)

G2001351

The vast majority (97.5 percent) of all assembly for this sample is done in the United States because of supply logistics and the current size of the market.

Figure 4-48
Other Communications Industry Semiconductor Supplier Selection Criteria

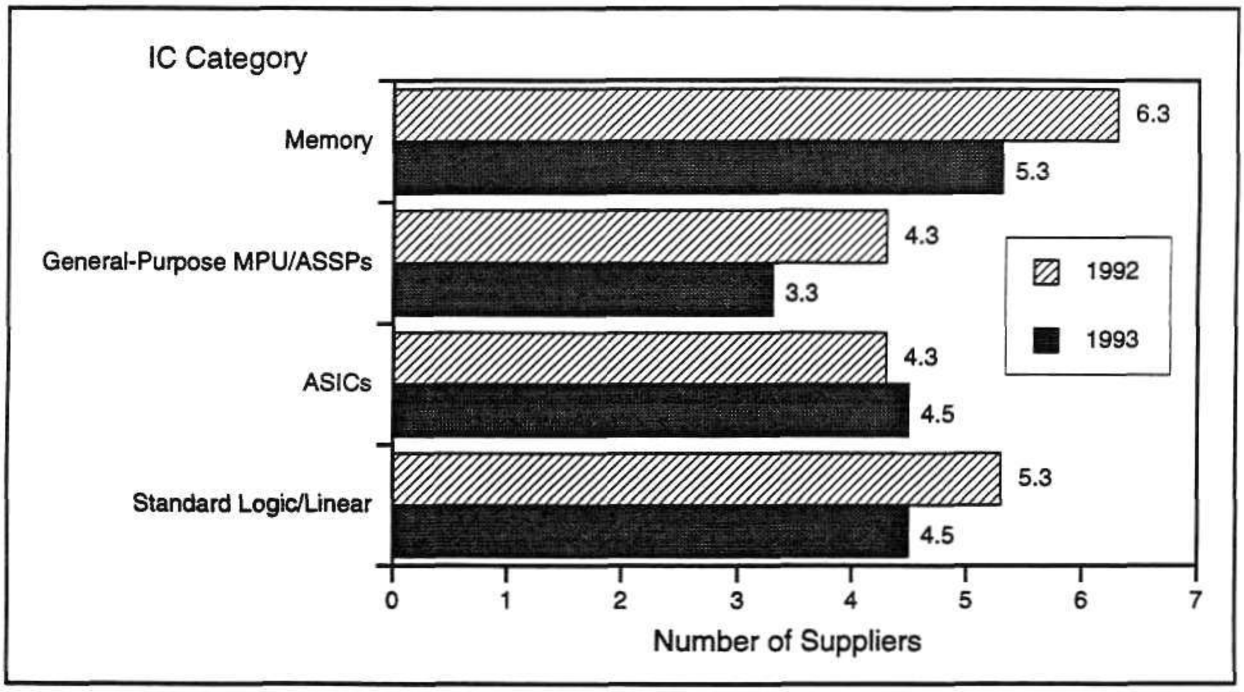


Source: Dataquest (December 1992)

G2001352

Although microcomponent suppliers are selected primarily on price consistency, ASIC suppliers are primarily judged on adherence to delivery schedules and quality specifications for this segment.

Figure 4-49
Other Communications Industry Supply Base Trend

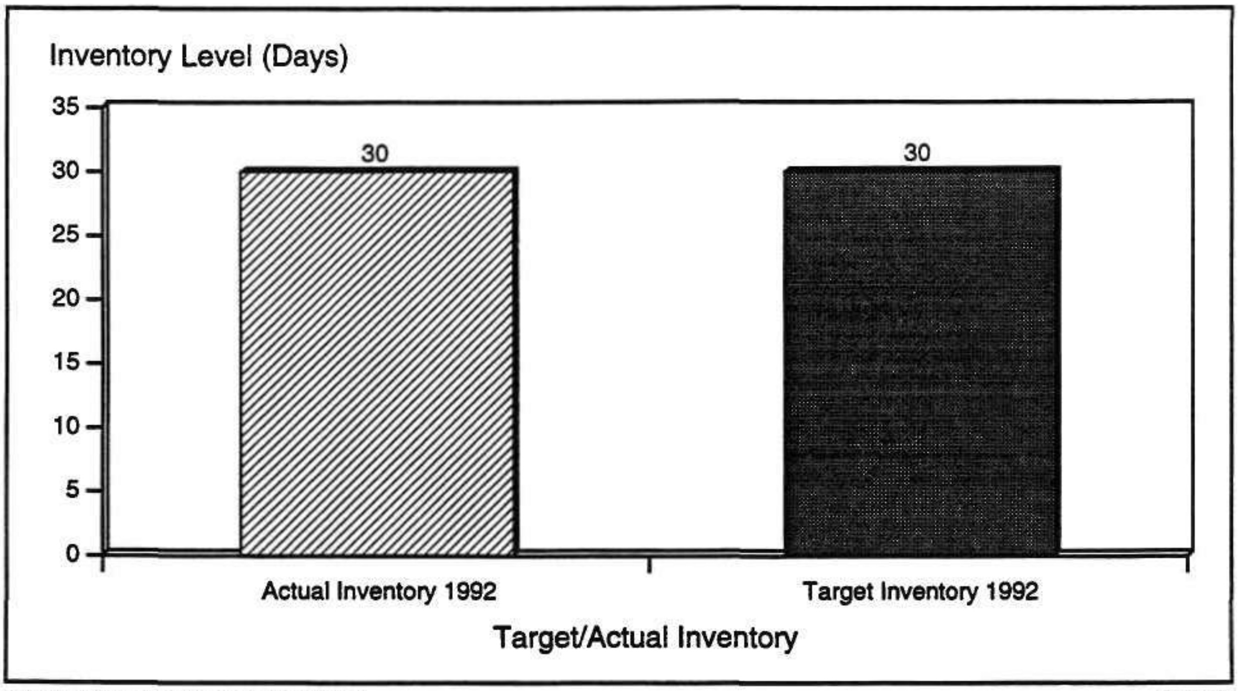


Source: Dataquest (December 1992)

G2001353

Aside from a small increment in the ASIC supply base, all other supplier levels are expected to decline next year.

Figure 4-50
Other Communications Industry Semiconductor Inventory Status

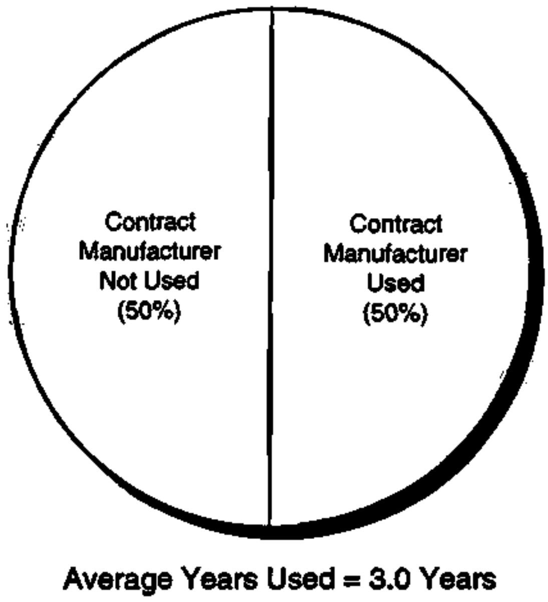


Source: Dataquest (December 1992)

G2001354

This segment of the industry is at its target semiconductor inventory level of 30 days. With the industry average at 20 days, this may be a challenge for these companies.

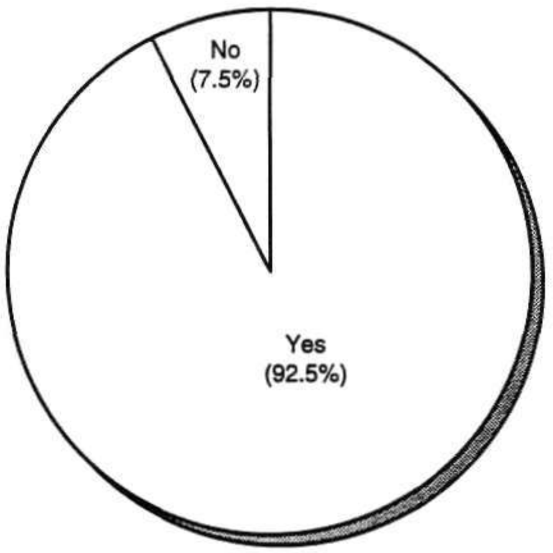
Figure 4-51
Other Communications Industry Contract Manufacturer Use



Source: Dataquest (December 1992)
G2001355

- *Although half of the respondents use contract manufacturing, the average period is only three years.*
- *As this market grows and becomes more commoditized, the level of contract manufacture is expected to grow.*

Figure 4-52
Other Communications Industry Semiconductor Distributor Use

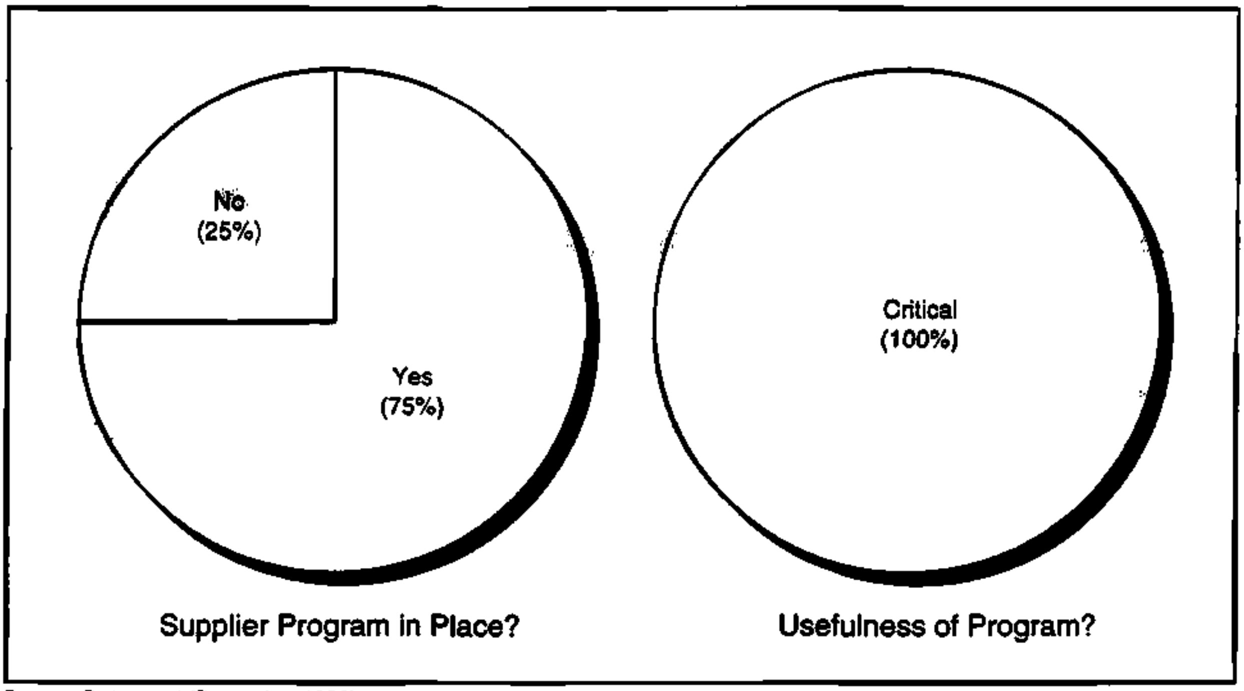


Source: Dataquest (December 1992)

G2001356

Because of the relative low volume of semiconductors in this segment's purchases, distribution plays a large role in supplying the service and devices this segment now needs.

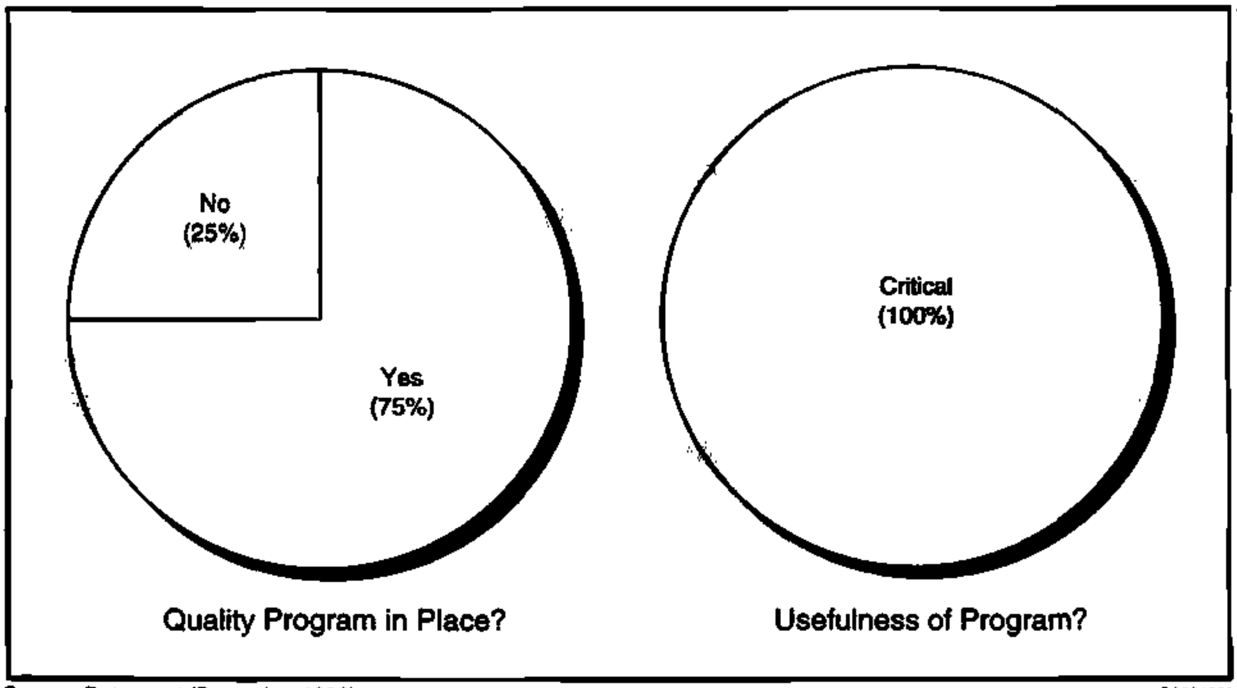
Figure 4-53
Other Communications Industry Strategic Supplier Status



Source: Dataquest (December 1992) G2001357

- *Despite their small size, many companies in this industry have strategic supplier programs in place.*
- *For those that do have them, all see the relationships as critical to business success.*

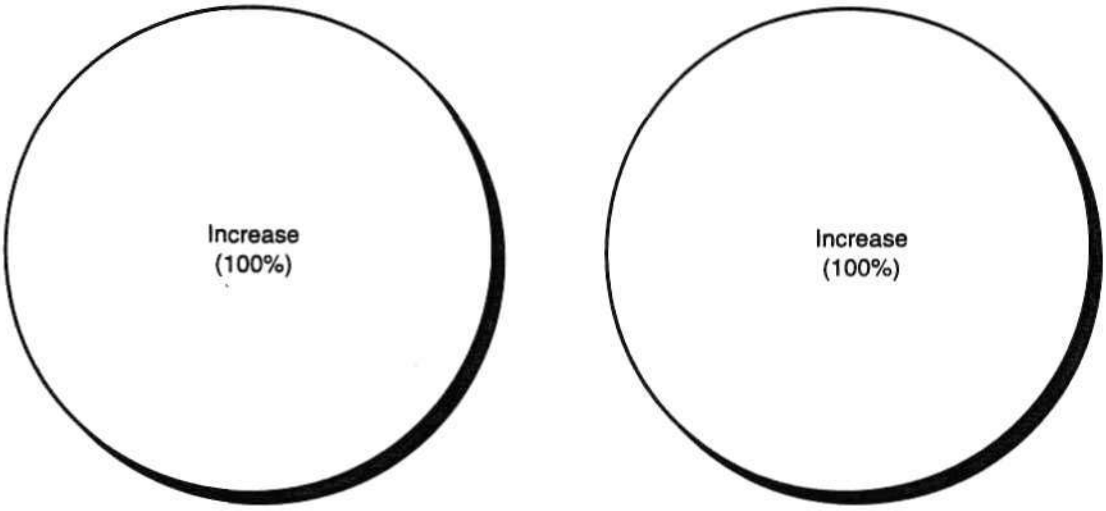
Figure 4-54
Other Communications Industry Quality Improvement Program Status



Source: Dataquest (December 1992) G2001356

- *Although three-fourths of the sample did not have a strategic supplier program, a like 75 percent have a formal quality improvement program running.*
- *Of those in quality improvement programs, all deemed them critical.*

Figure 4-55
Other Communications Industry Surveyed Growth Outlook



Average
1992 Growth Estimate = 22.5%

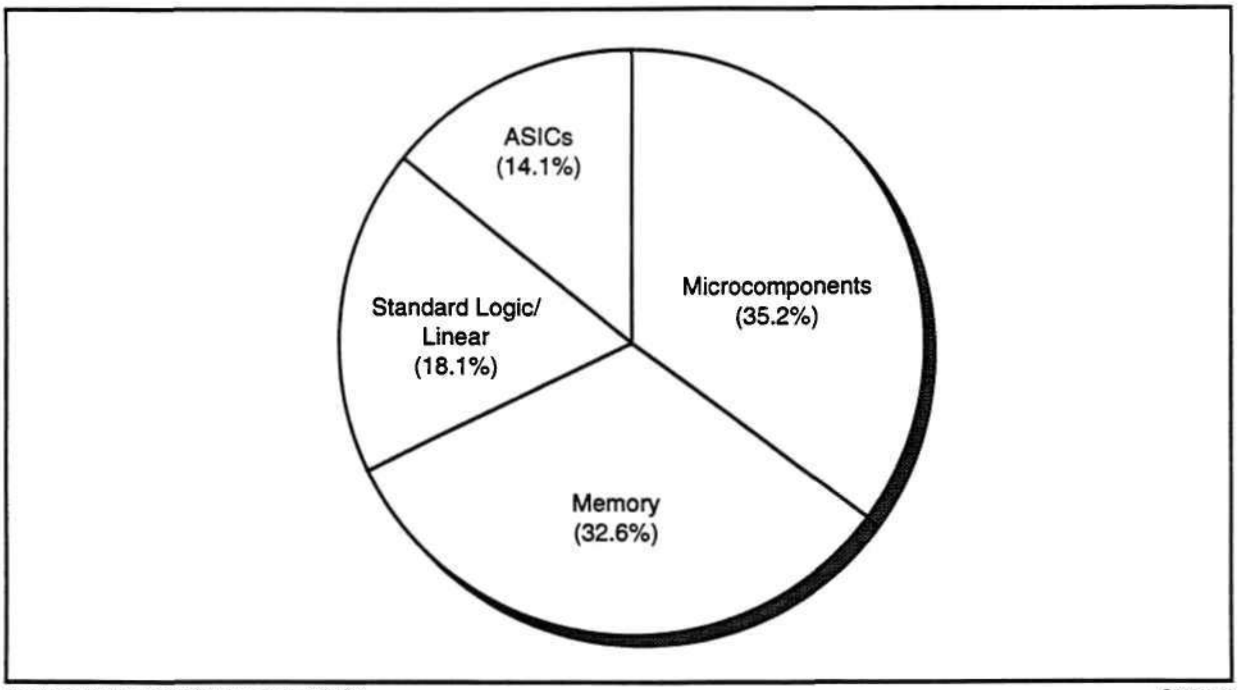
Average
1993 Growth Forecast = 15.0%

Source: Dataquest (December 1992)

G2001359

For both years 1992 and 1993, it was unanimous that the industry would grow: an aggressive 22.5 percent in 1992 and an optimistic 15.0 percent in 1993.

Figure 4-56
Instrumentation Industry Survey IC Purchases

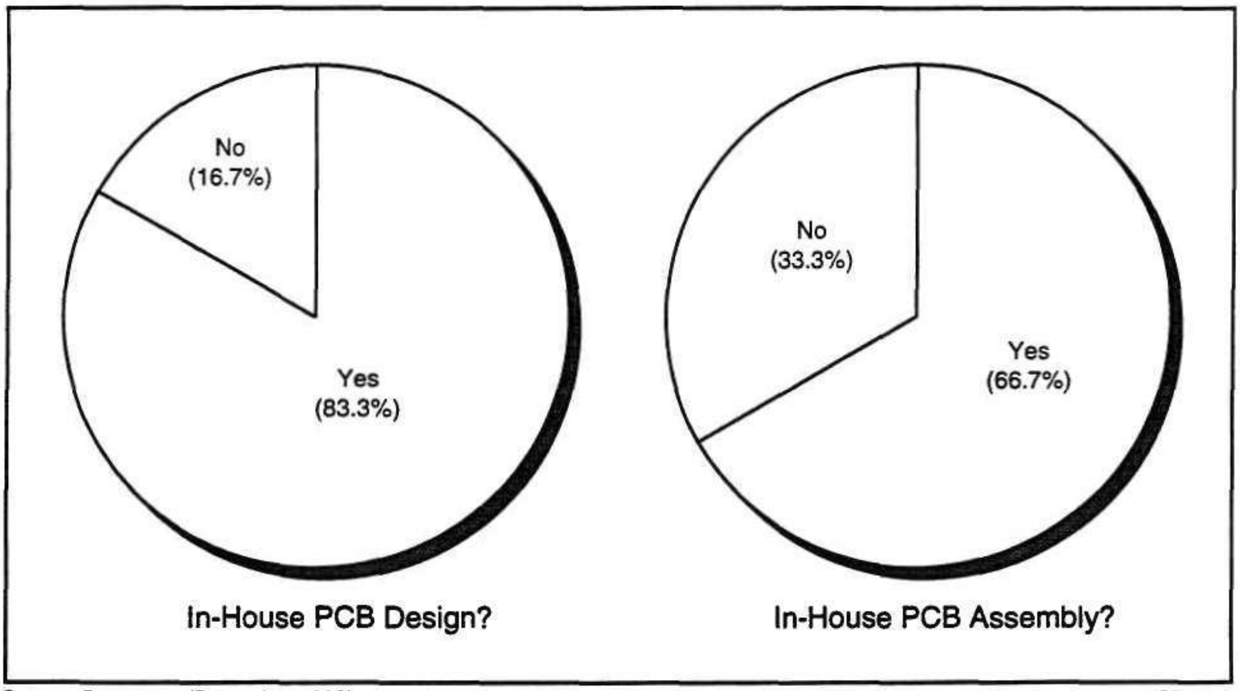


Source: Dataquest (December 1992)

G2001360

- *More than two-thirds of the semiconductor buy goes to memory and microcomponents, with an emphasis on embedded control ASSPs.*
- *Standard logic and linear still outweigh the ASIC solution because space is often not a critical issue with instruments.*

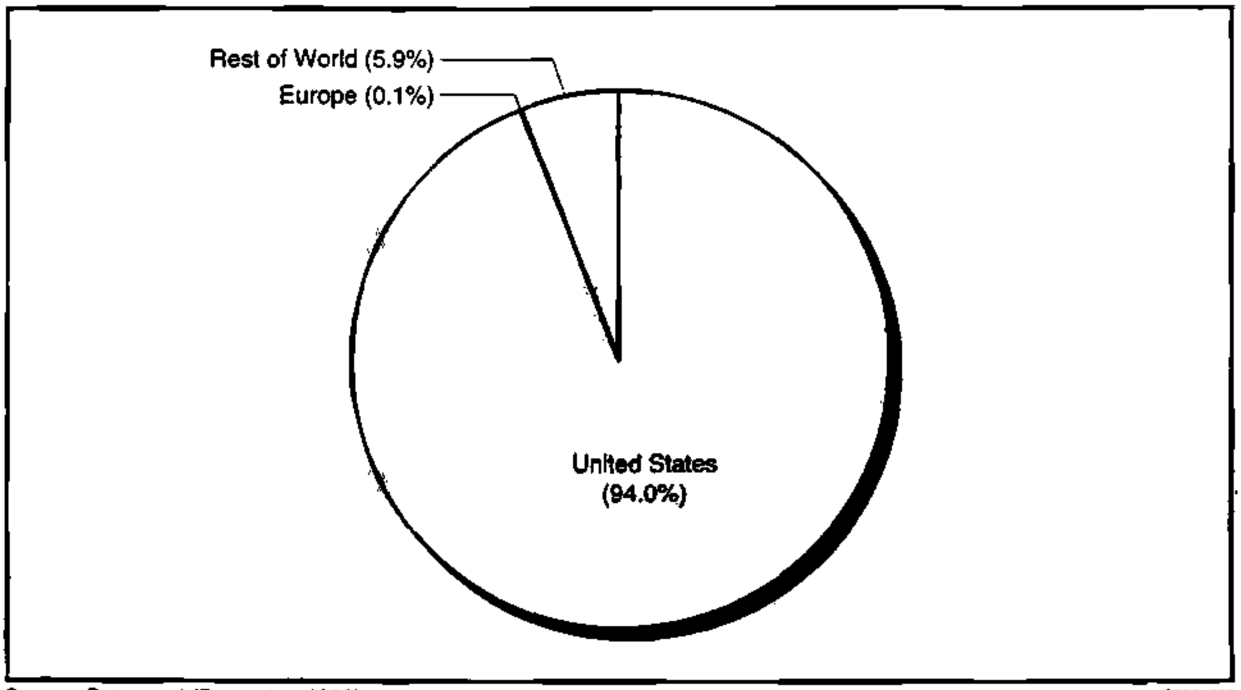
Figure 4-57
Instrumentation Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992) G2001361

A strong 83.3 percent of circuit boards are designed by the respondents, and a third are assembled by contract manufacturers.

Figure 4-58
Instrumentation Industry Physical Circuit Board Assembly Region

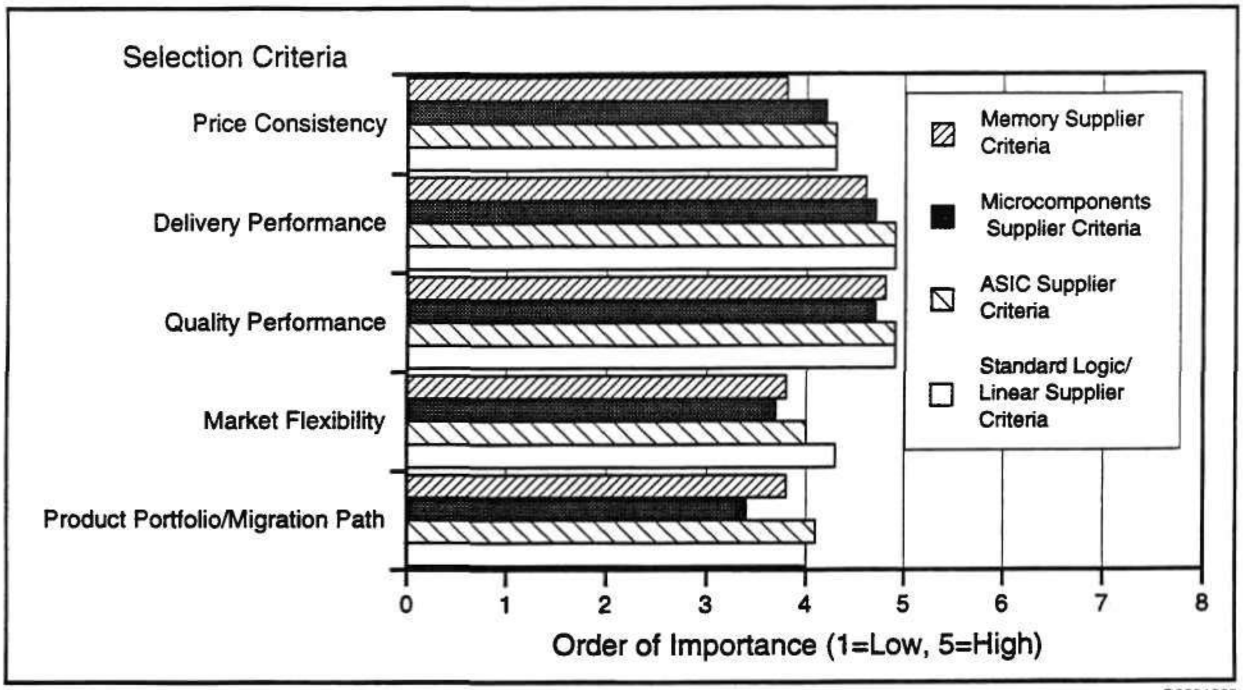


Source: Dataquest (December 1992)

G2001362

The United States remains the region where most of this segment's physical assembly is performed, followed distantly by the Asia assembly base.

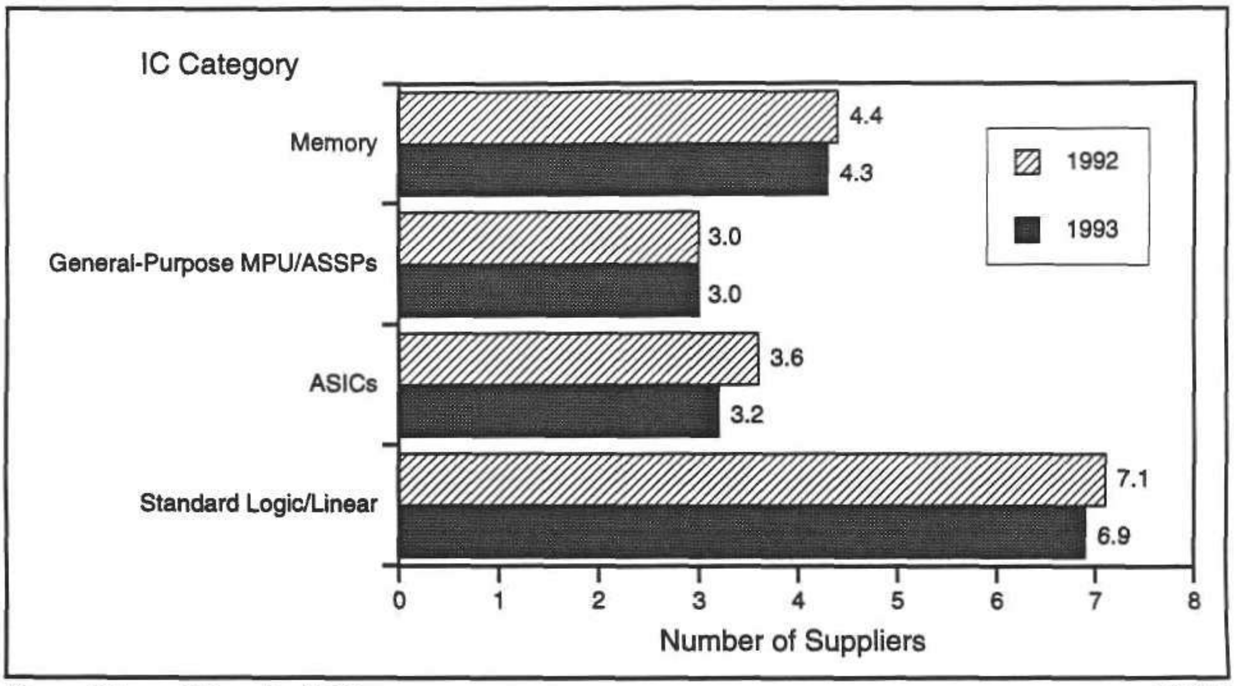
Figure 4-59
Instrumentation Industry Semiconductor Supplier Selection Criteria



Source: Dataquest (December 1992) G2001363

Quality and delivery performance are the key criteria that the instrumentation sample uses in selecting its semiconductor suppliers.

Figure 4-60
Instrumentation Industry Supply Base Trend

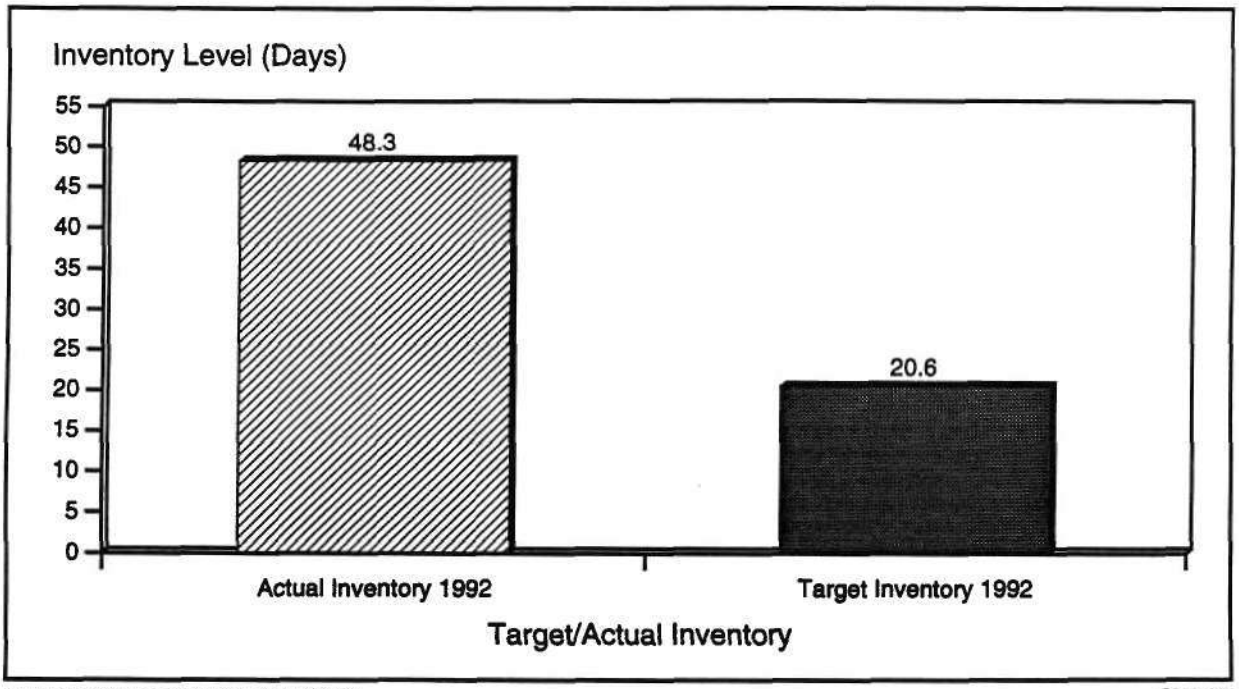


Source: Dataquest (December 1992)

G2001364

For the most part, the supply base for this segment is static, with a few minor changes expected to be made as users balance their new requirements with their existing suppliers.

Figure 4-61
Instrumentation Industry Semiconductor Inventory Status

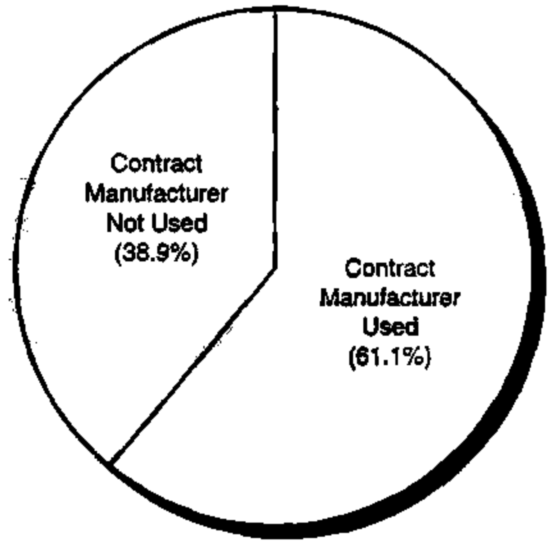


Source: Dataquest (December 1992)

G2001365

The respondents in this segment have an excess semiconductor inventory situation that needs addressing. There is opportunity for suppliers to work more closely with this market segment in order to lower the user costs and increase business levels.

Figure 4-62
Instrumentation Industry Contract Manufacturer Use

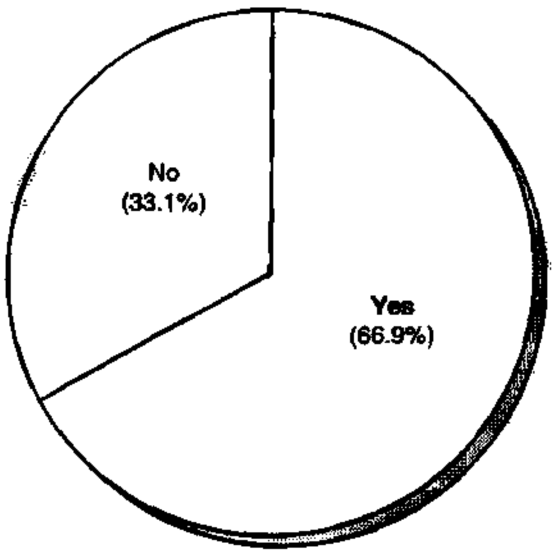


Source: Dataquest (December 1992)

G2001366

Contract manufacturing is being used by more than 60 percent of the sample and for an average of 7.2 years.

Figure 4-63
Instrumentation Industry Semiconductor Distributor Use

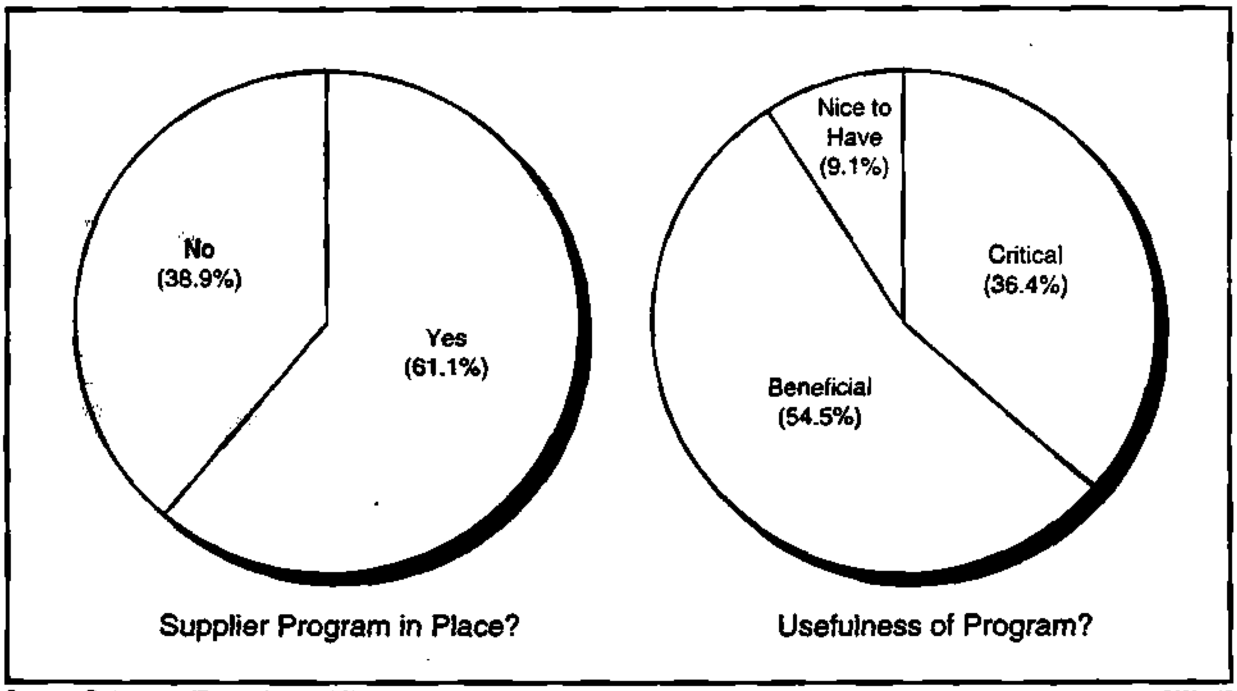


Source: Dataquest (December 1992)

G2001367

Two-thirds of the respondents use distribution because of the relative low volumes and specific needs of this market.

Figure 4-64
Instrumentation Industry Strategic Supplier Status

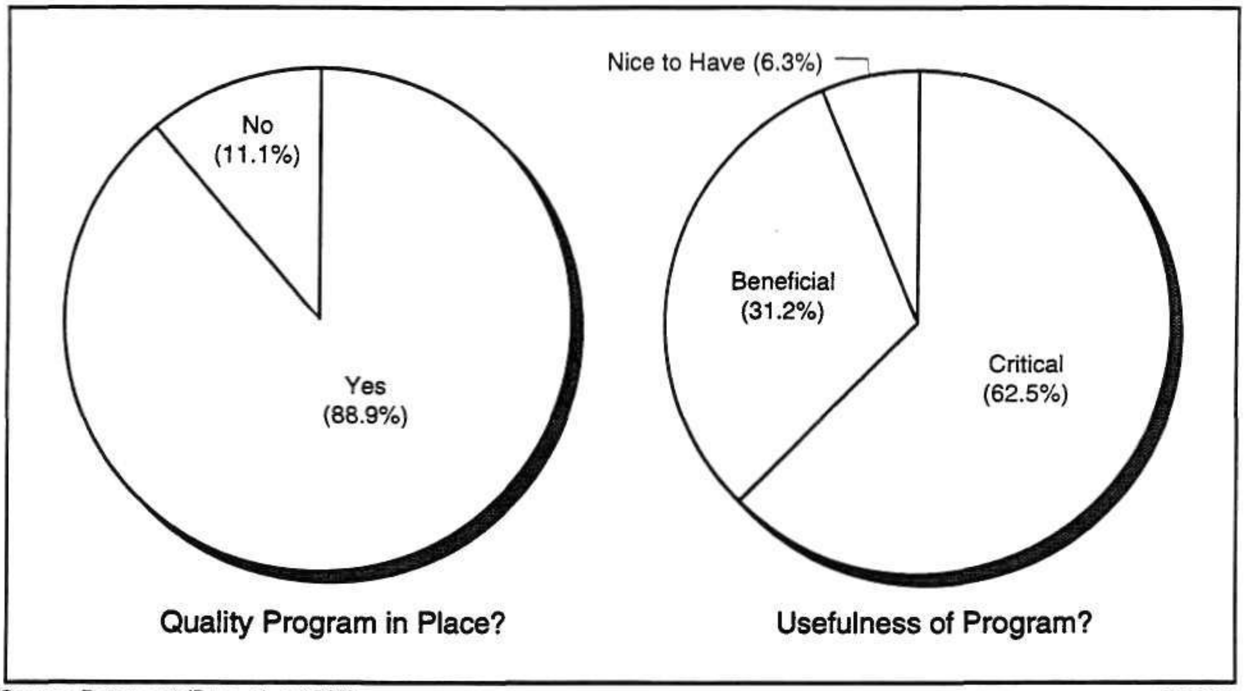


Source: Dataquest (December 1992)

G2001368

Although 61.1 percent of the respondents have a strategic supplier program in place, more than 90 percent of those in the program find it beneficial or critical to business operation.

Figure 4-65
Instrumentation Industry Quality Improvement Program Status

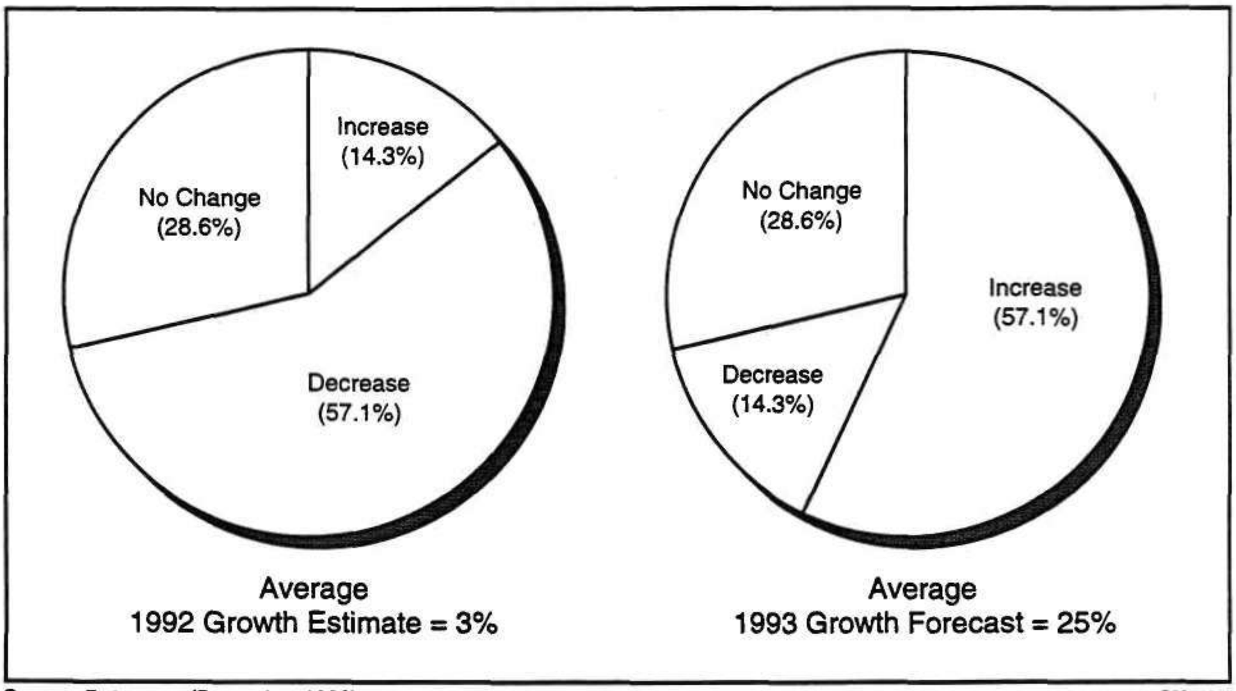


Source: Dataquest (December 1992)

G2001369

A strong 89 percent of the sample uses a quality improvement program and more than 62 percent find the program critical to operation.

Figure 4-66
Instrumentation Industry Surveyed Growth Outlook

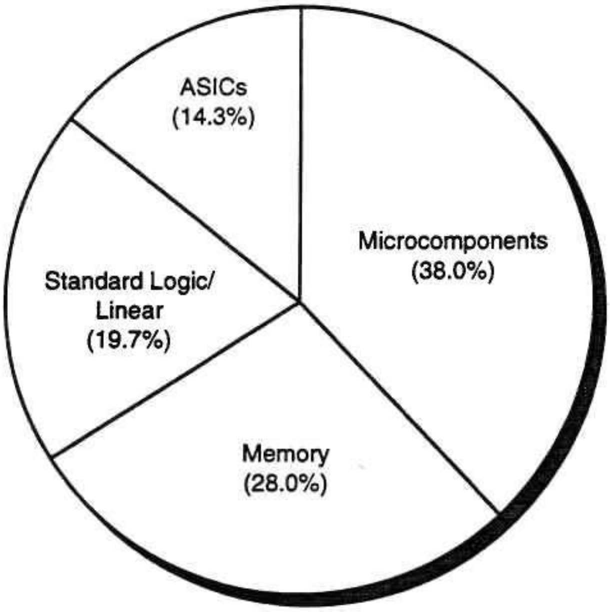


Source: Dataquest (December 1992)

G2001370

Although a majority see this segment declining in growth in 1992, a like 57.1 percent see the market turning around in 1993 at an average 25 percent growth.

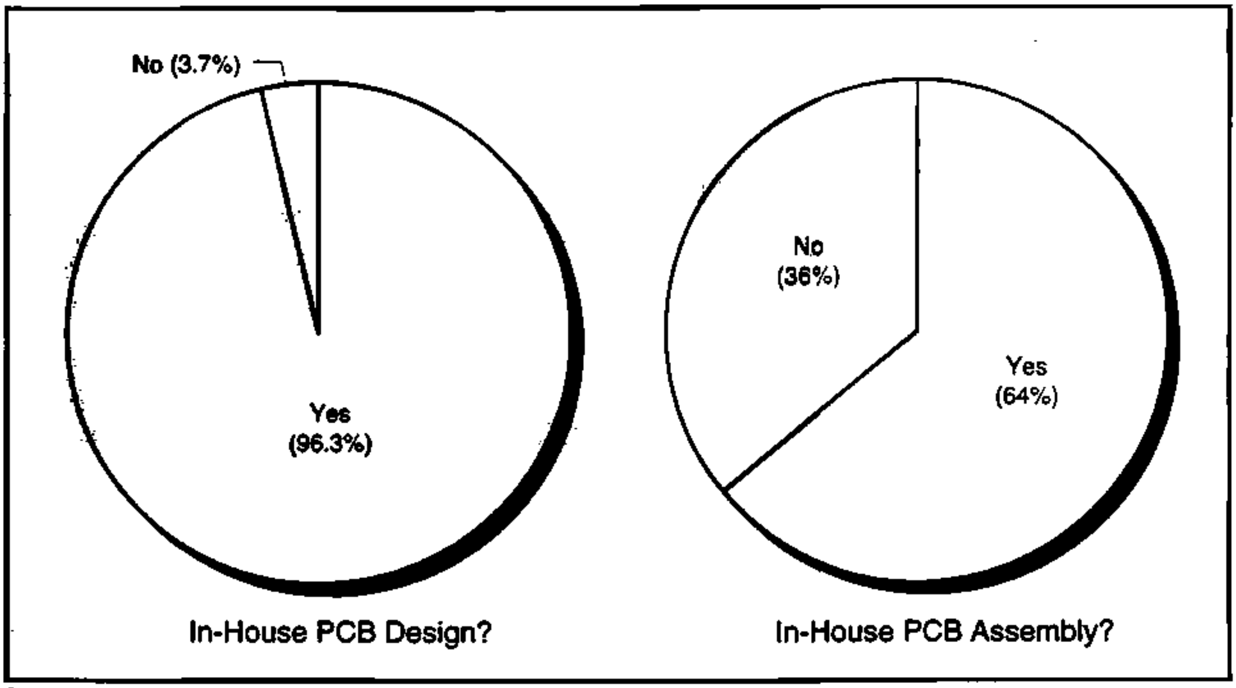
Figure 4-67
Other Industrial Survey IC Purchases



Source: Dataquest (December 1992) G2001371

- *Two-thirds of the semiconductor purchase again goes to memory and microcomponent services.*
- *Much of the 38 percent of microcomponent usage goes to embedded control microcontrollers and ASSP devices.*

Figure 4-68
Other Industrial Circuit Board Design and Assembly

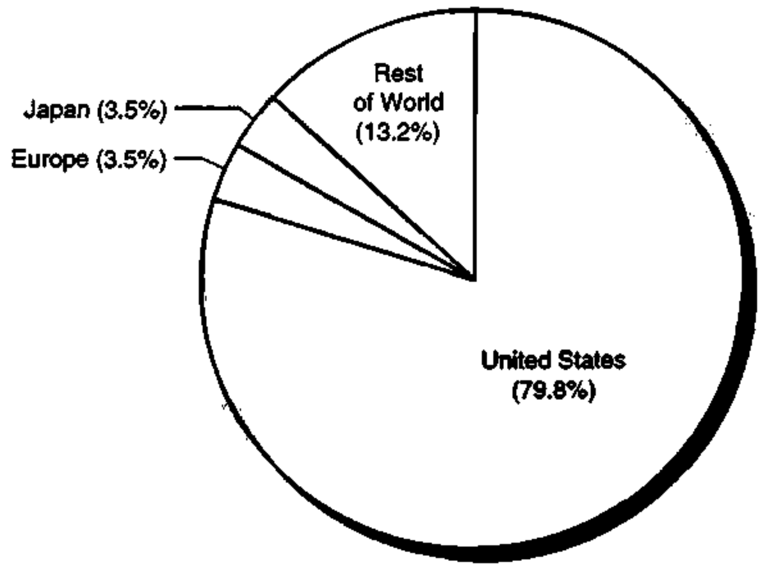


Source: Dataquest (December 1992)

G2001372

A large majority (96.3 percent) of respondents design their own circuit boards, while 36 percent utilize contract manufacturers to assemble them.

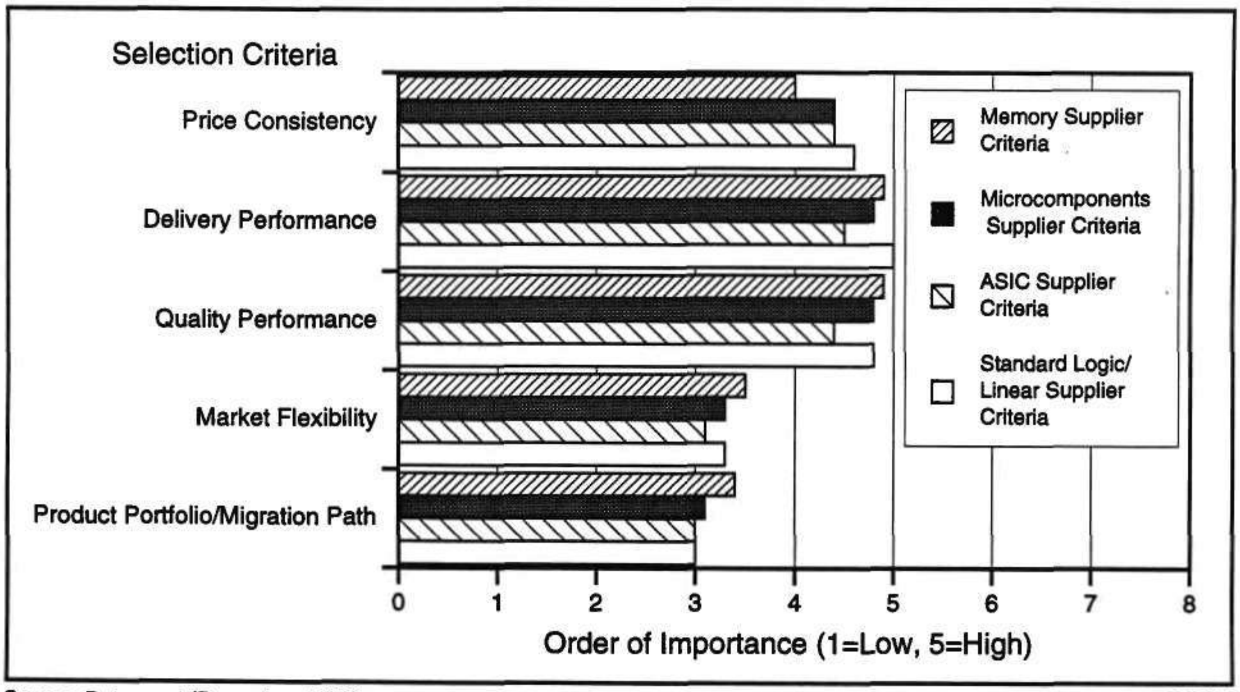
Figure 4-69
Other Industrial Physical Circuit Board Assembly Region



Source: Dataquest (December 1992) G2001373

Although nearly 80 percent of this segment's circuit boards are assembled in the United States, 13.2 percent are assembled in Asia outside of Japan.

Figure 4-70
Other Industrial Semiconductor Supplier Selection Criteria

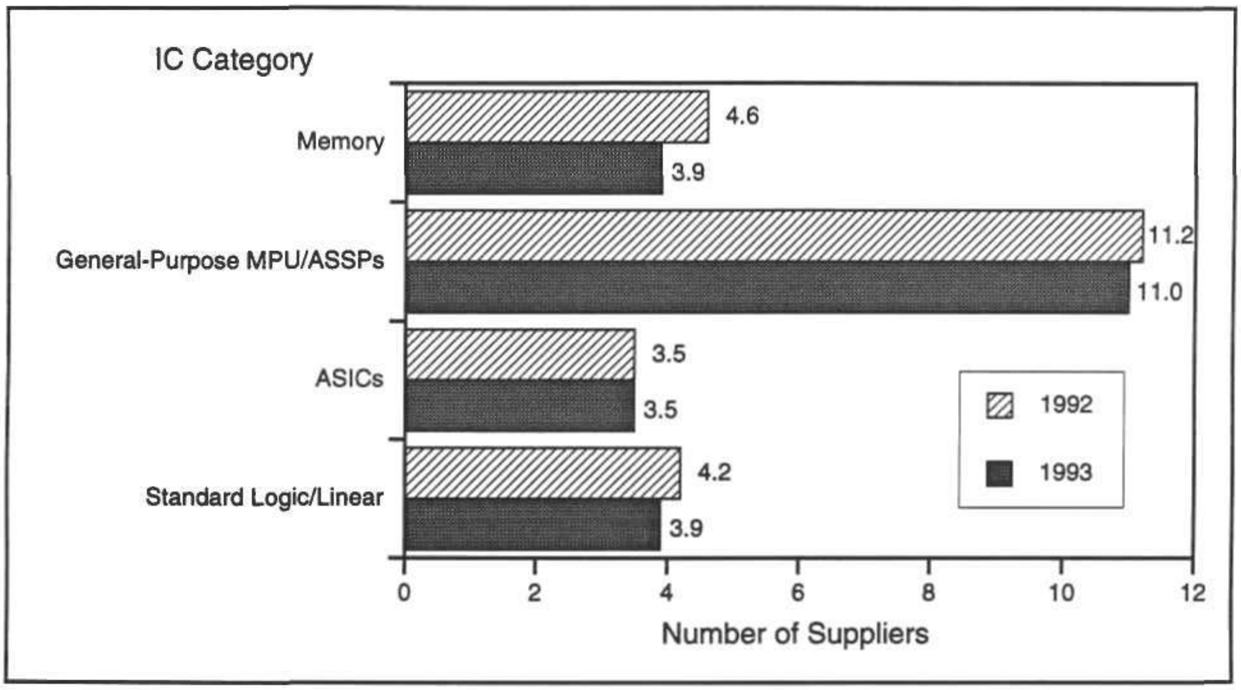


Source: Dataquest (December 1992)

G2001374

Because of the relatively higher usage of memory and microcomponents, these two supplier groupings have generally higher selection criteria than the rest of the industry.

Figure 4-71
Other Industrial Supply Base Trend

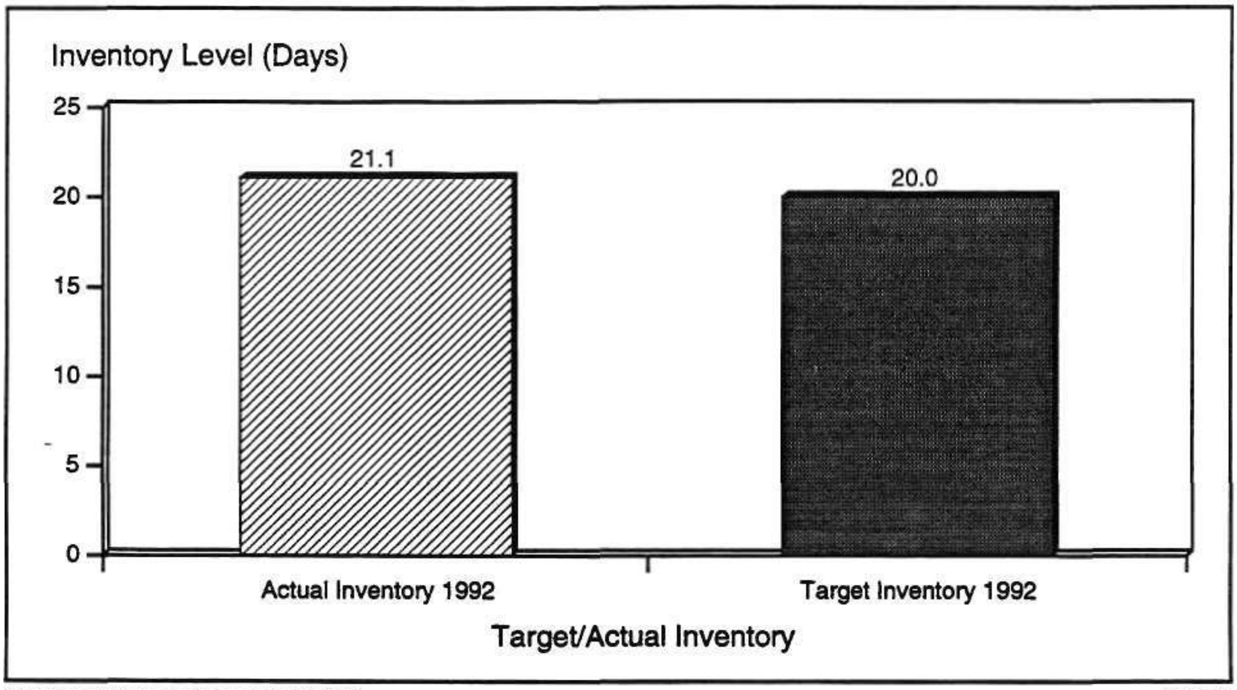


Source: Dataquest (December 1992)

G2001375

For the most part, the supply base for this segment is slowly declining, yet the high level of MPU/ASSP suppliers may have room for further reduction.

Figure 4-72
Other Industrial Semiconductor Inventory Status

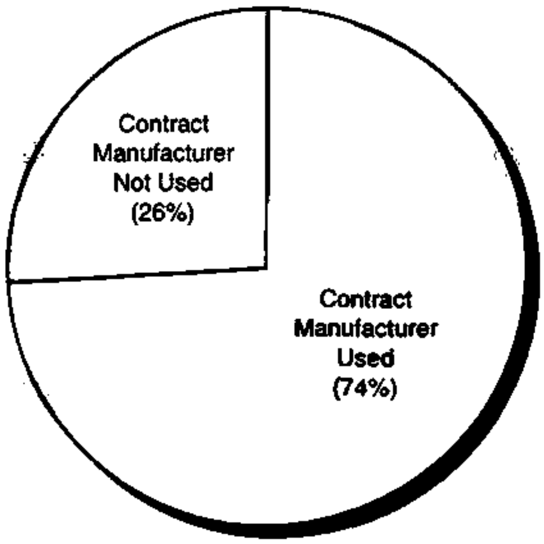


Source: Dataquest (December 1992)

G2001376

The target/actual inventory levels for this grouping are very much under control, reflecting good use of contract manufacturing.

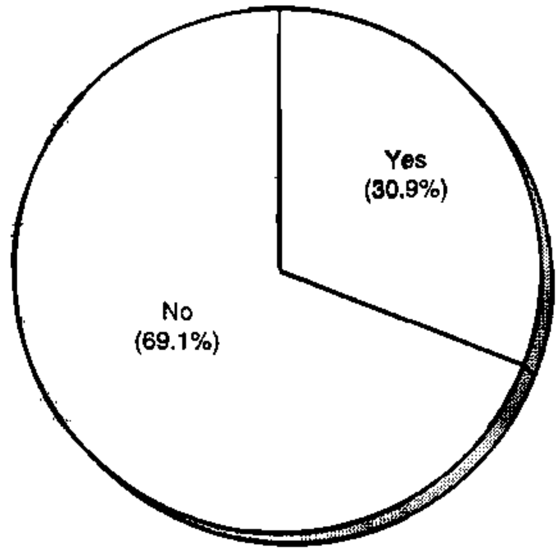
Figure 4-73
Other Industrial Average Contract Manufacturer Usage



Source: Dataquest (December 1992) G2001377

This segment of our survey was the largest user of contract manufacturing and on average has used this option for nearly 10 years.

Figure 4-74
Other Industrial Semiconductor Distributor Use

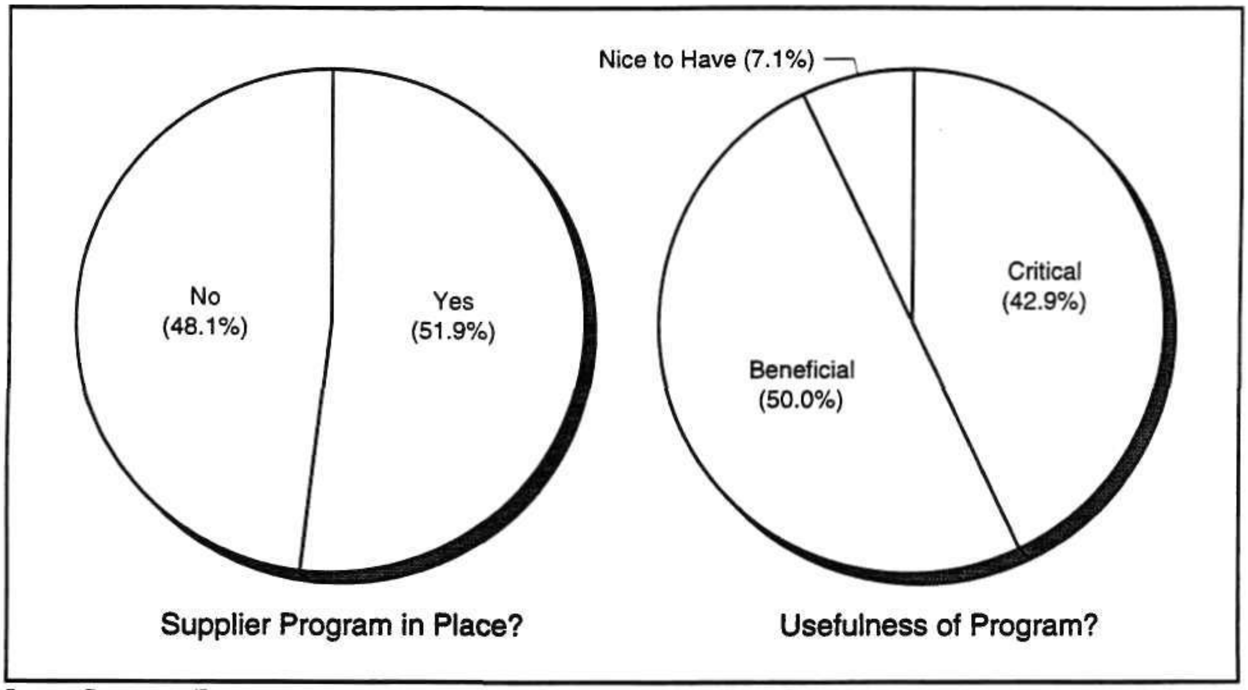


Source: Dataquest (December 1992)

G2001378

Although this sample is a large user of contract manufacturing, only 31 percent claim to use distribution. It is possible that much of the contract manufacturing is turnkey business.

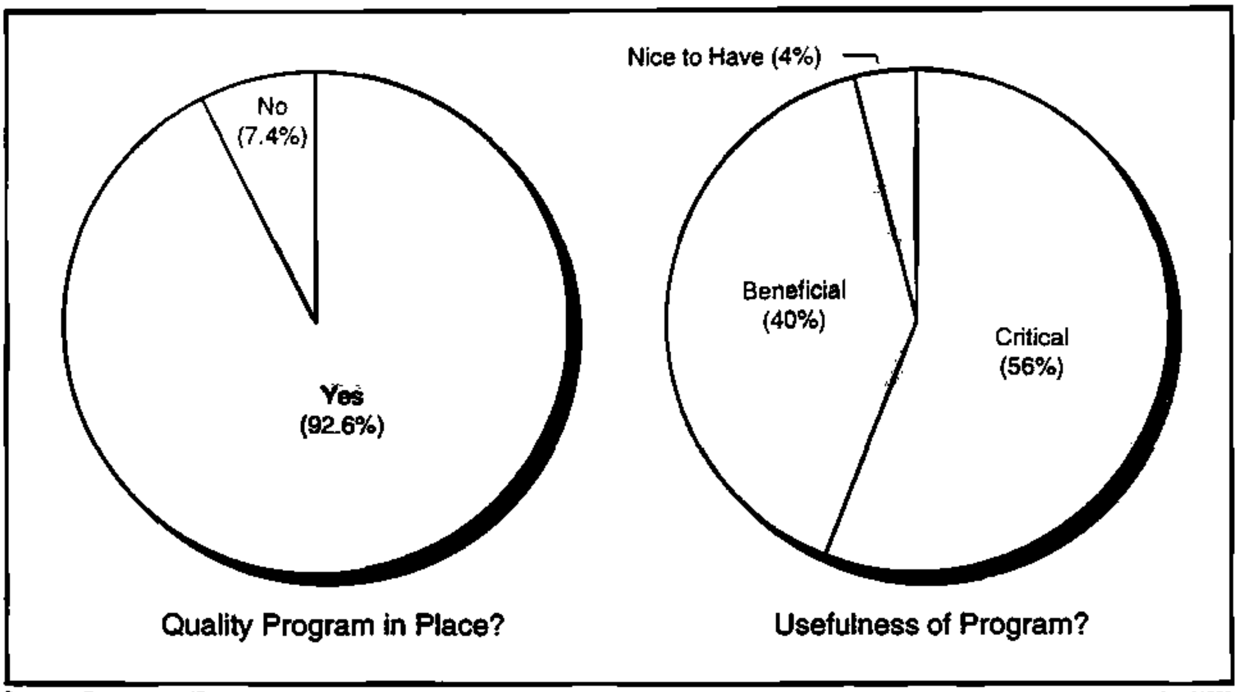
Figure 4-75
Other Industrial Strategic Supplier Status



Source: Dataquest (December 1992) G2001379

- *A bare majority (51.9 percent) of this sample utilize a strategic supplier program.*
- *For those with plans in place, 93 percent find the exercise either beneficial or critical to operations.*

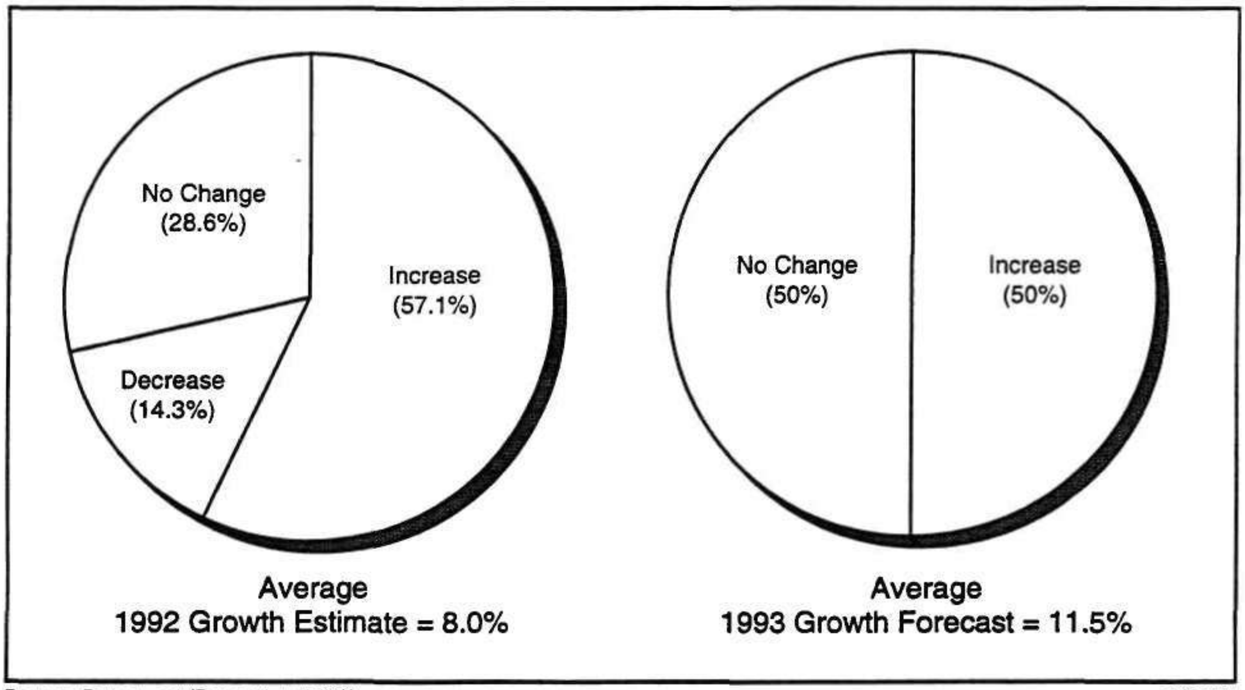
Figure 4-76
Other Industrial Quality Improvement Program Status



Source: Dataquest (December 1992) G2001380

- *Another strong 93 percent of the respondents have a formal quality program in place.*
- *Fifty-six percent of the quality program participants found the exercise critical for business success.*

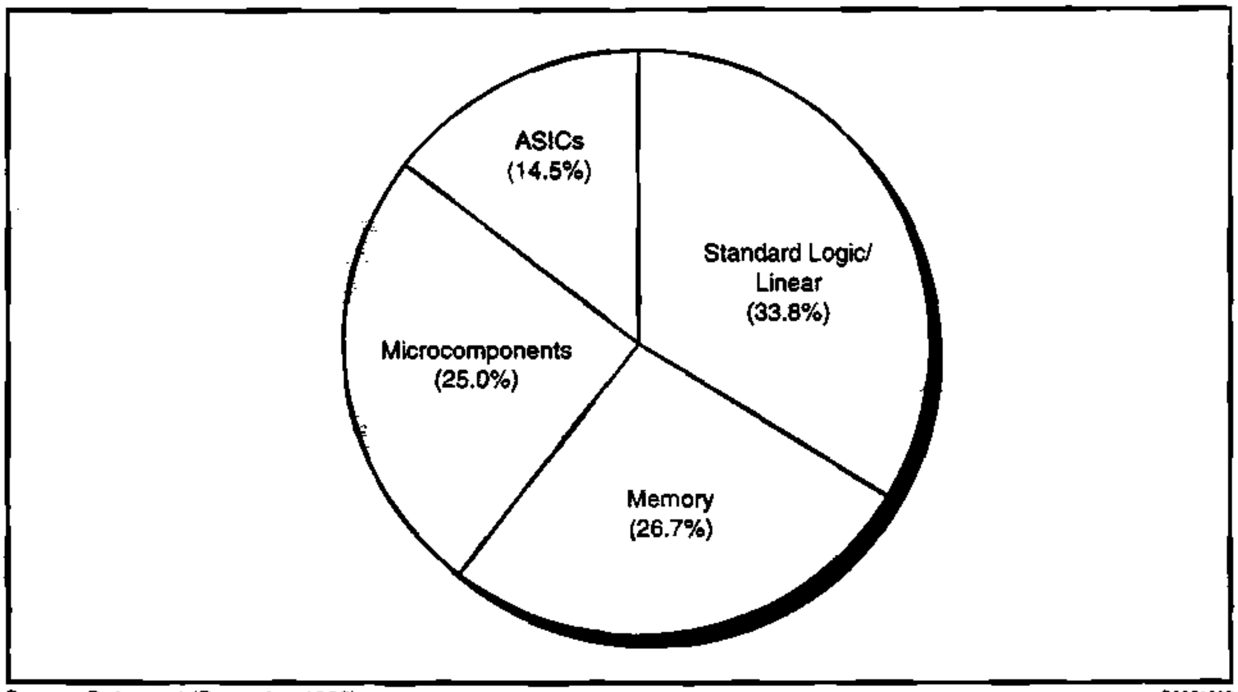
Figure 4-77
Other Industrial Surveyed Growth Outlook



Source: Dataquest (December 1992) G2001381

- *Although nearly 60 percent of the sample expects 1992 business to grow an average 8.0 percent, 14.3 percent believe that business will decline.*
- *The group expecting declines in 1992 either has raised its outlook for 1993 to no change or to an average business improvement of 11.5 percent.*

Figure 4-78
Consumer/Automotive Industry Survey IC Purchases

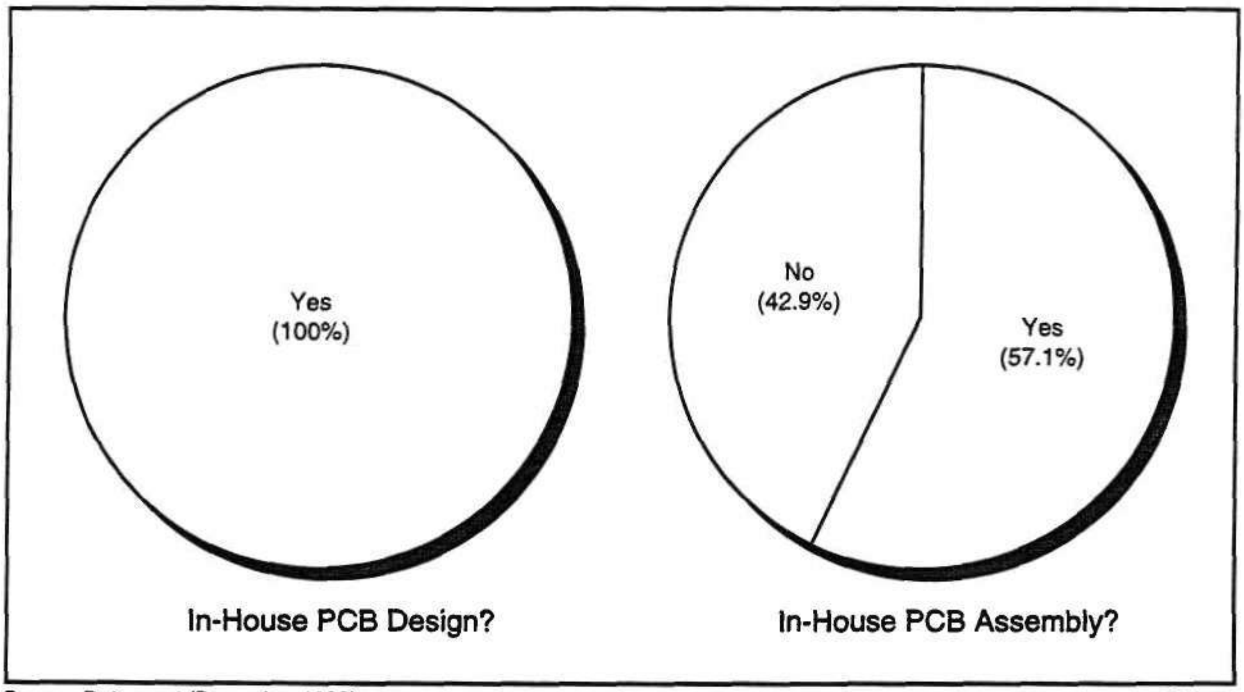


Source: Dataquest (December 1992)

G2001382

More than one-third (33.8 percent) of this segment's respondents' semiconductor procurement dollar goes to standard logic/linear services because of the high level of linear/analog devices used in both these industries.

Figure 4-79
Consumer/Automotive Industry Circuit Board Design and Assembly

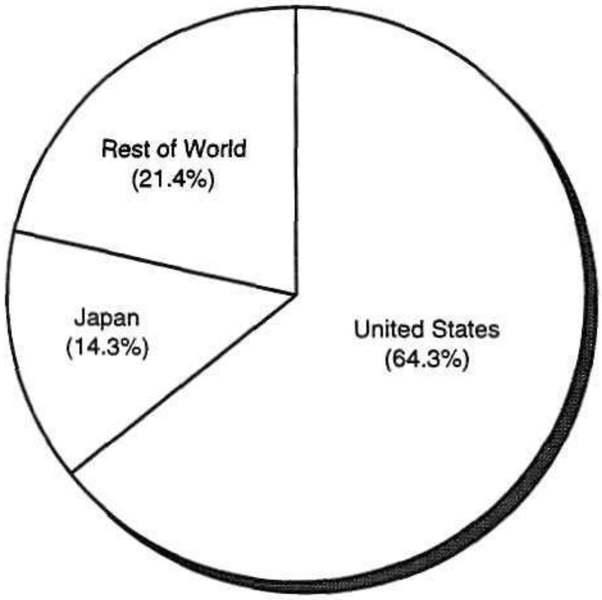


Source: Dataquest (December 1992)

G2001383

Although all respondents in the sample design their own circuit boards, 43 percent utilize outsourced assembly, most likely in the consumer market.

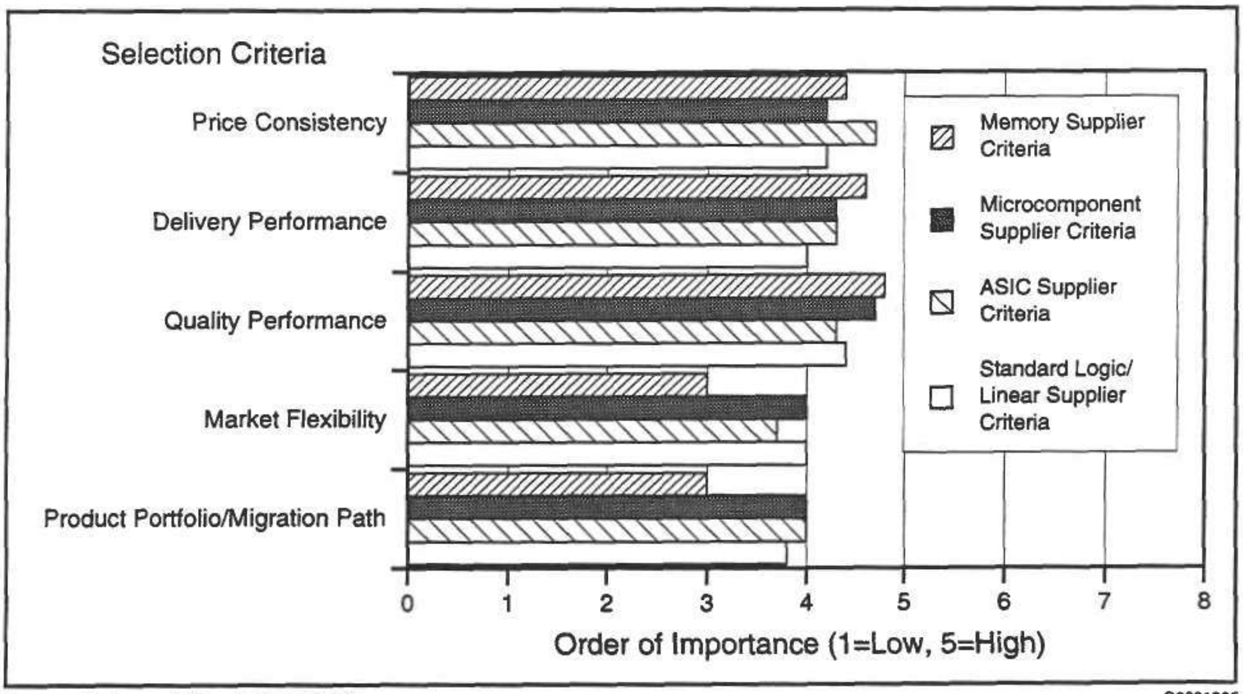
Figure 4-80
Consumer/Automotive Industry Physical Circuit Board Assembly Region



Source: Dataquest (December 1992) G2001384

Nearly two-thirds (64.3 percent) of this segment assembles its circuit boards in the United States, followed by the Rest of World region with 21.4 percent.

Figure 4-81
Consumer/Automotive Industry Semiconductor Supplier Selection Criteria

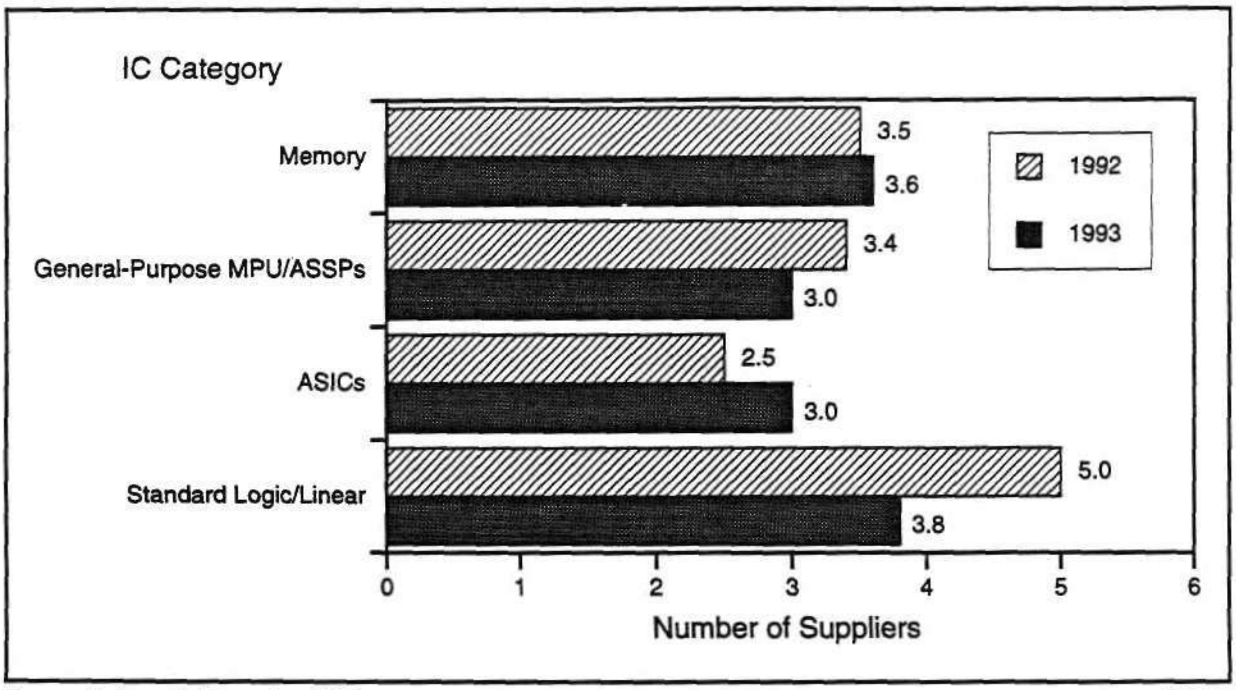


Source: Dataquest (December 1992)

G2001385

Memory and microcomponents are mainly selected based on quality and delivery, while ASIC suppliers are gauged first on price for this consumer/automotive sample.

Figure 4-82
Consumer/Automotive Industry Supply Base Trend

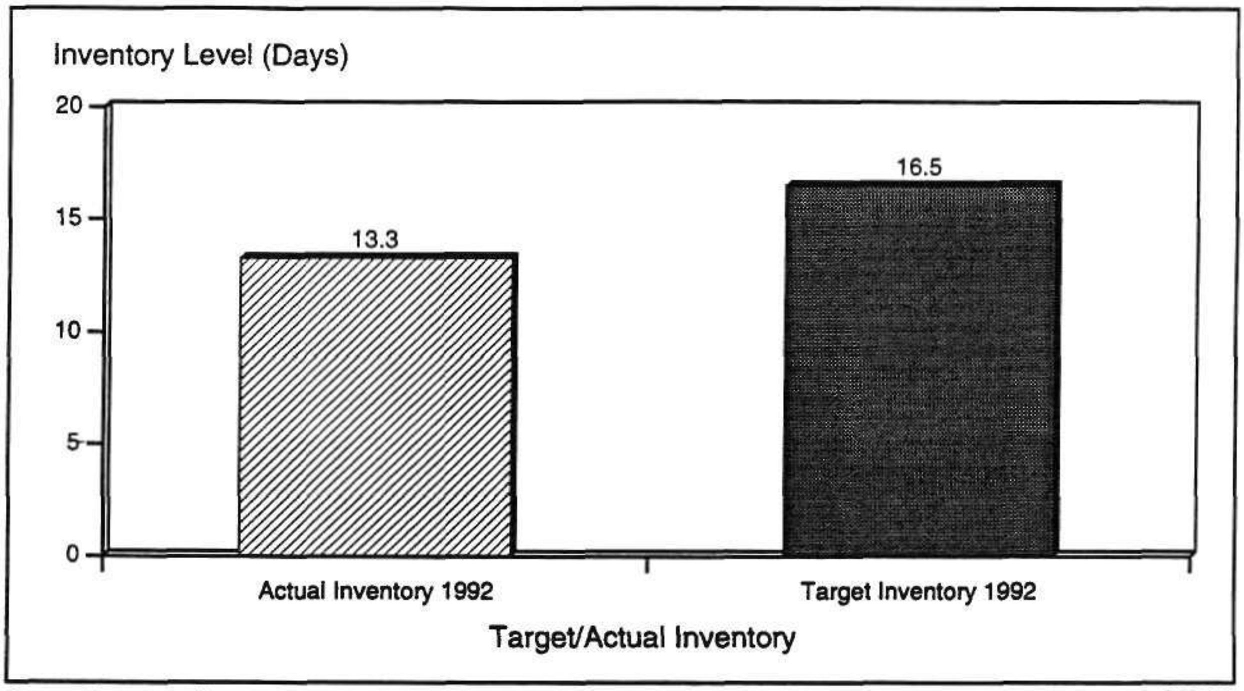


Source: Dataquest (December 1992)

G2001386

- *The supply base of this segment is churning, with planned reduction in supplies of microcomponents and standard/linear, while there are expected increases in the memory and ASIC supply base.*
- *An average supplier level of three apparently is the goal for this segment.*

Figure 4-83
Consumer/Automotive Industry Semiconductor Inventory Status

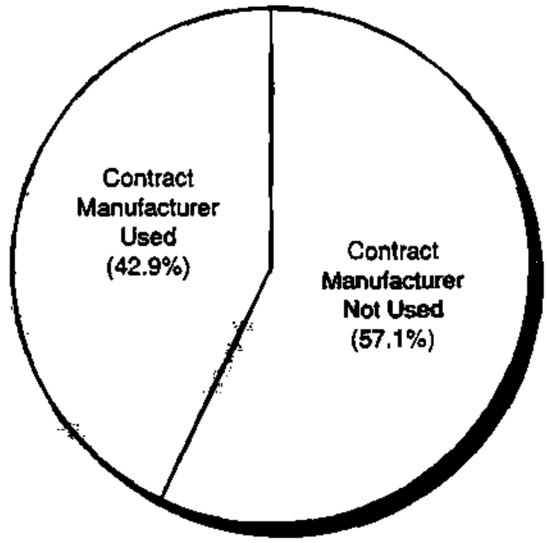


Source: Dataquest (December 1992)

G2001387

- *This is one segment that has actual semiconductor levels below target.*
- *Well under industry averages, this level of inventory control highlights how rapidly changing markets can benefit from good inventory management.*

Figure 4-84
Consumer/Automotive Industry Contract Manufacturer Use

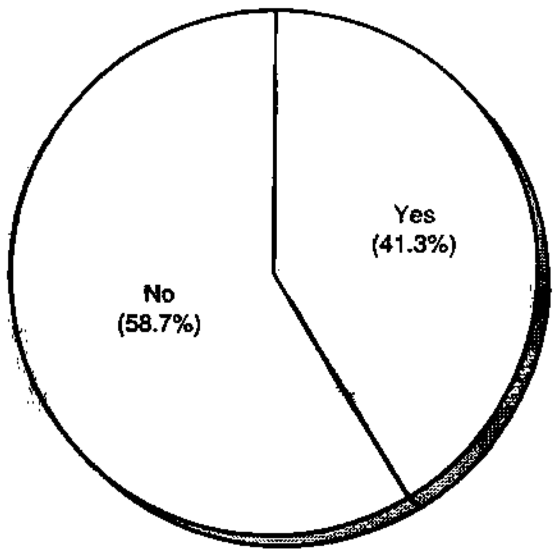


Source: Dataquest (December 1992)

G2001368

- *This is the only segment that had more than half (57.1 percent) of the sample not using contract manufacturing.*
- *For the balance that did use contractors, the average length of time is 7.3 years.*

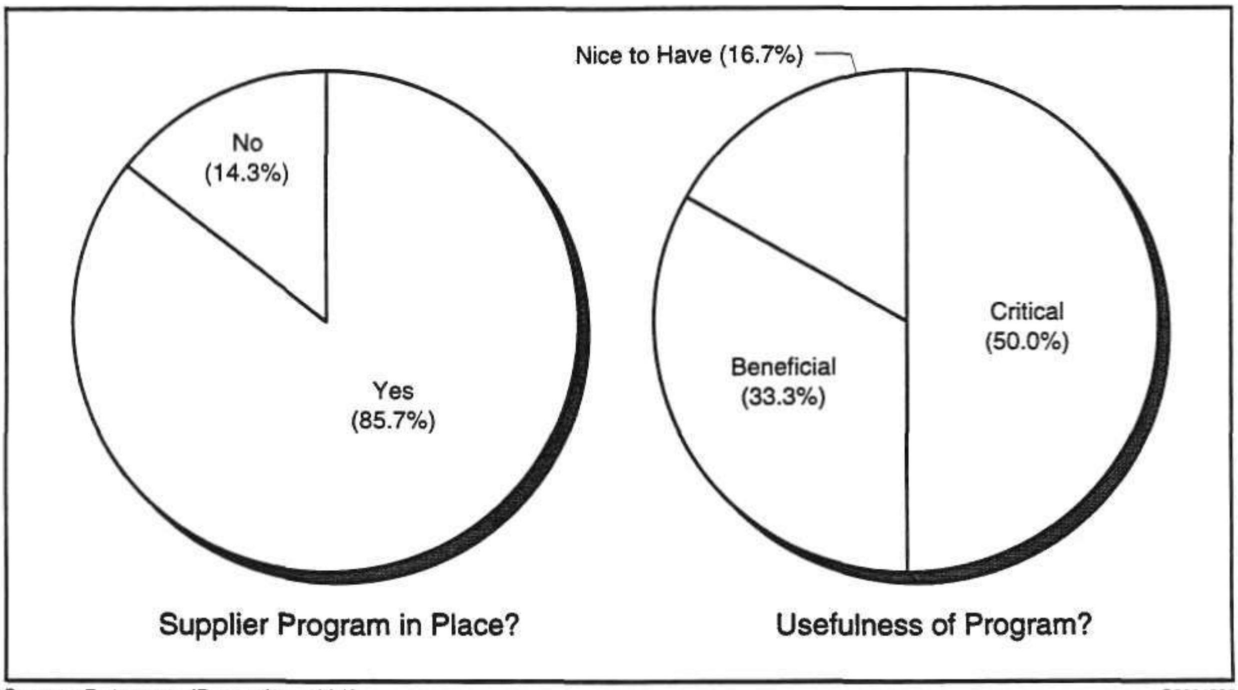
Figure 4-85
Consumer/Automotive Industry Semiconductor Distributor Use



Source: Dataquest (December 1992)
G2001389

A comparable percentage (41.3 percent) of this sample reported using semiconductor distribution.

Figure 4-86
Consumer/Automotive Industry Strategic Supplier Status

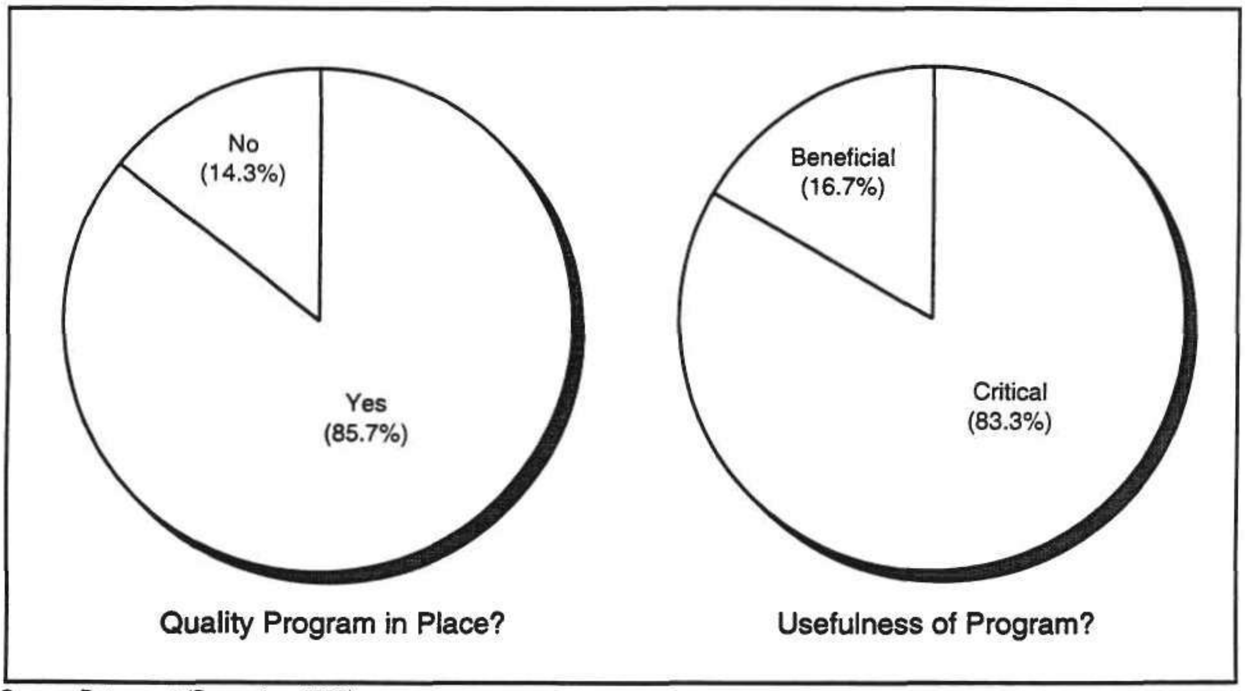


Source: Dataquest (December 1992)

G2001390

A strong 86 percent of the respondents have strategic supplier programs in place and half of those using plans note that they are critical to ongoing operation.

Figure 4-87
Consumer/Automotive Industry Quality Improvement Program Status

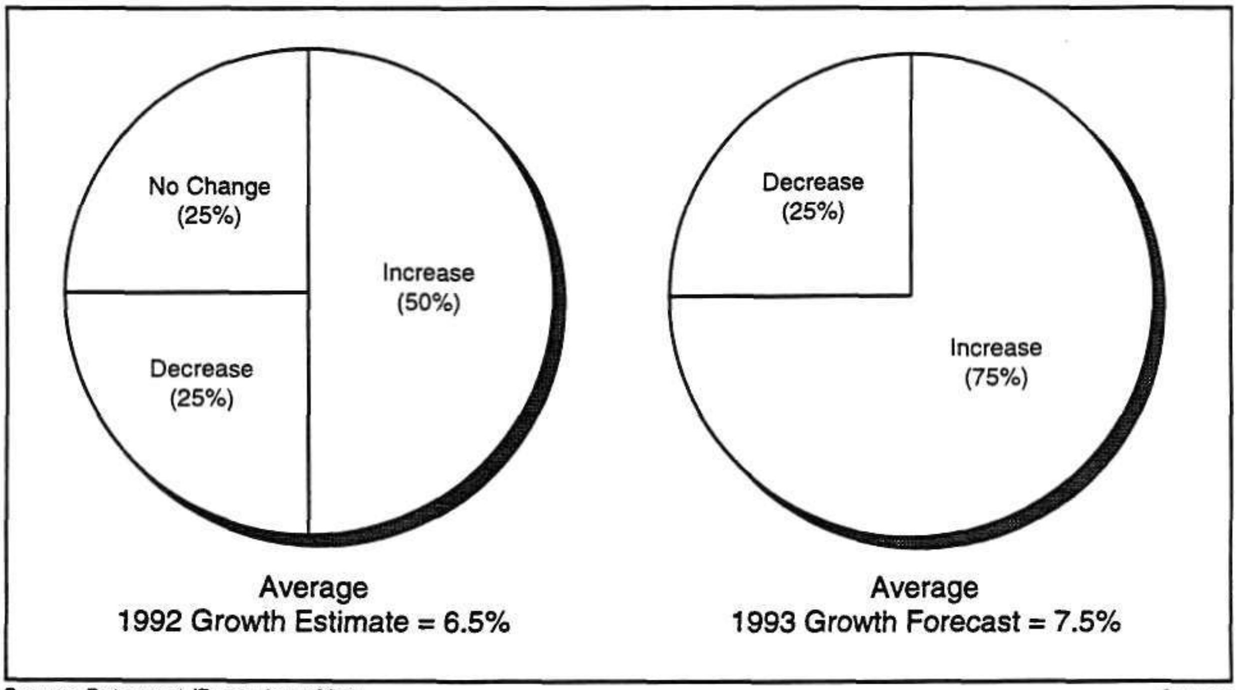


Source: Dataquest (December 1992)

G2001391

A like 85.7 percent of this segment's respondents have in place formal quality improvement programs, which are critical to the business of 83.3 percent of the participants.

Figure 4-88
Consumer/Automotive Industry Surveyed Growth Outlook

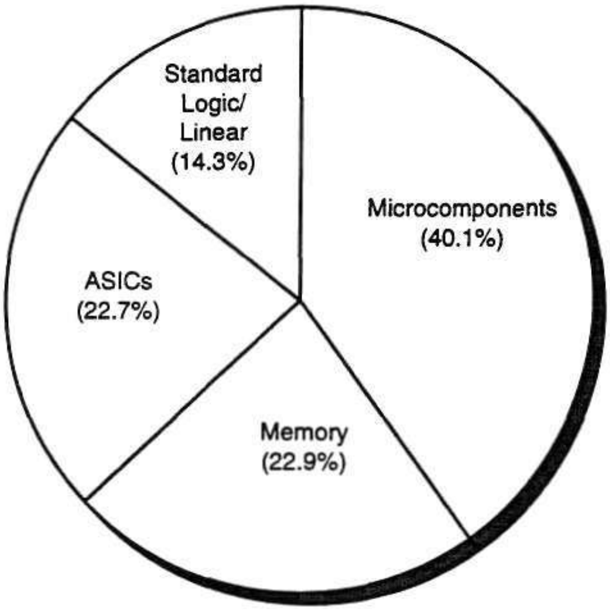


Source: Dataquest (December 1992)

G2001392

- *Because of economic uncertainty, 25 percent of the respondents expect business to decline in 1992, while half expect to see a modest uptick of 6.5 percent.*
- *Three-fourths of the respondents expect business to improve an average 7.5 percent in 1993.*

Figure 4-89
Military/Aerospace Industry Survey IC Purchases

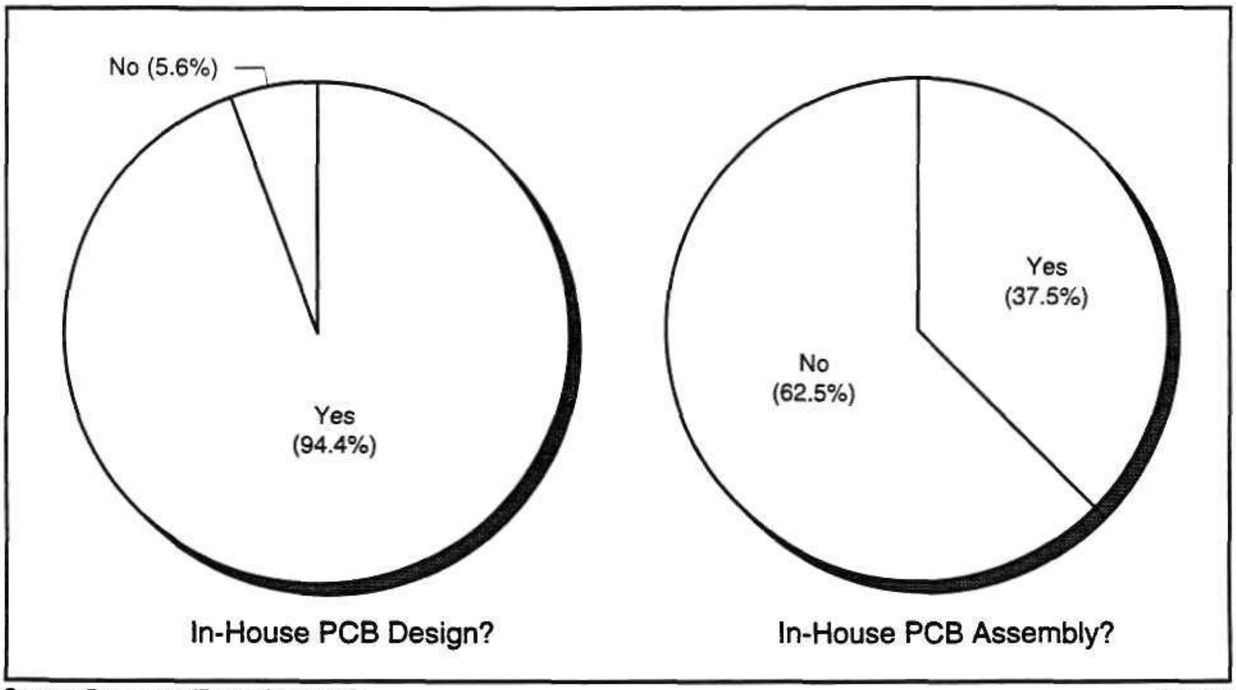


Source: Dataquest (December 1992)

G2001393

The largest portion of this segment's semiconductor buy goes to the microcomponent segment, with more than 40 percent being spent there.

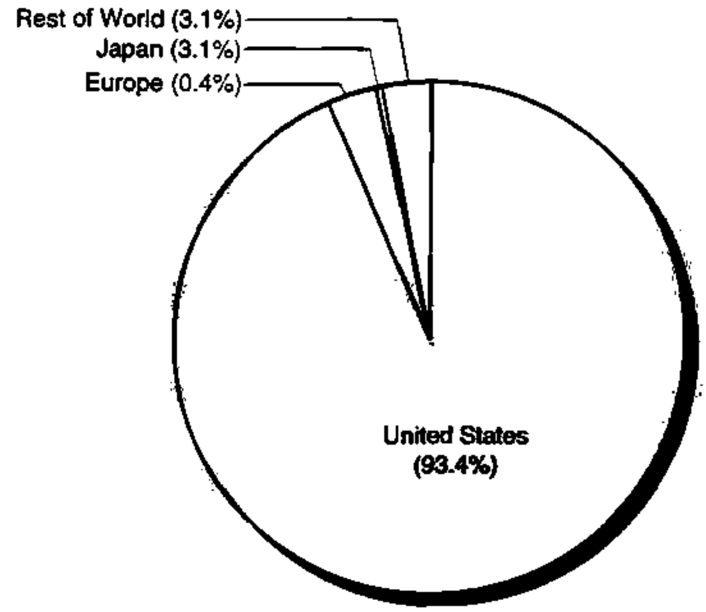
Figure 4-90
Military/Aerospace Industry Circuit Board Design and Assembly



Source: Dataquest (December 1992)
G2001394

Nearly 95 percent of the respondents design their own circuit boards, yet nearly two-thirds subcontract out their assembly because of the high overhead and low volume associated with this market.

Figure 4-91
Military/Aerospace Industry Physical Circuit Board Assembly Region

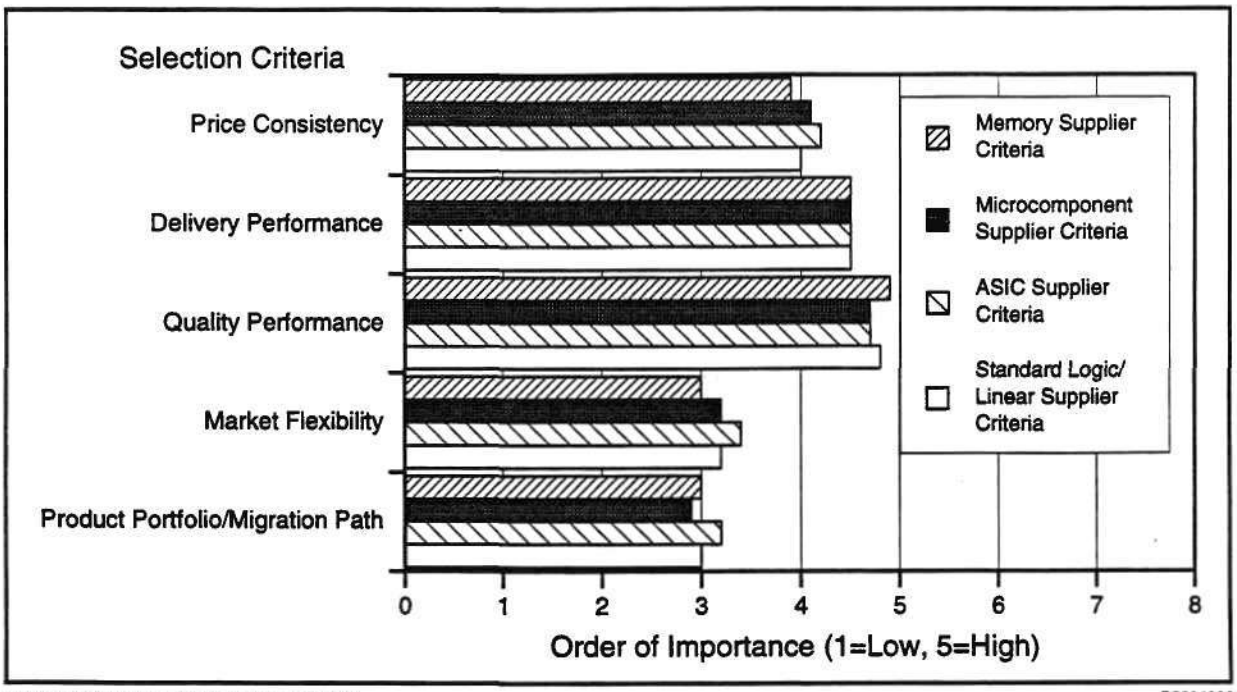


Source: Dataquest (December 1992)

G2001395

The lion's share (93.4 percent) of physical assembly is done in the United States, yet a small portion is being done in Japan and Asia.

Figure 4-92
Military/Aerospace Industry Semiconductor Supplier Selection Criteria

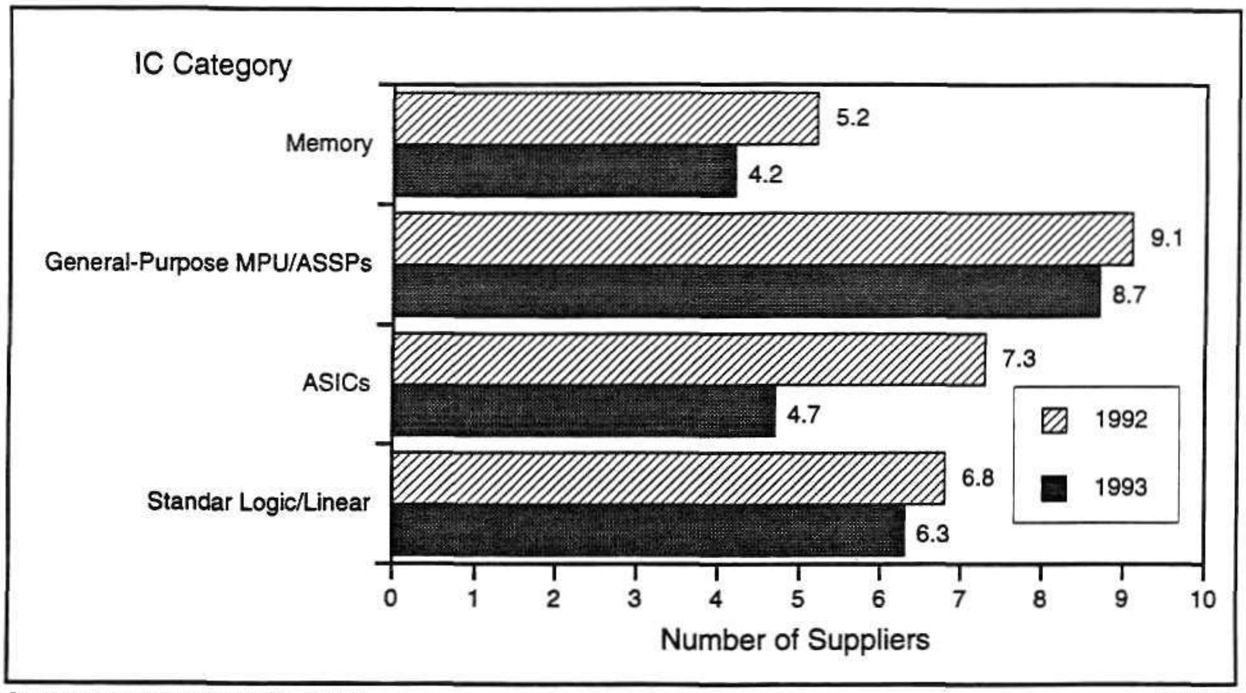


Source: Dataquest (December 1992)

G2001396

Very much like the overall industry, this segment of the market keys on quality and then delivery when selecting a semiconductor supplier, be it an OEM, distributor, or contract manufacturer.

Figure 4-93
Military/Aerospace Industry Supply Base Trend

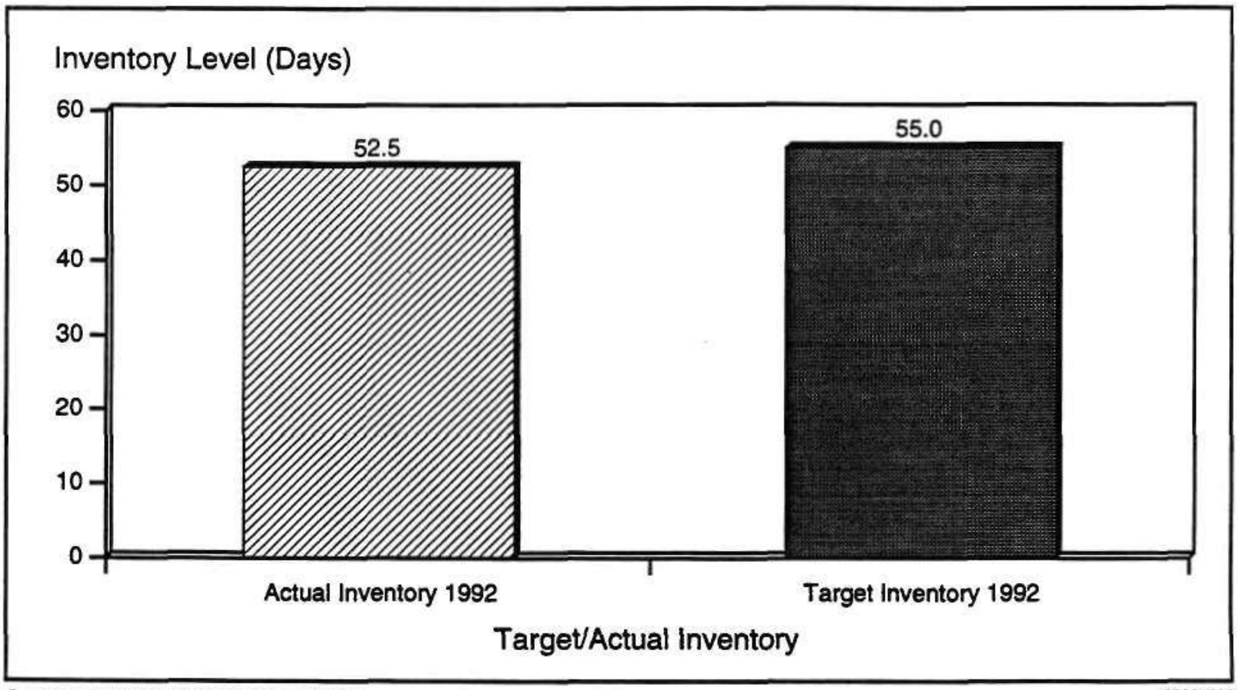


Source: Dataquest (December 1992)

G2001397

Aside from incremental reduction in the memory and standard logic/linear supplier levels, the microcomponent and ASIC supply base is expected to be reduced for this segment next year.

Figure 4-94
Military/Aerospace Industry Semiconductor Inventory Status

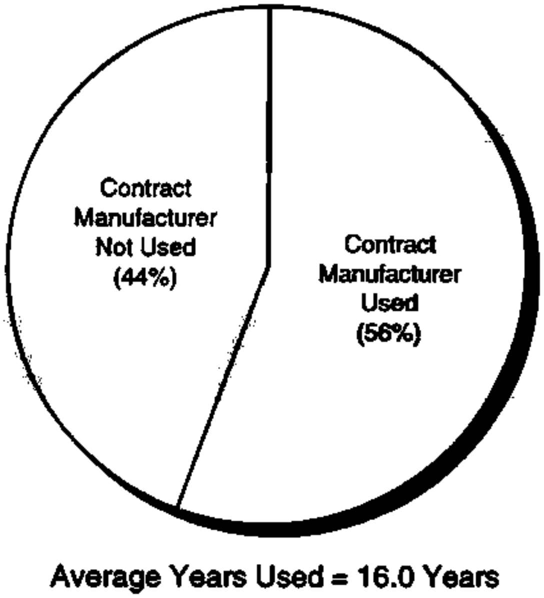


Source: Dataquest (December 1992)

G2001398

- *Although relatively high, compared with commercial industry standards, the target to actual inventory levels for this subset are well under control.*
- *Government contracts often require 60 days or more of inventory to always be on hand.*

Figure 4-95
Military/Aerospace Industry Contract Manufacturer Use

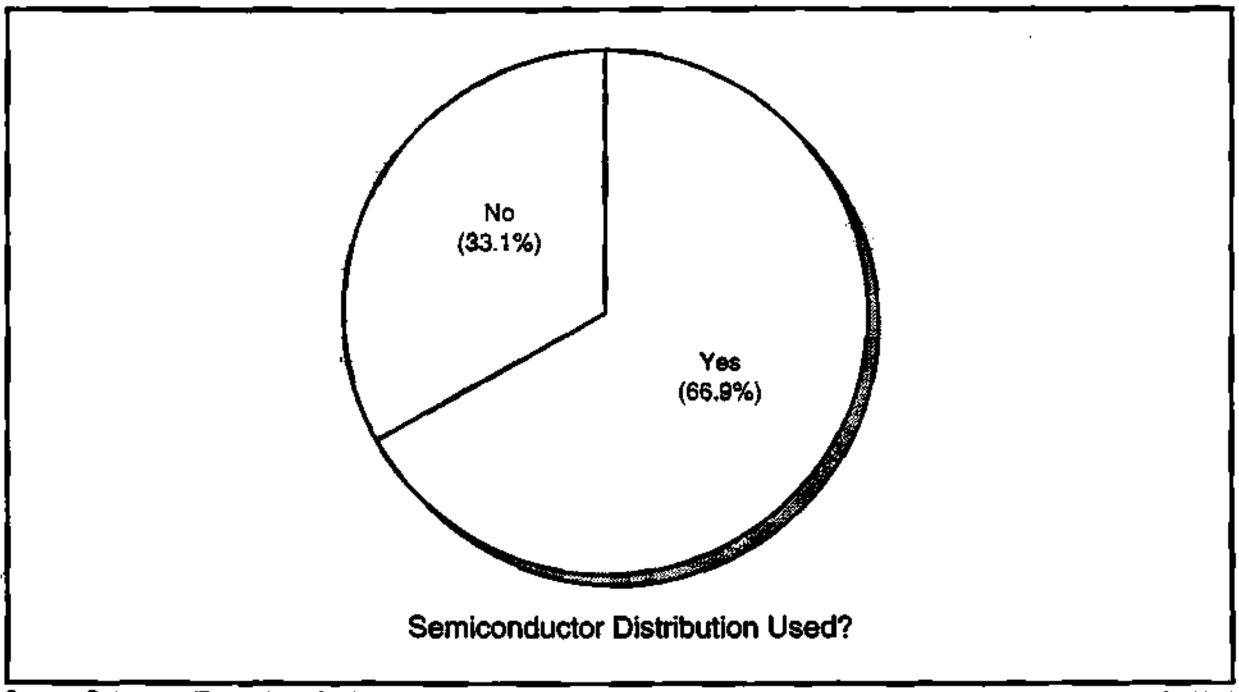


Source: Dataquest (December 1992)

G2001399

- *Although the average percentage of contract manufacturing use is within the overall industry average, the average length of time subcontractors have been used is 16 years.*
- *Because of the nature of this industry, much work is completed by subcontracting out assembly and manufacturing.*

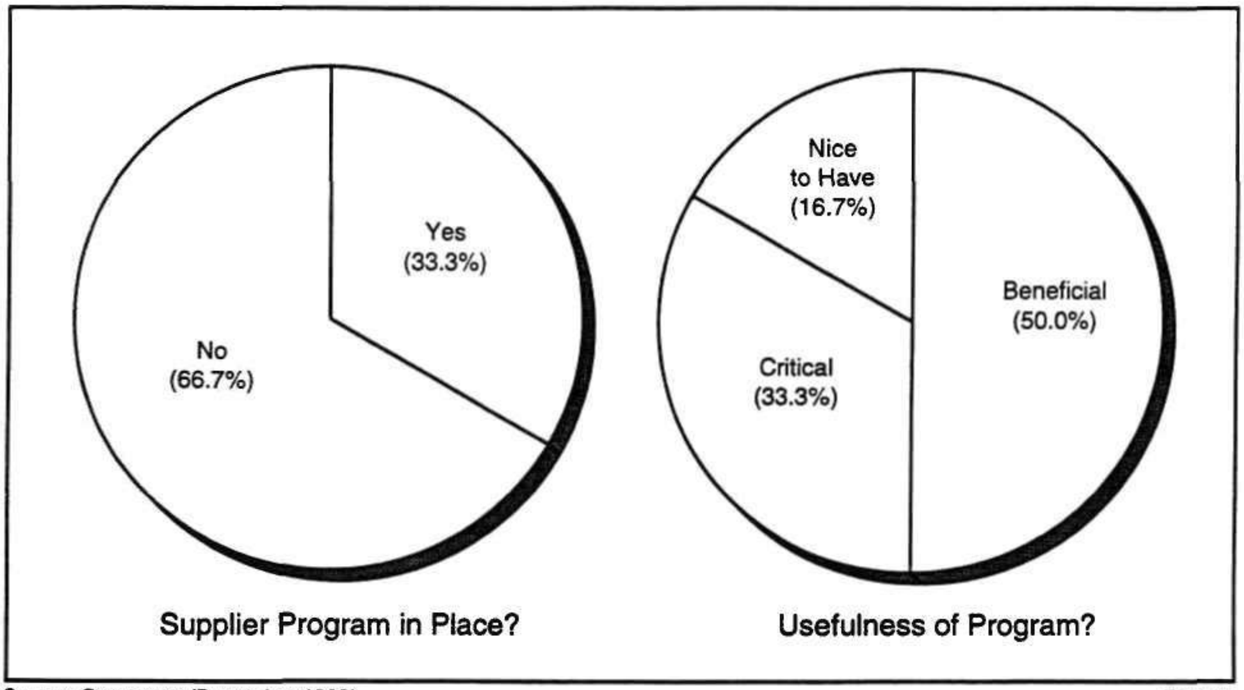
Figure 4-96
Military/Aerospace Industry Semiconductor Distributor Use



Source: Dataquest (December 1992) G2001400

More than two-thirds (66.9 percent) of this market segment uses semiconductor distribution because of the relatively low volume and special needs of this industry.

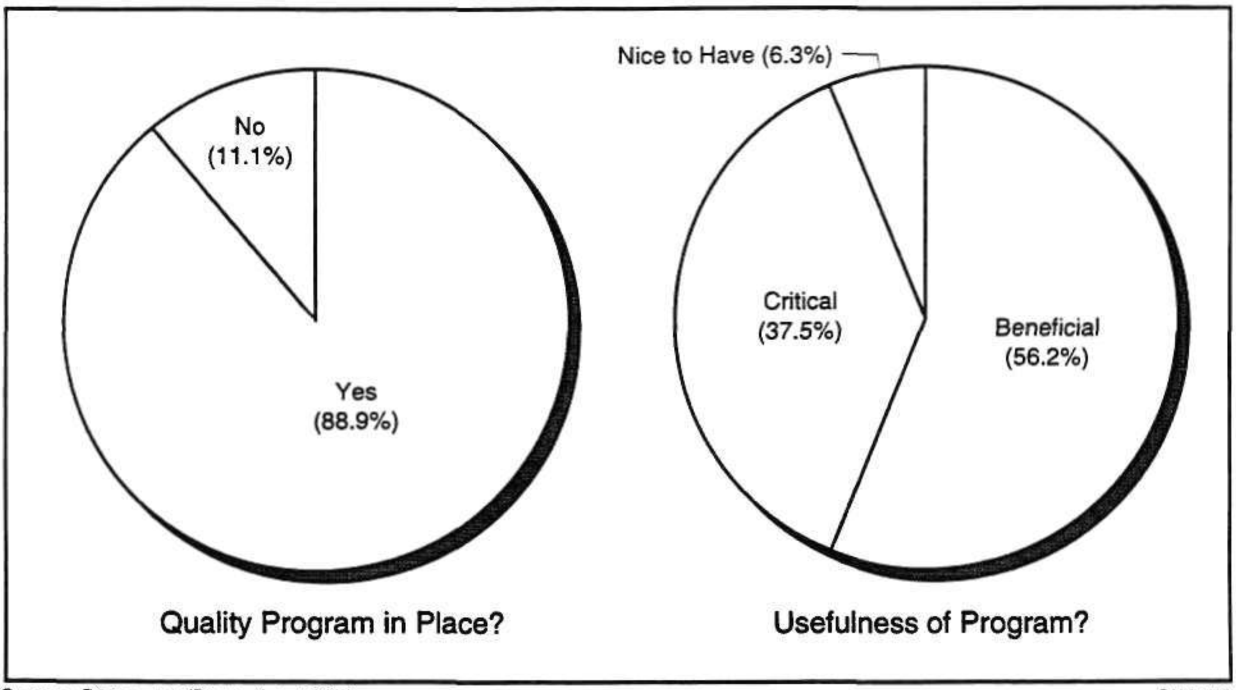
Figure 4-97
Military/Aerospace Industry Strategic Supplier Status



Source: Dataquest (December 1992)
G2001401

- *Because of the low unit volumes involved, it is not surprising to see a low level of strategic supplier programs in place.*
- *Compared with distribution usage, a strong correlation exists where distribution customers do not need strategic supplier programs—their distributor provides the services of such a program.*

Figure 4-98
Military/Aerospace Industry Quality Improvement Program Status

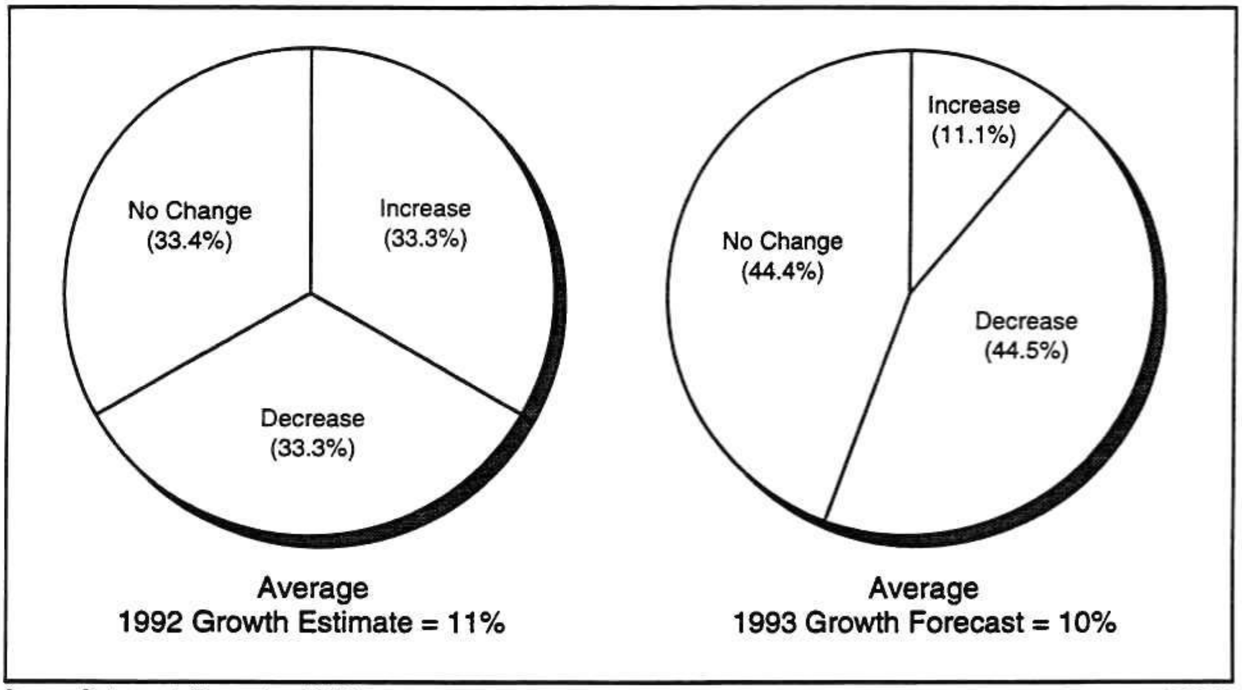


Source: Dataquest (December 1992)

G2001402

Because of the nature of military contracts, it is surprising to see that more than 11 percent of the respondents do not have a quality program in place.

Figure 4-99
Military/Aerospace Industry Surveyed Growth Outlook



Source: Dataquest (December 1992)

G2001403

- *The responses were equally split regarding the economic outlook for 1992, with those that expect growth seeing an increase of 11 percent.*
- *Because of the smaller response to the 1993 outlook, a more bleak forecast appears. Yet for those expecting business to improve, the average increase is expected to be 10 percent.*

Chapter 5
Semiconductor User Needs, by Product Category

This chapter focuses on purchasing information as seen from an IC category perspective. The information and analysis should be useful for those individuals interested in product granularity. We chose the following four areas to detail:

- Memory ICs
- Microcomponent ICs
- ASIC
- Standard logic and analog

These categories were chosen to keep the survey manageable and to cluster products that exhibit similar buying behavior.

This chapter is organized into the four product categories mentioned. We will examine, from the OEM's perspective, semiconductor supplier selection criteria, quality definitions, and the number of qualified semiconductor suppliers within each product category. Regarding supplier selection criteria, we asked purchasers to note the importance of the following five factors:

- Pricing consistency—Maintaining predictable (plannable) pricing practices, regardless of fluctuating market conditions.
- Delivery performance—The ability to deliver the correct product order when specified.
- Quality performance—The ability to deliver product that meets or exceeds required incoming quality levels.
- Market flexibility—A supplier's ability to be flexible with delivery schedules and quantities to match fluctuating OEM demand.
- Product portfolio and migration path—The breadth, depth, and plans for products needed by the customer.

On the quality question, we asked OEMs to define minimum acceptable incoming quality on a defective ppm basis. We also asked OEMs to identify the number of qualified suppliers in each product area for 1992 and the planned number for 1993.

Memory ICs

Figures 5-1 through 5-8 detail the survey results from buyers of memory ICs on supplier selection criteria, quality definitions, and number of suppliers. Memory ICs include such products as DRAMs, SRAMs, VRAMs, ROM, EPROM, EEPROM, flash, and various combinations and specialty products such as dual ports.

Microcomponent ICs

Figures 5-9 through 5-16 detail the survey results from buyers of microcomponent ICs on supplier selection criteria, quality definitions, and number of suppliers. Microcomponents include such products as microprocessors, microcontrollers, coprocessors, DSP microprocessors, processor support functions (DMA controllers, among others), dedicated controllers (networking, graphics, and storage), and various functional chip sets.

ASICs

Figures 5-17 through 5-24 detail the survey results from buyers of ASICs on supplier selection criteria, quality definitions, and number of suppliers. ASICs include such products as PLDs, FPGAs, gate arrays, cell-based ICs, custom ICs, and variations combining these.

Standard Logic and Analog ICs

Figures 5-25 through 5-32 detail the survey results from buyers of standard logic and analog ICs on supplier selection criteria, quality definitions, and number of suppliers. Included in this category are family and interface logic products as well as standard analog functions such as amplifiers, regulators and references, data conversion, and consumer circuits.

Summary

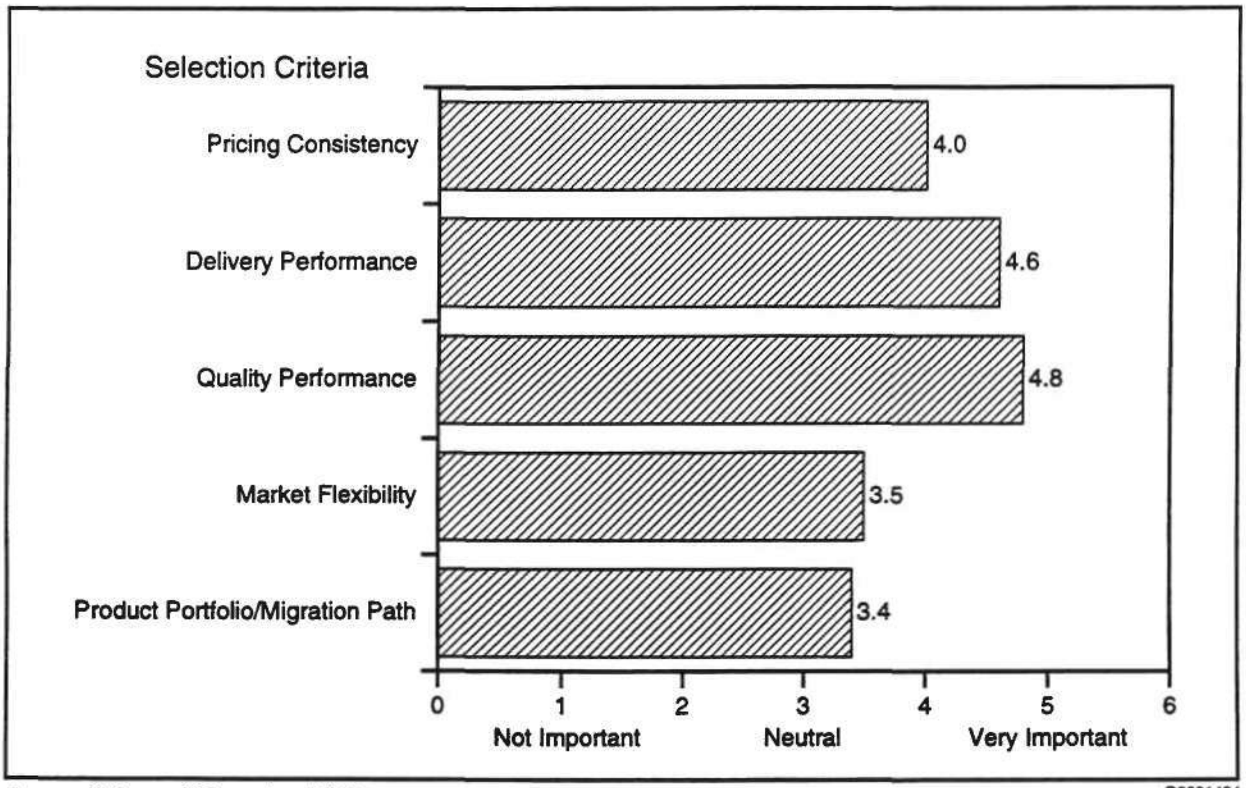
On average, quality and delivery performance remain the most stringently employed supplier selection criteria. Microcomponents (MPUs, among others) was the only category of product where pricing was a serious contender as a selection criteria. This perception is probably because of the relative higher prices of these parts and the limiting sourcing options in some cases.

Quality performance across the board was clearly a prerequisite to doing business. All four surveyed product areas had average minimum acceptable quality levels of about 60 ppm. The higher volume businesses such as PCs required even more restrictive quality performance.

The high ranking of delivery performance, especially in ASICs, seemed to underscore the importance of timing in today's global market. With product life cycles running under two years in many some volume segments, even a week slippage can hurt an OEM's market positioning.

Approved supplier lists are slated to shrink next year for almost all industries, for all semiconductor products. OEMs on average maintained eight microcomponent, six standard logic and analog suppliers, five ASIC, and five memory suppliers during 1992. High-volume users tended to keep the number smaller, whereas military/aerospace users had nearly double the amount in some cases.

Figure 5-1
Memory IC Supplier Selection Criteria: Overall

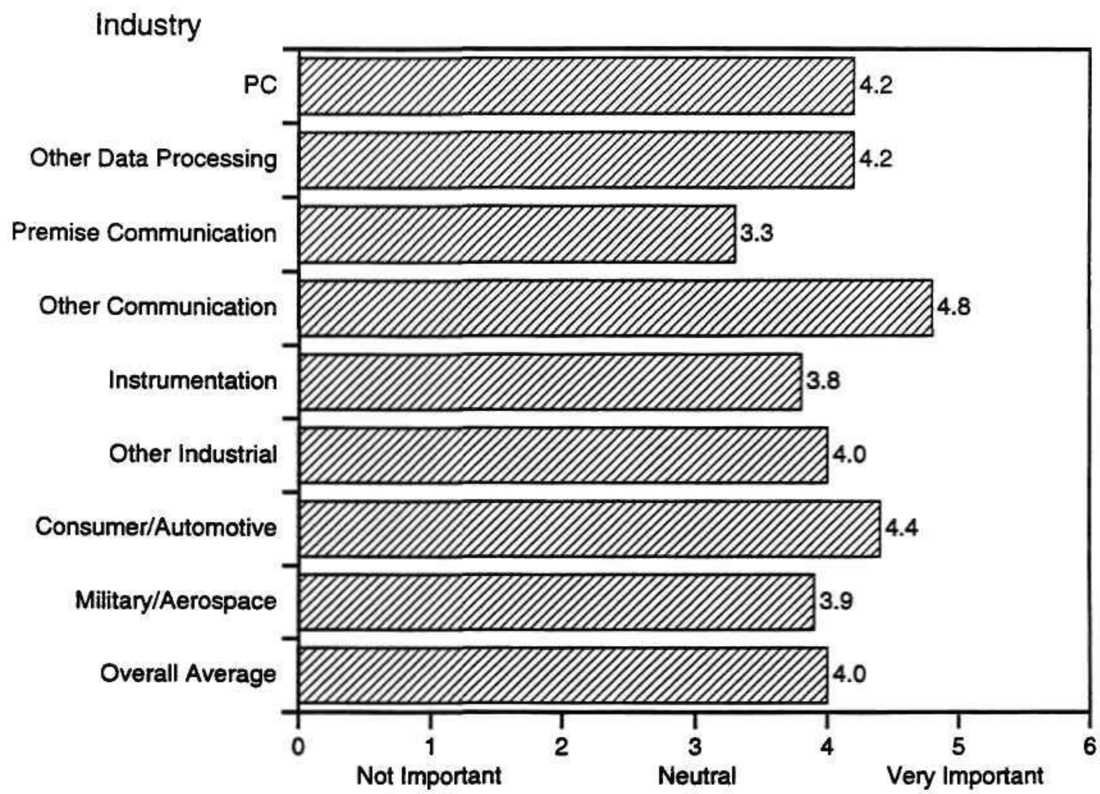


Source: Dataquest (December 1992)

G2001404

- *Quality and delivery performance are the top criteria when it comes to selecting a memory supplier. This is a surprising result given the extreme cost sensitivity of areas such as PCs and consumer electronics during their recent profitability slump.*
- *Quality and pricing are most likely prerequisite factors, whereas delivery has become more of a defining issue.*

Figure 5-2
Memory IC Supplier Selection Criteria: Pricing Consistency

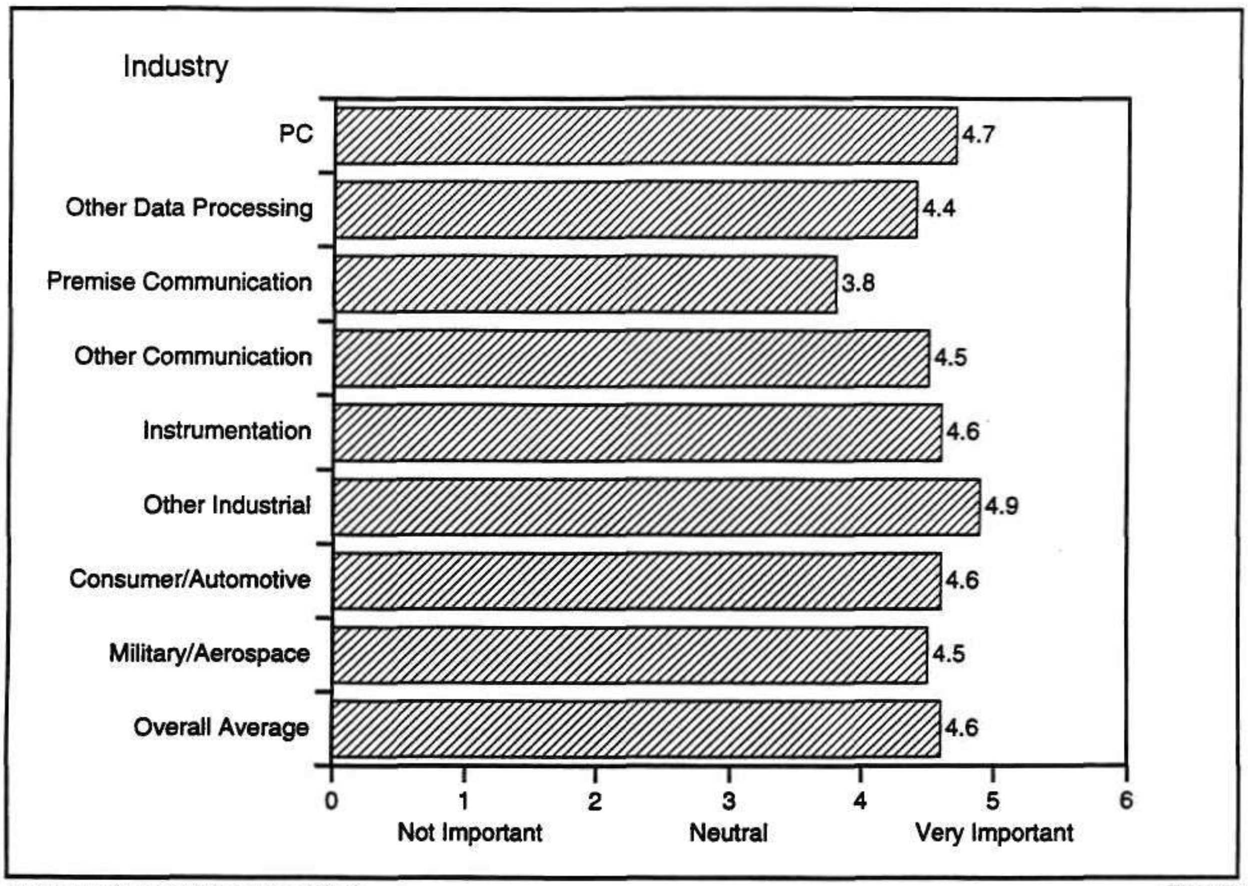


Source: Dataquest (December 1992)

G2001405

With the exception of the communication categories, pricing consistency is fairly level in relative importance across industries.

Figure 5-3
Memory IC Supplier Selection Criteria: Delivery Performance

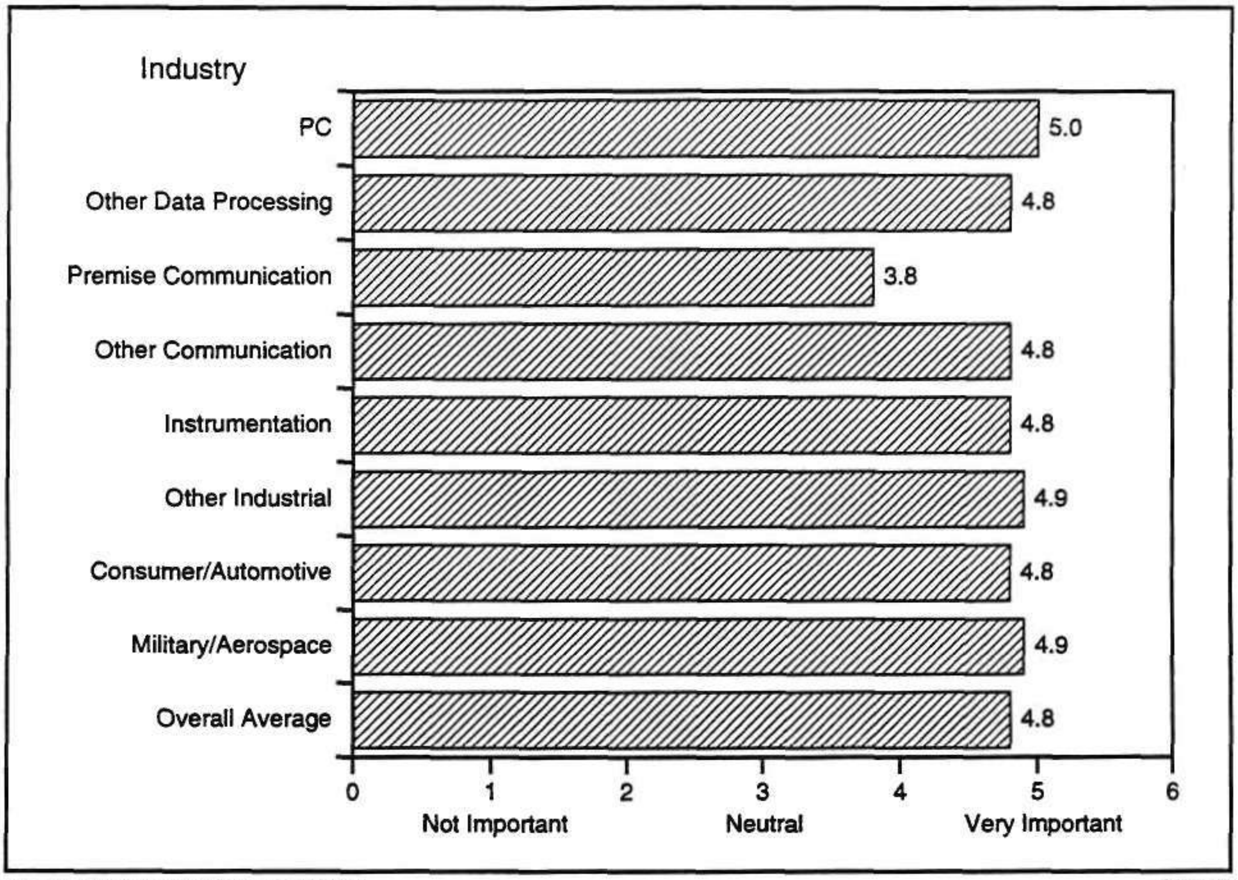


Source: Dataquest (December 1992)

G2001406

Just-in-time delivery has become a true competitive weapon as OEMs depend on it for not only cost management but to ensure quick time to market for their products.

Figure 5-4
Memory IC Supplier Selection Criteria: Quality Performance

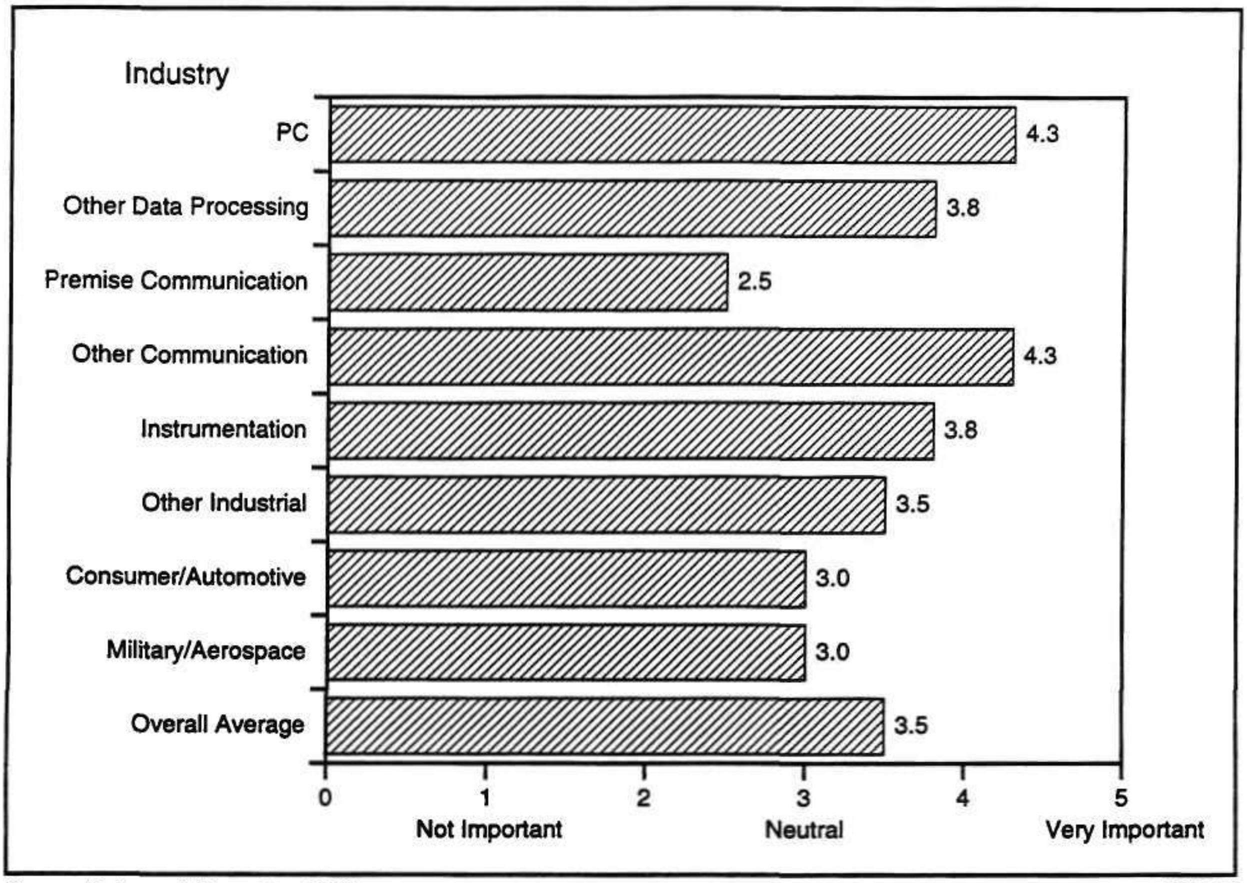


Source: Dataquest (December 1992)

G2001407

Superior quality is clearly a prerequisite before any business can take place.

Figure 5-5
Memory IC Supplier Selection Criteria: Market Flexibility

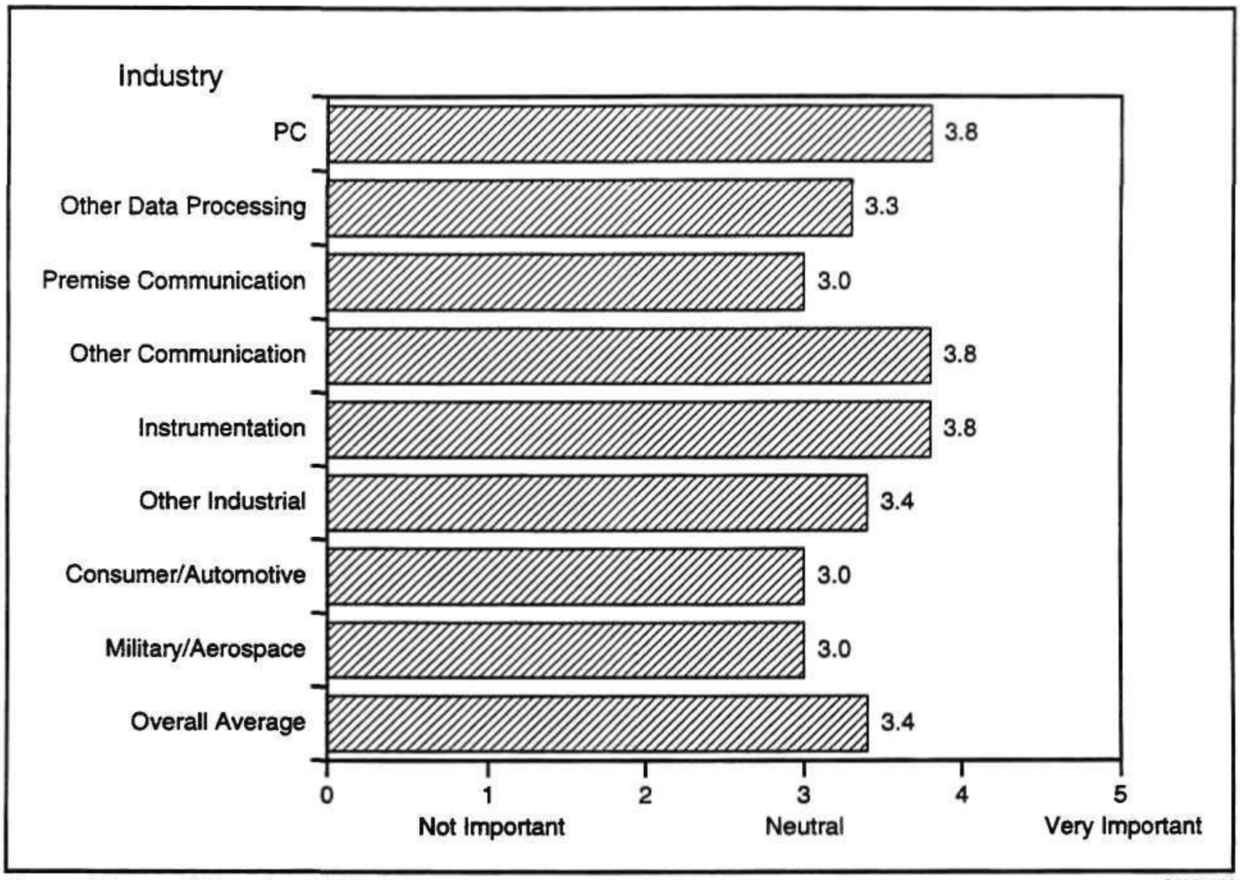


Source: Dataquest (December 1992)

G2001408

This is less of an issue because memory suppliers remain bountiful, and multiple suppliers can be substituted for most parts.

Figure 5-6
Memory IC Supplier Selection Criteria: Product Portfolio and Migration Path

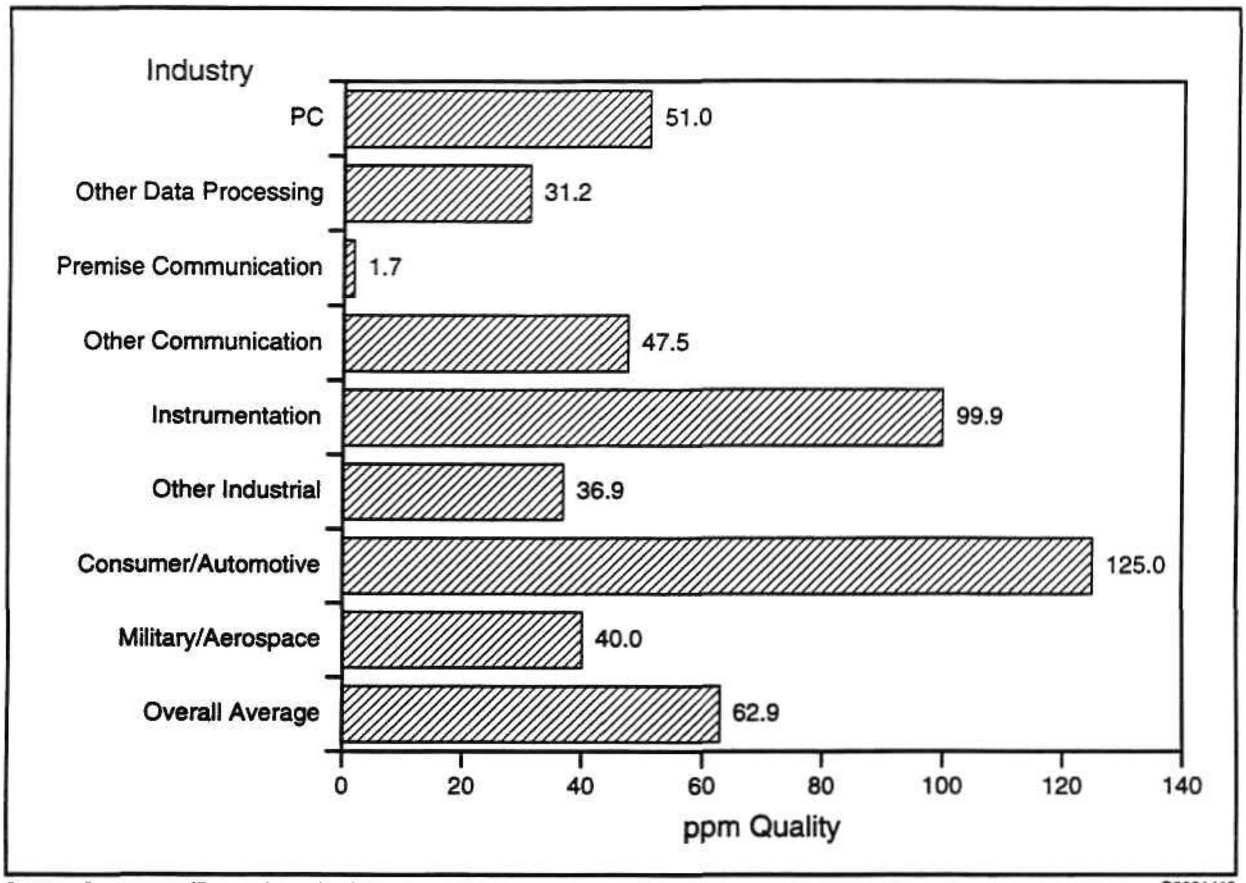


Source: Dataquest (December 1992)

G2001409

The somewhat predictable nature of memory product improvements (for example, denser and faster) make this less of an issue.

Figure 5-7
Minimum Necessary Quality for Memory ICs (ppm)

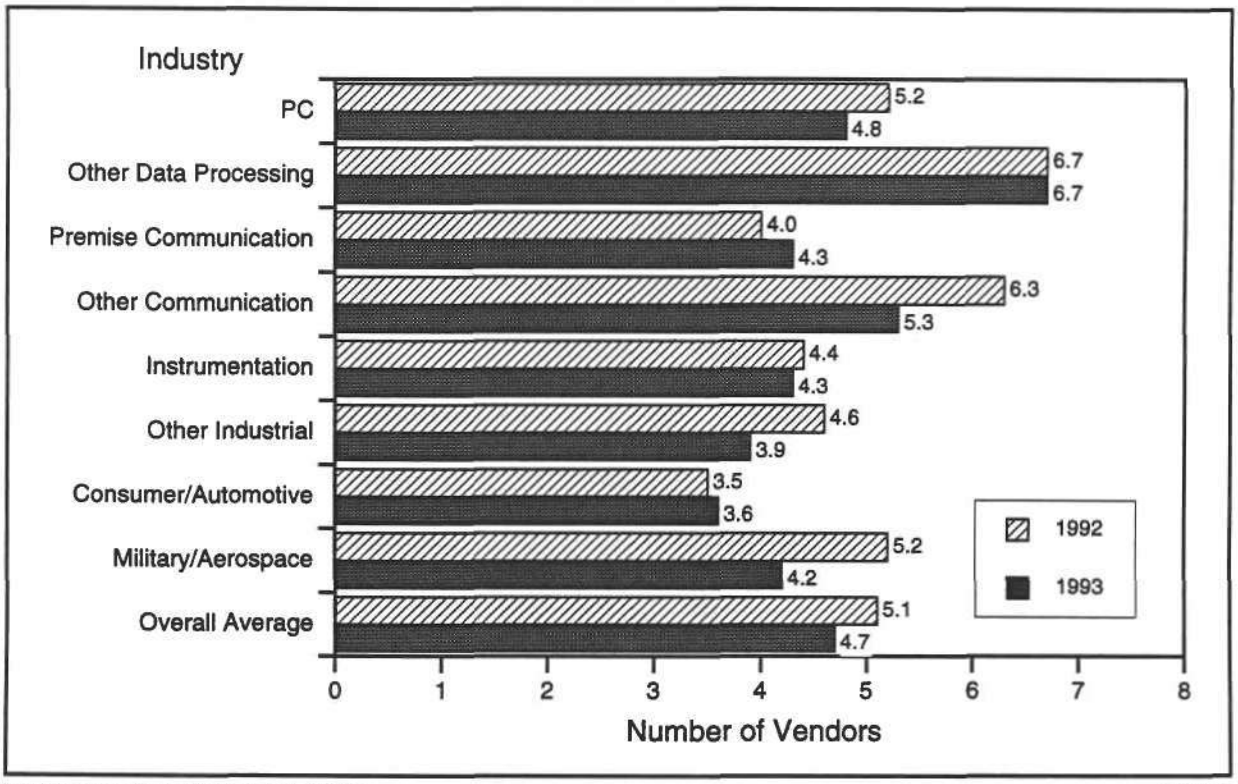


Source: Dataquest (December 1992)

G2001410

Buyers for memory-intensive products such as computers and laser printers appear to desire stricter quality standards than the average.

Figure 5-8
Number of Memory IC Suppliers

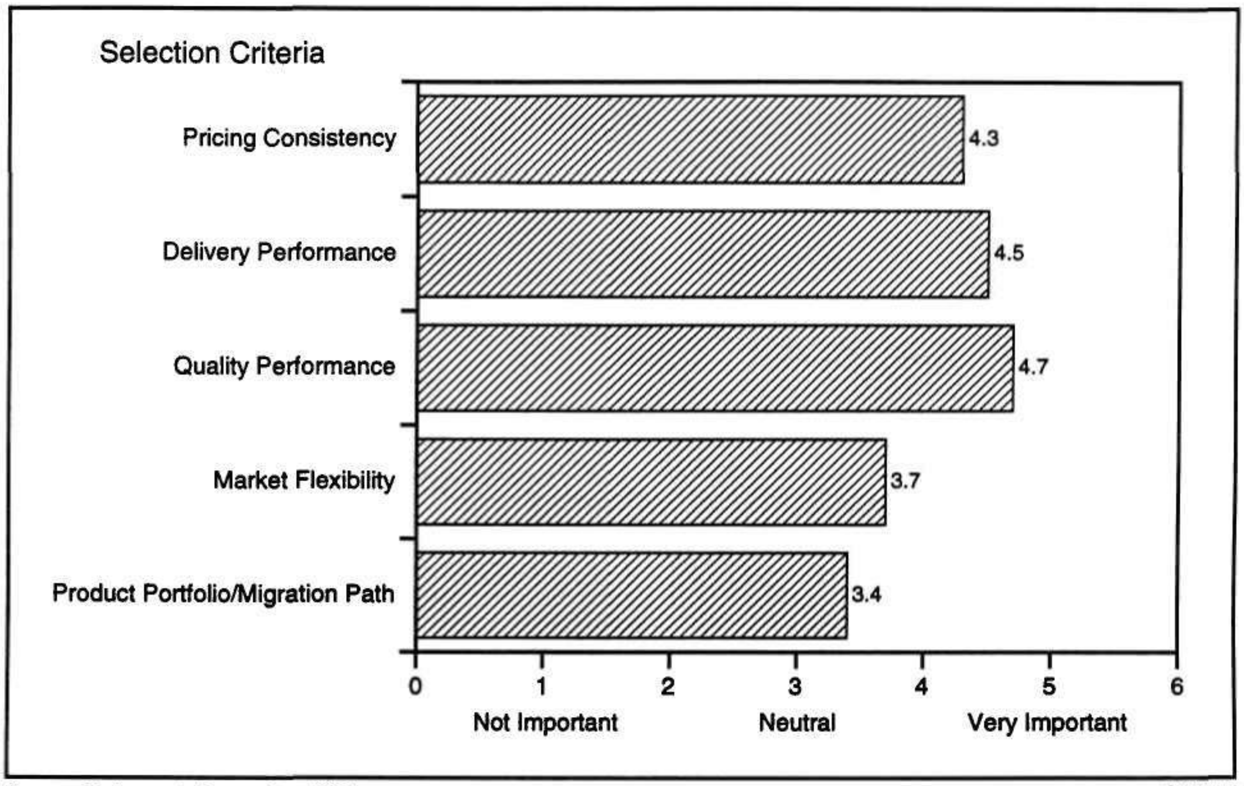


Source: Dataquest (December 1992)

G2001411

On average memory buyers maintained about five separate memory suppliers in 1992, with plans to reduce that number in 1993.

Figure 5-9
Microcomponent IC Supplier Selection Criteria: Overall

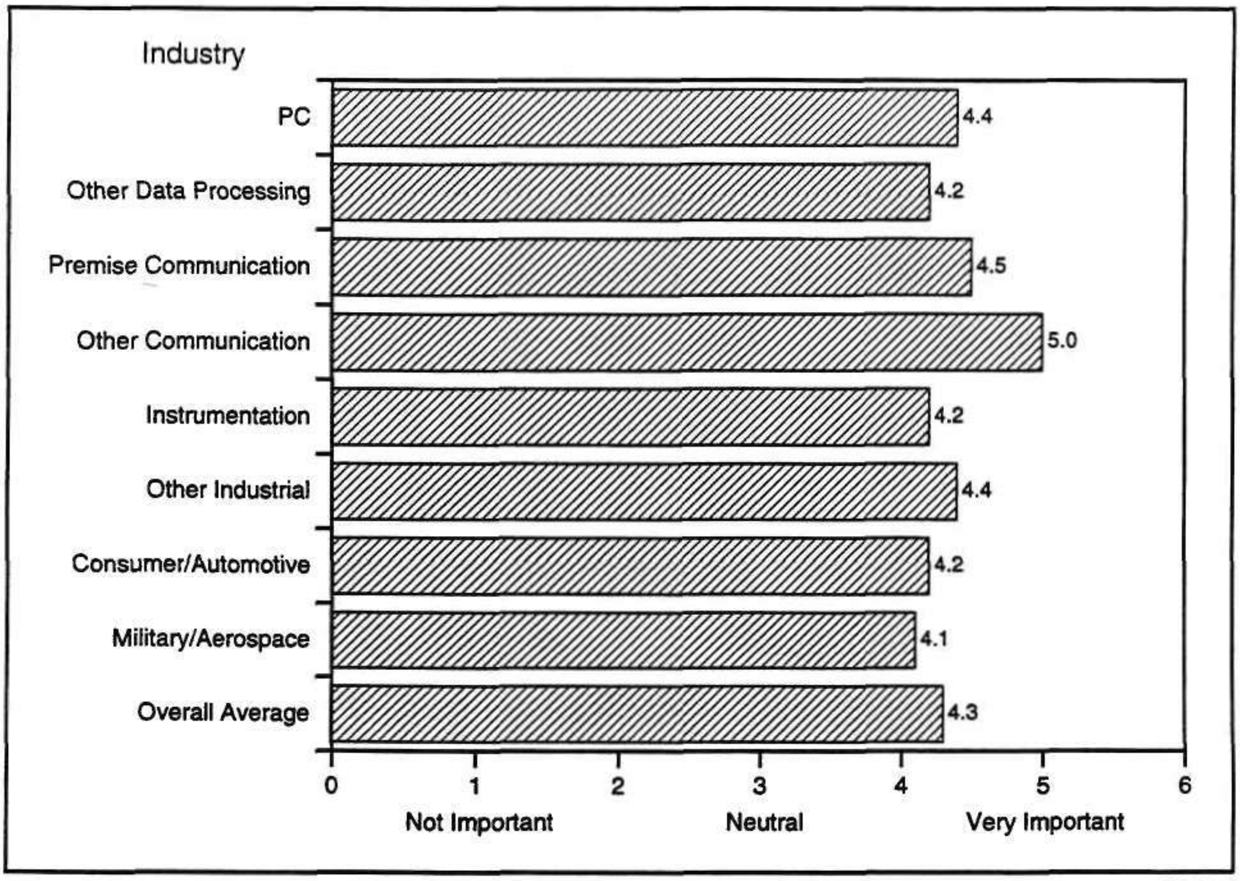


Source: Dataquest (December 1992)

G2001412

Quality and delivery performance are also the top criteria, with pricing, however, being more of a consideration than in other product areas.

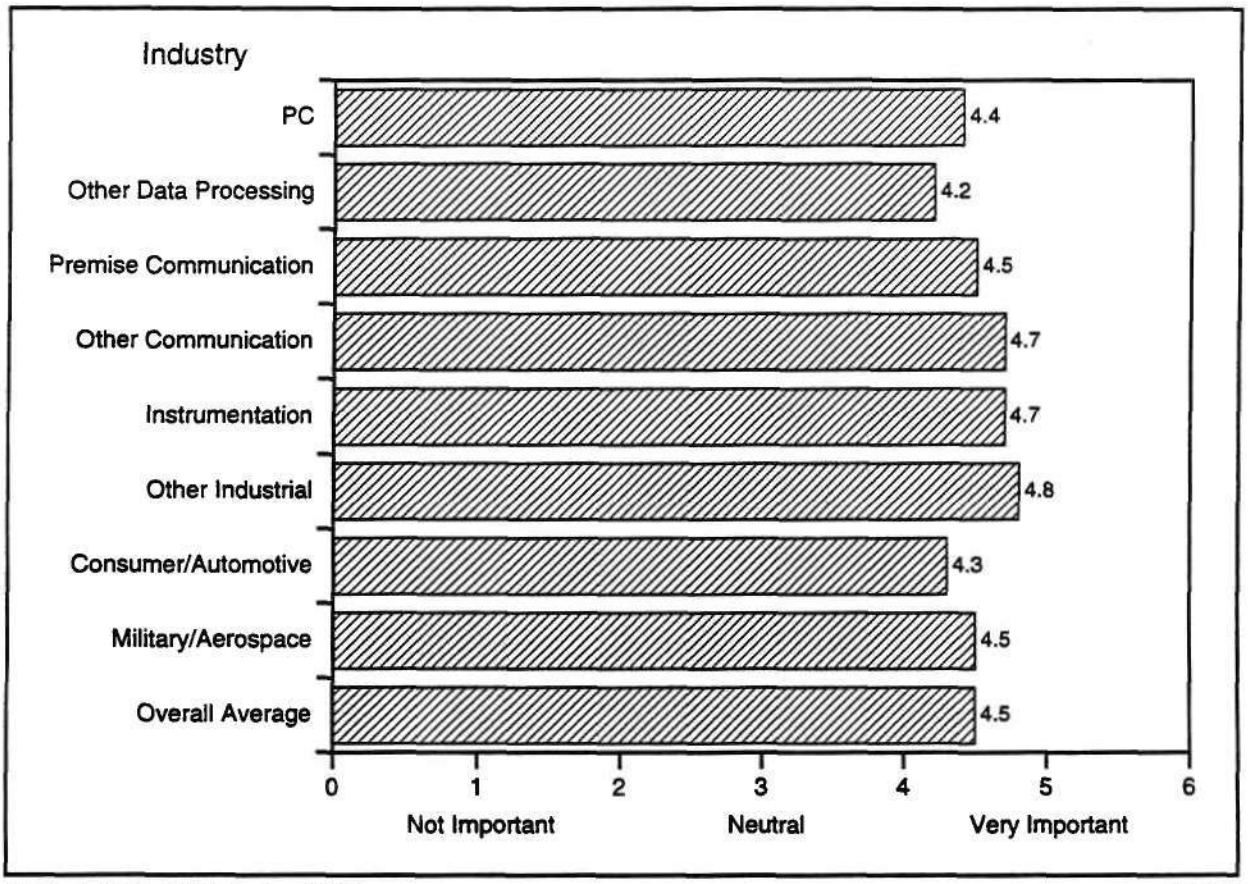
Figure 5-10
Microcomponent IC Supplier Selection Criteria: Pricing Consistency



Source: Dataquest (December 1992) G2001413

With the exception of the communication categories, pricing consistency is fairly level in relative importance across industries.

Figure 5-11
Microcomponent IC Supplier Selection Criteria: Delivery Performance

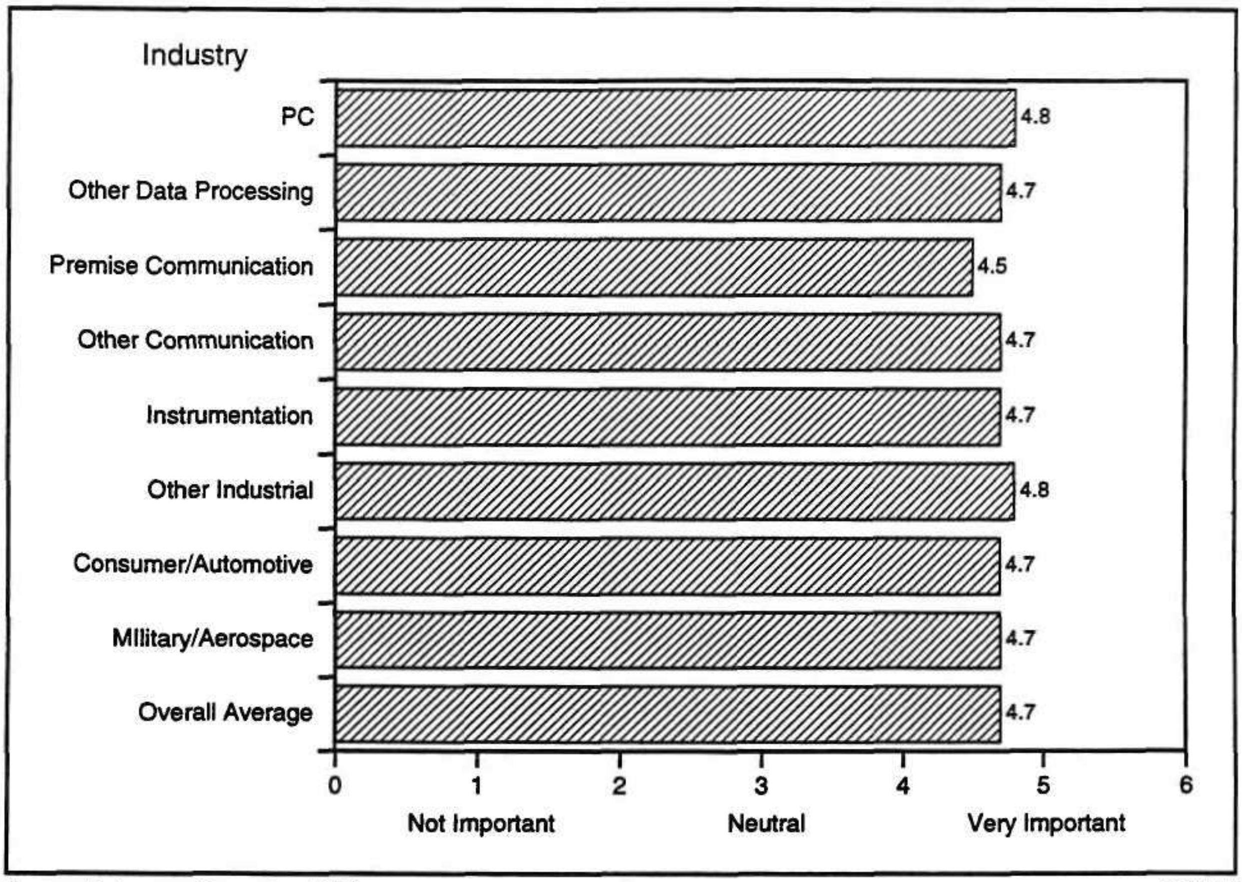


Source: Dataquest (December 1992)

G2001414

Apparently delivery is an important issue for the more fragmented industrial/instrumentation industries.

Figure 5-12
Microcomponent IC Supplier Selection Criteria: Quality Performance

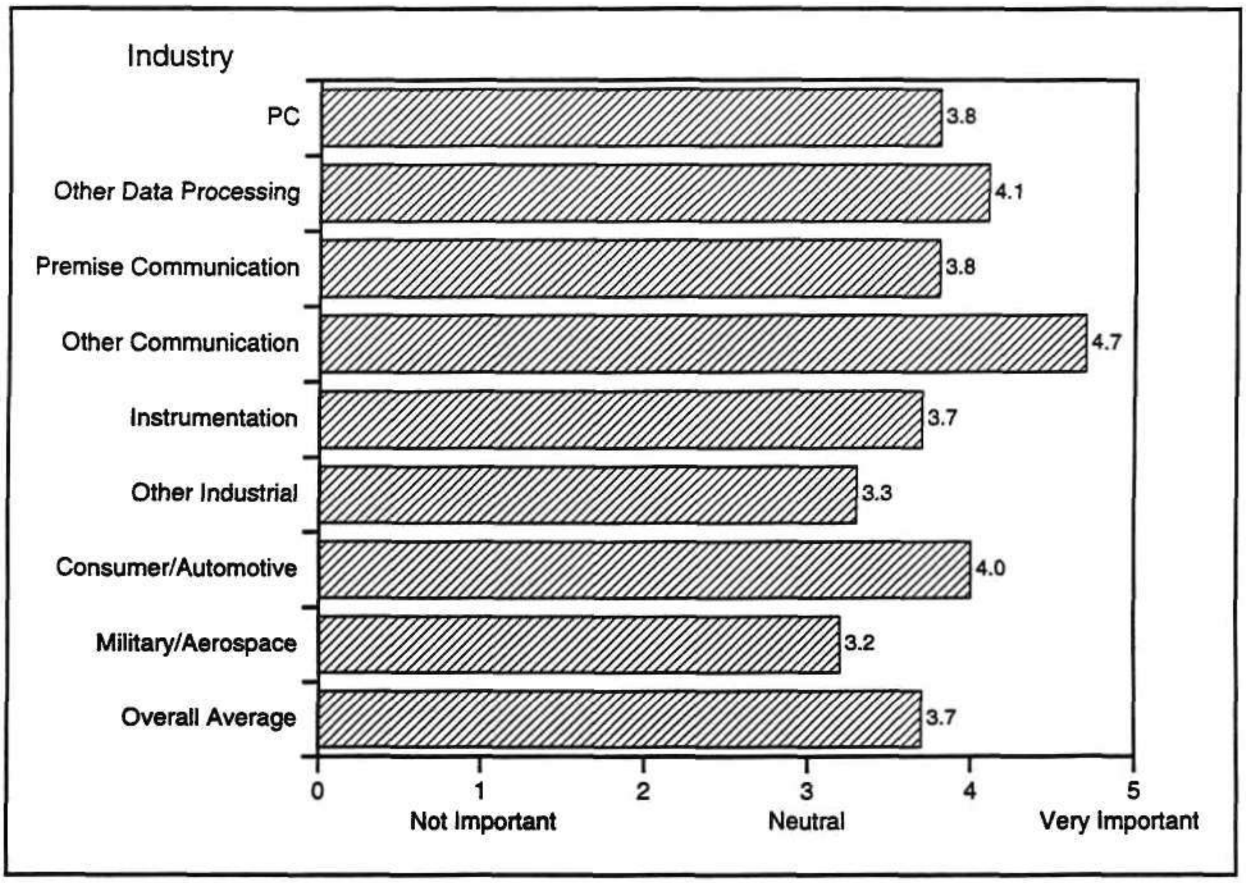


Source: Dataquest (December 1992)

G2001415

Superior quality is clearly a prerequisite before any business can take place.

Figure 5-13
Microcomponent IC Supplier Selection Criteria: Market Flexibility

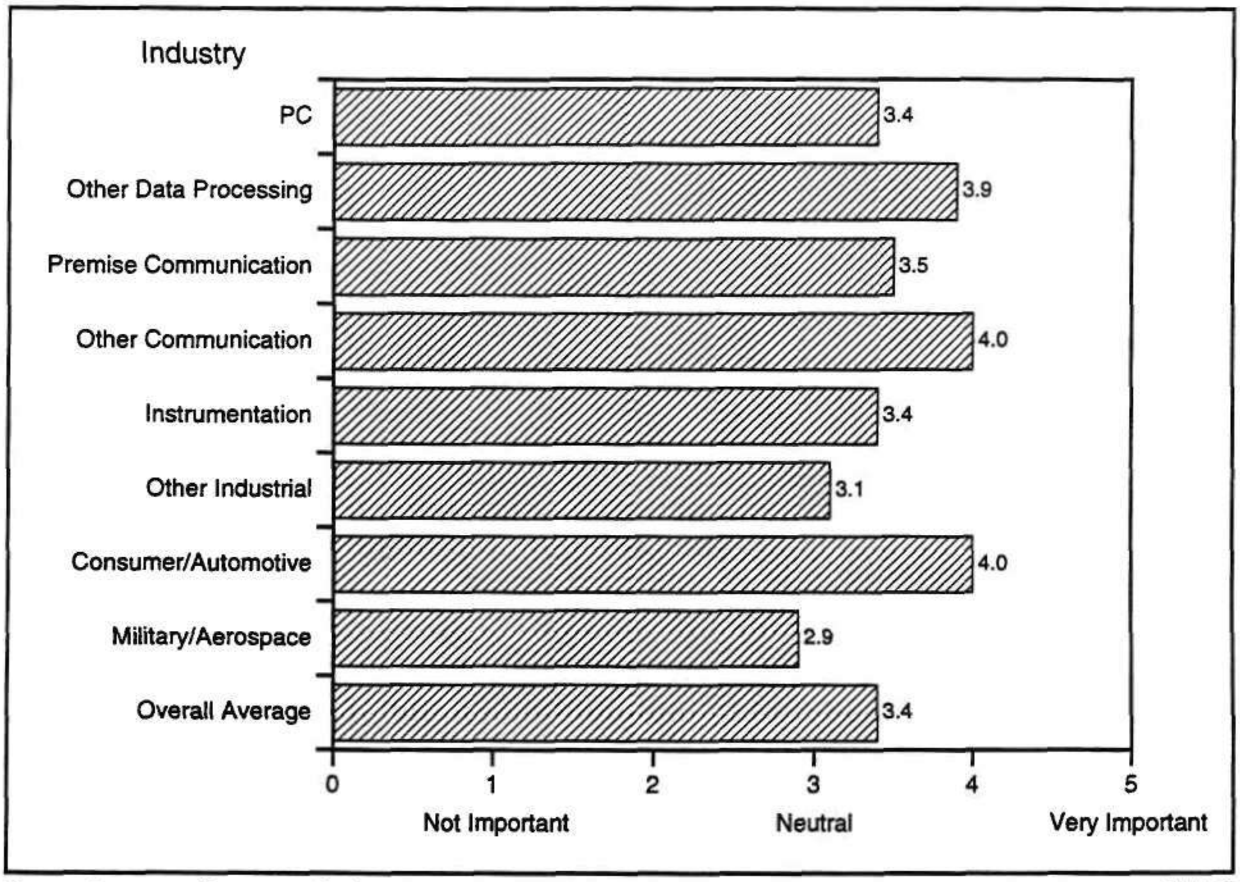


Source: Dataquest (December 1992)

G2001416

Data processing, communication, and consumer/automotive desire the most flexibility because their markets remain subject to substantial fluctuations.

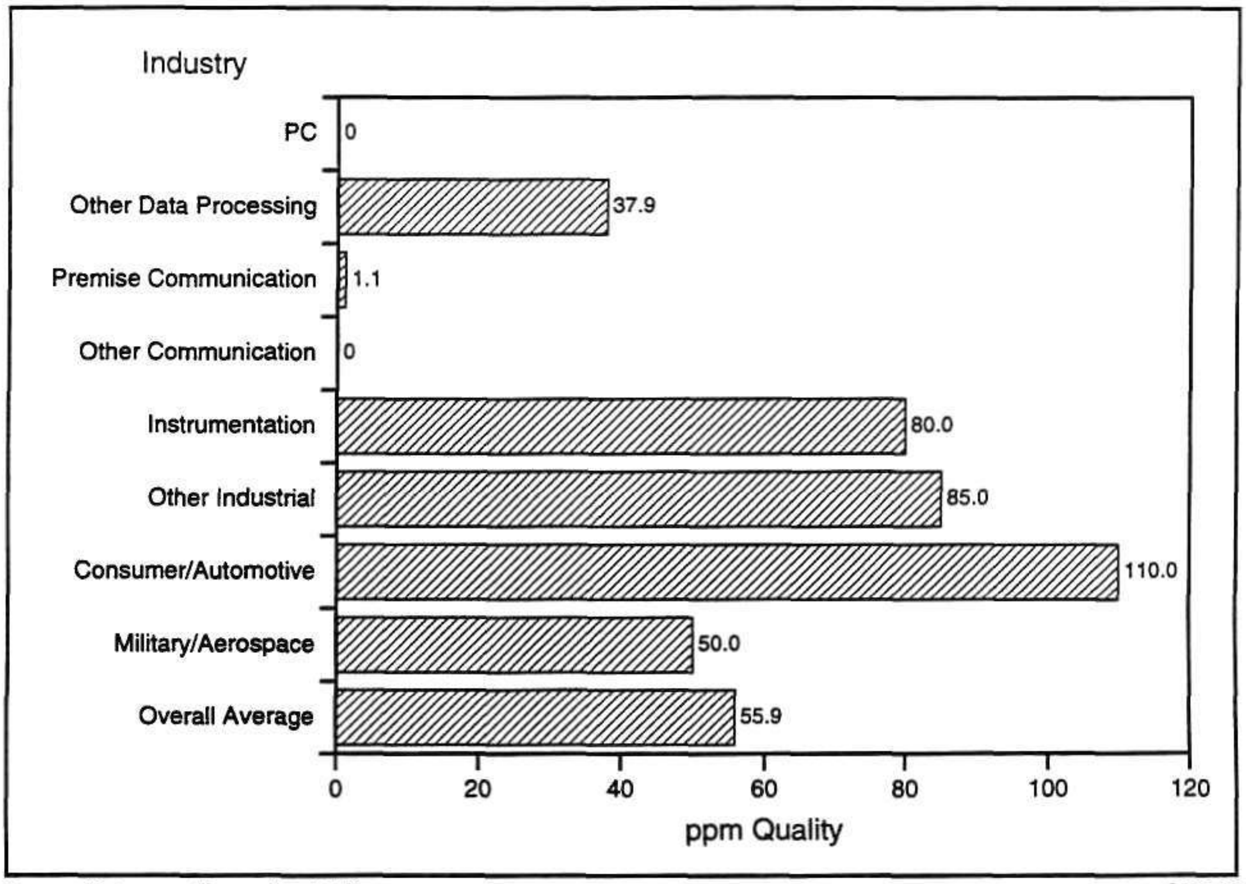
Figure 5-14
Microcomponent IC Supplier Selection Criteria: Product Portfolio and Migration Path



Source: Dataquest (December 1992) G2001417

This criterion is not much of a concern, except with performance-sensitive computer and communications OEMs.

Figure 5-15
Minimum Necessary Quality for Microcomponent ICs (ppm)

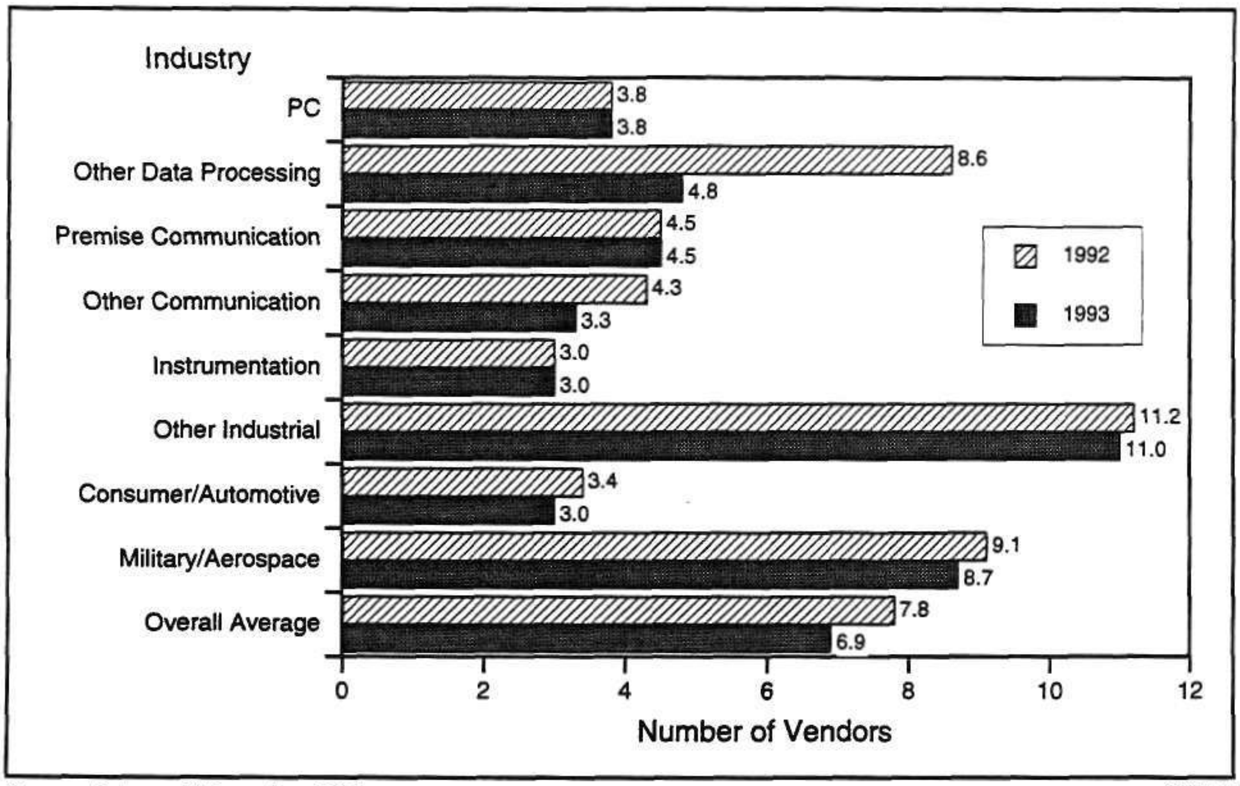


Source: Dataquest (December 1992)

G2001418

Probably because of ship-to-stock setups to reduce costs and improve time-to-market, the PC industry requires near perfect quality.

Figure 5-16
Number of Microcomponent IC Suppliers

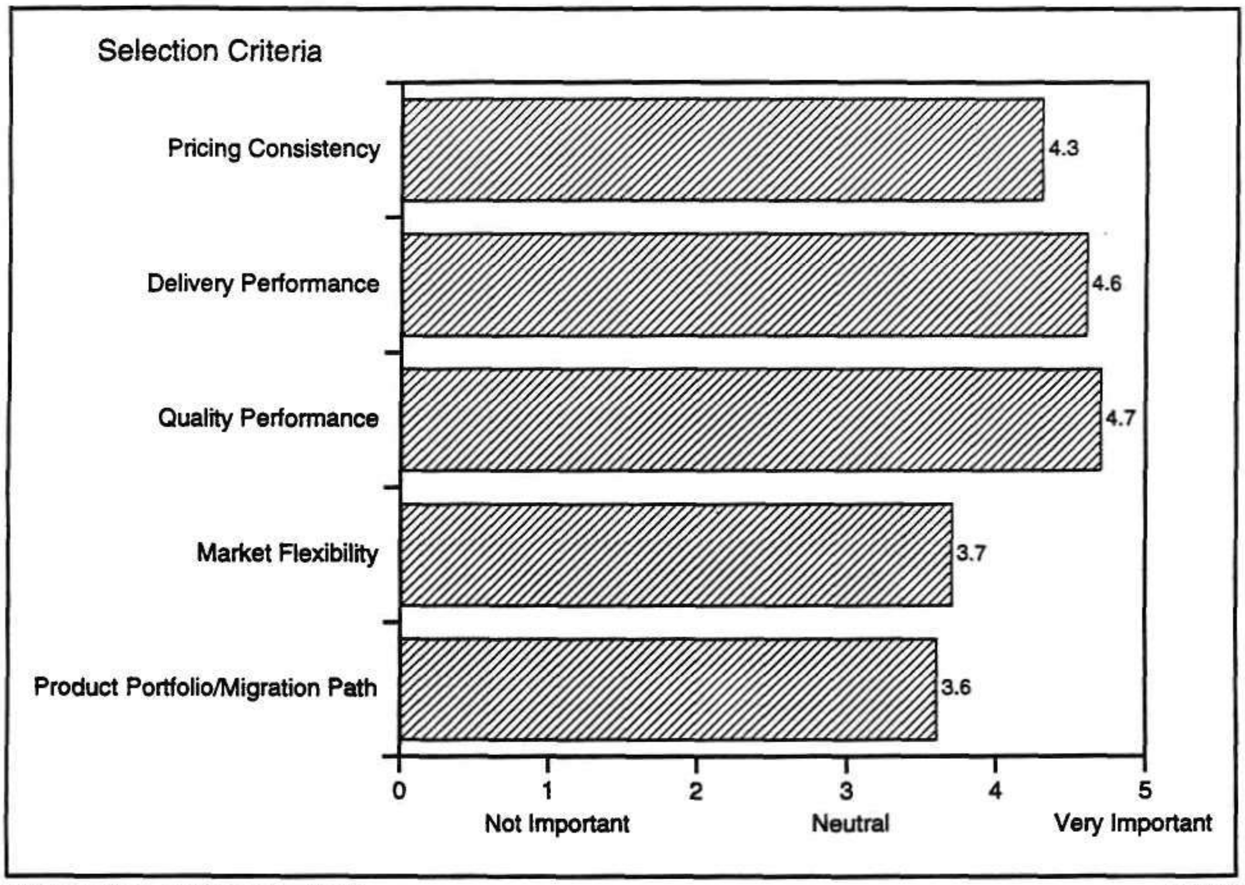


Source: Dataquest (December 1992)

G2001419

On average, microcomponent buyers maintained about eight separate suppliers in 1992, with plans to reduce that number in 1993 to seven.

Figure 5-17
ASIC IC Supplier Selection Criteria: Overall

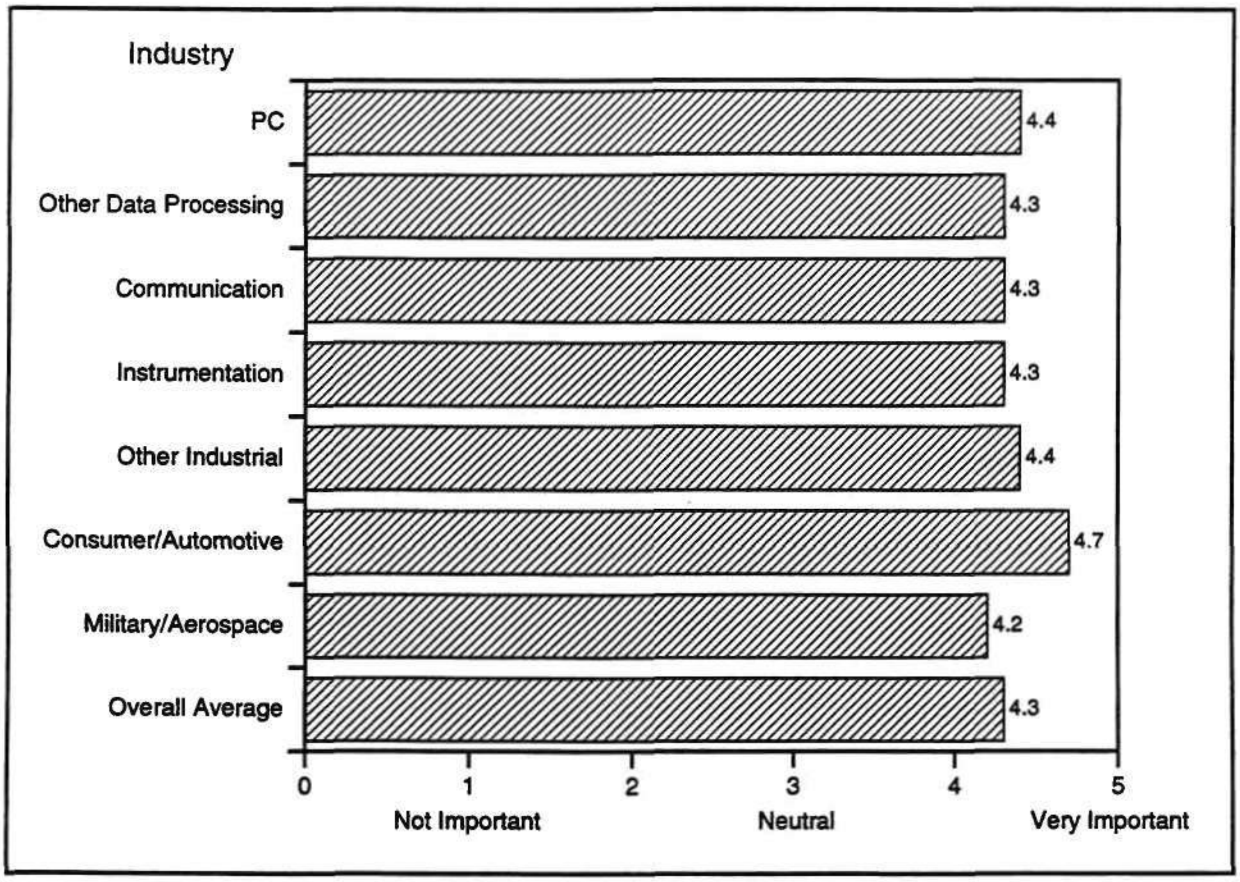


Source: Dataquest (December 1992)

G2001420

Delivery performance has risen in importance because ASICs and their prototypes remain a technology that OEMs need for getting to market quickly.

Figure 5-18
ASIC IC Supplier Selection Criteria: Pricing Consistency

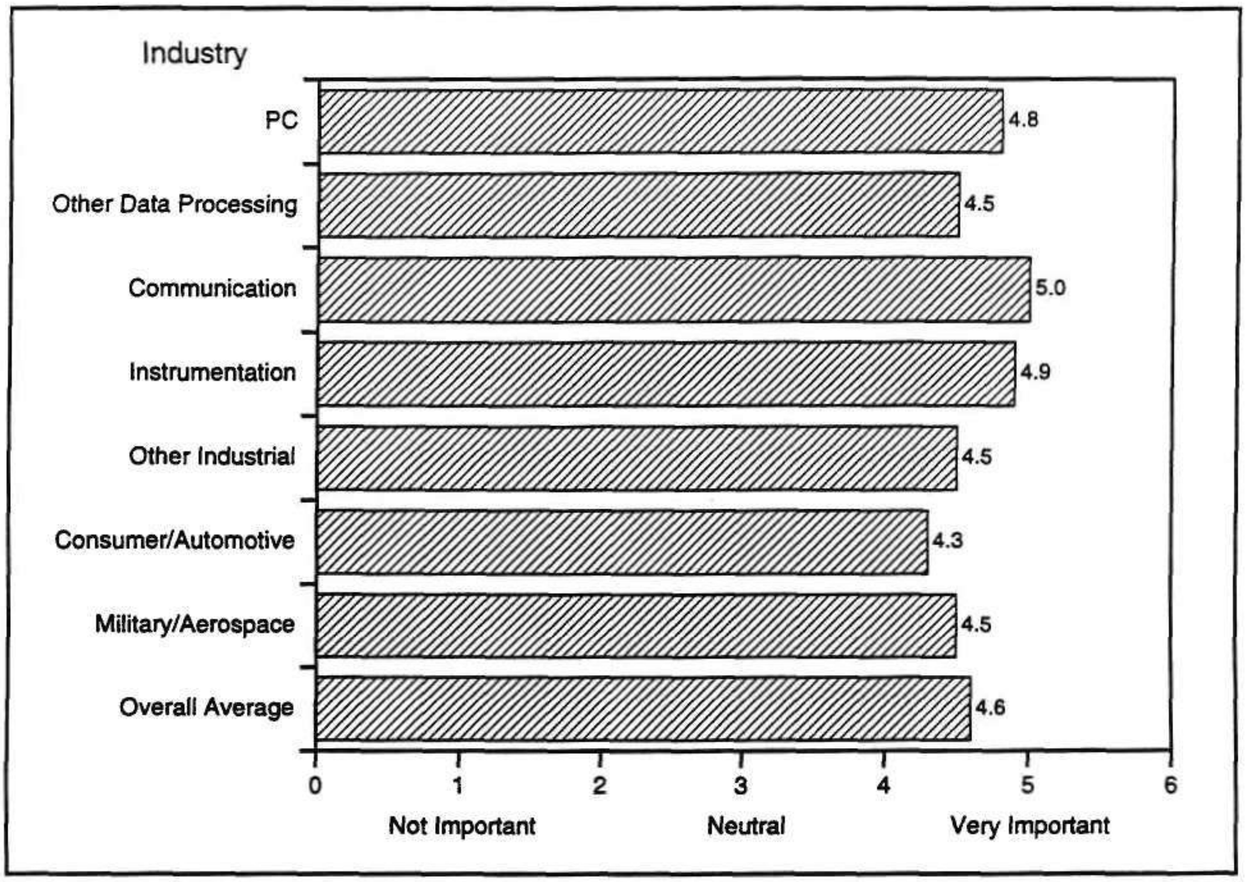


Source: Dataquest (December 1992)

G2001421

With the exception of the cost-sensitive consumer/automotive areas, pricing consistency is fairly level in relative importance across industries.

Figure 5-19
ASIC IC Supplier Selection Criteria: Delivery Performance

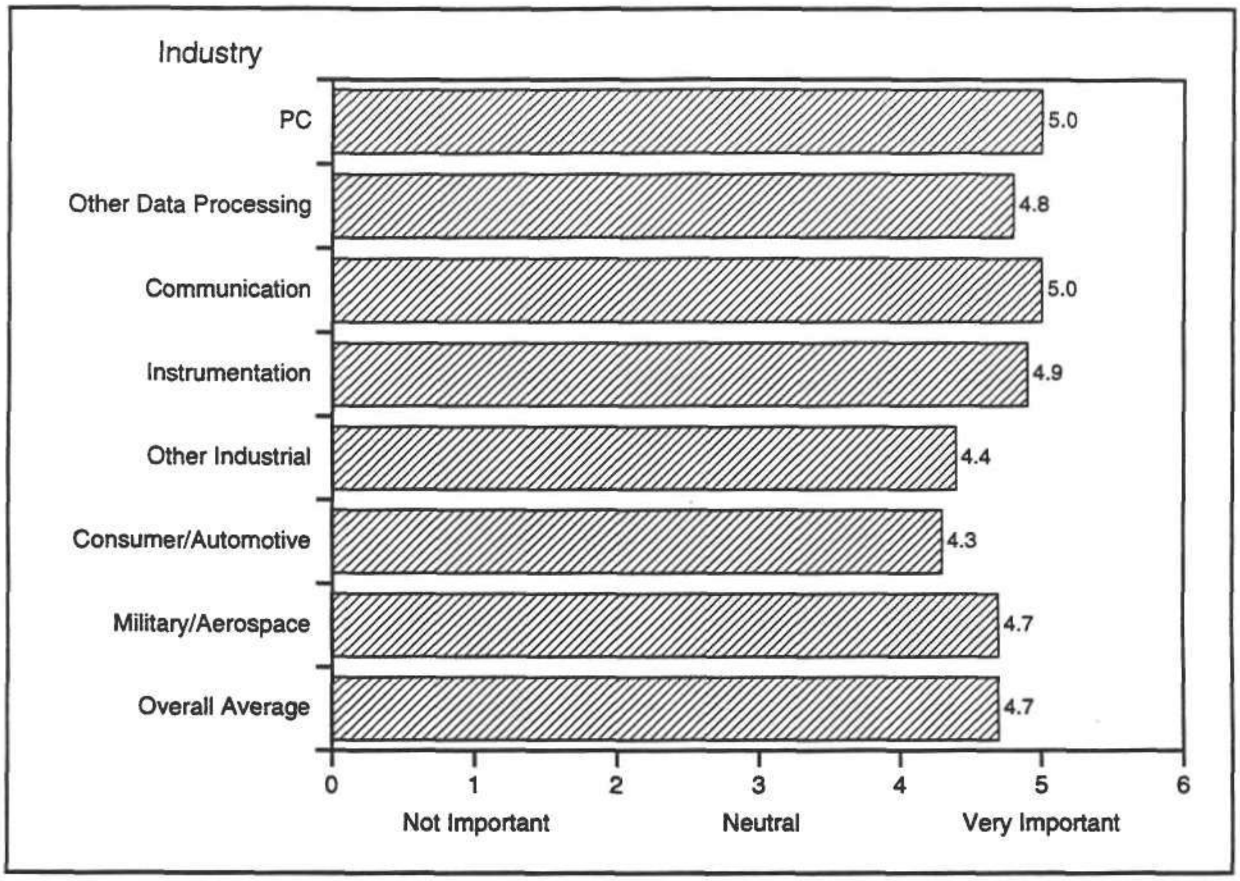


Source: Dataquest (December 1992)

G2001422

Although important to almost all industries, delivery performance is crucial to the communications industry, which is heavily dependent on customization and differentiation by using ASICs.

Figure 5-20
ASIC IC Supplier Selection Criteria: Quality Performance

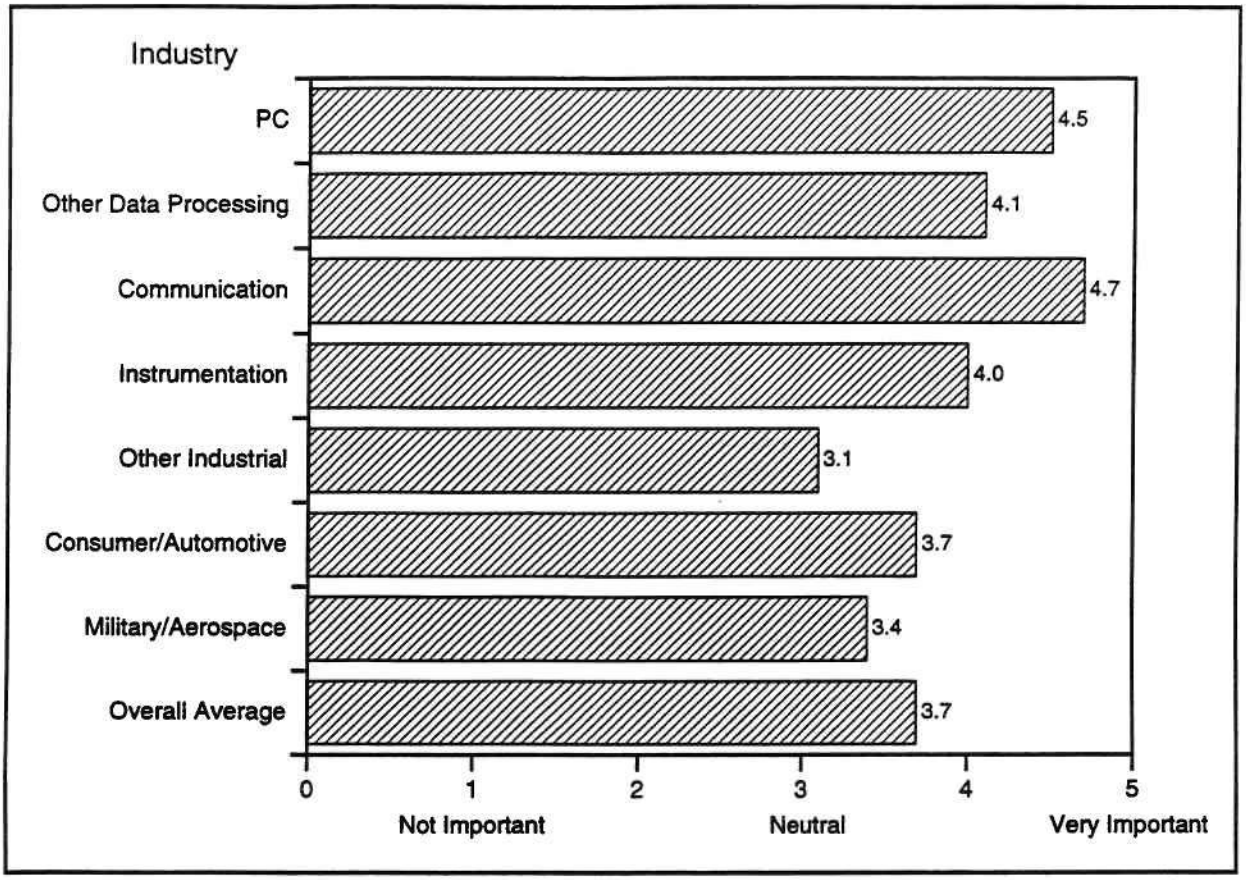


Source: Dataquest (December 1992)

G2001423

The semicustom and design-crucial nature of ASICs seems to shape expectations about quality and design fidelity.

Figure 5-21
ASIC IC Supplier Selection Criteria: Market Flexibility

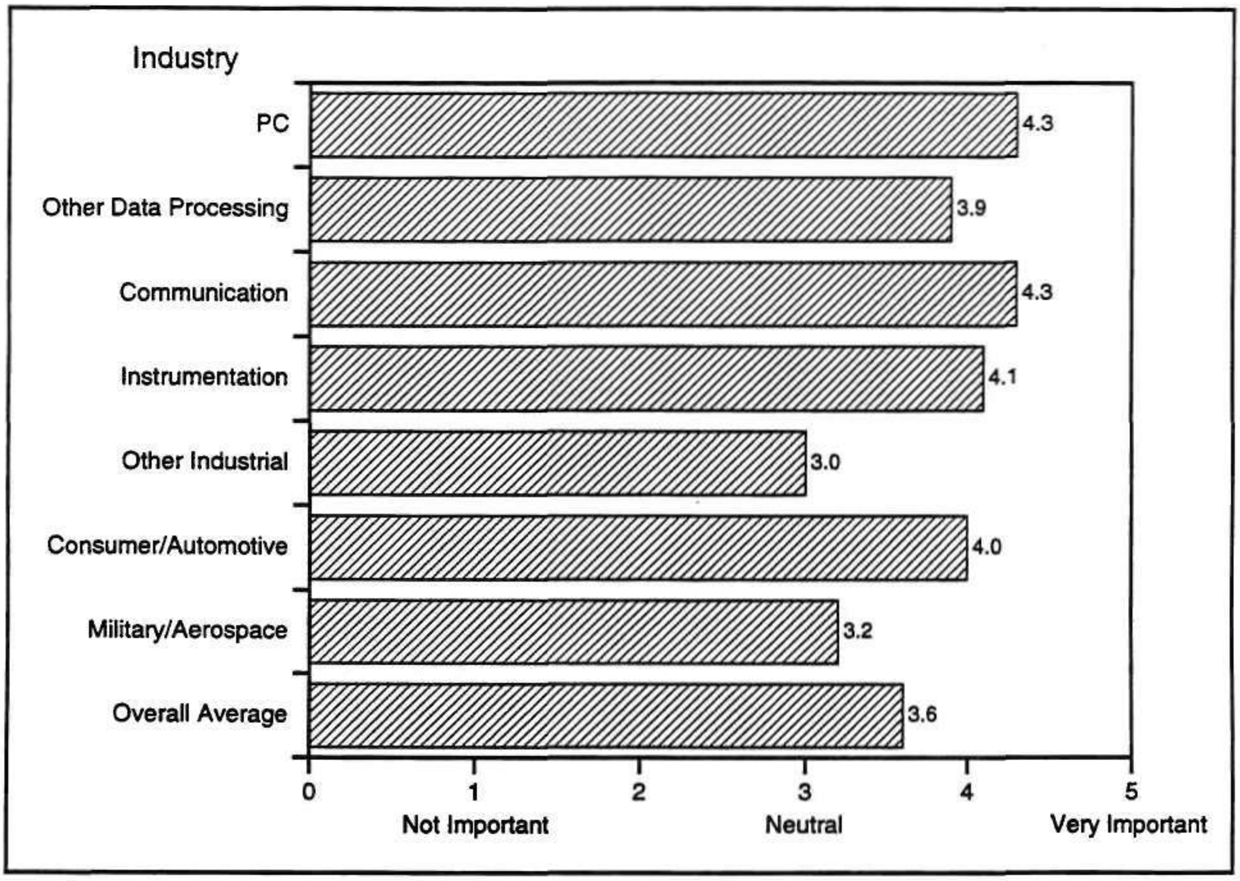


Source: Dataquest (December 1992)

G2001424

Communications and PC OEMs desire the most flexibility.

Figure 5-22
ASIC IC Supplier Selection Criteria: Product Portfolio and Migration Path

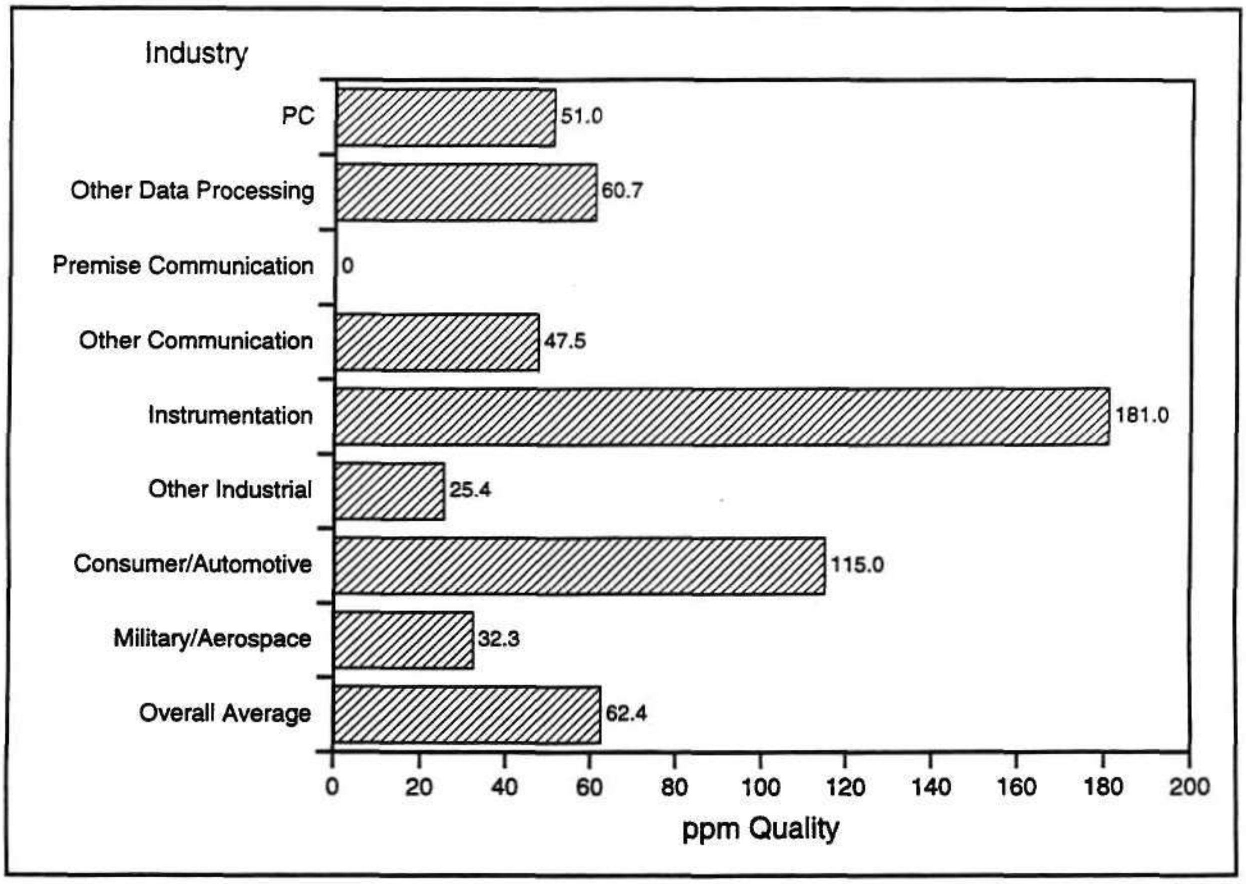


Source: Dataquest (December 1992)

G2001425

OEMs with performance-sensitive applications in computing and communication are concerned about supplier plans to update their ASIC process and design technologies.

Figure 5-23
Minimum Necessary Quality for ASICs (ppm)

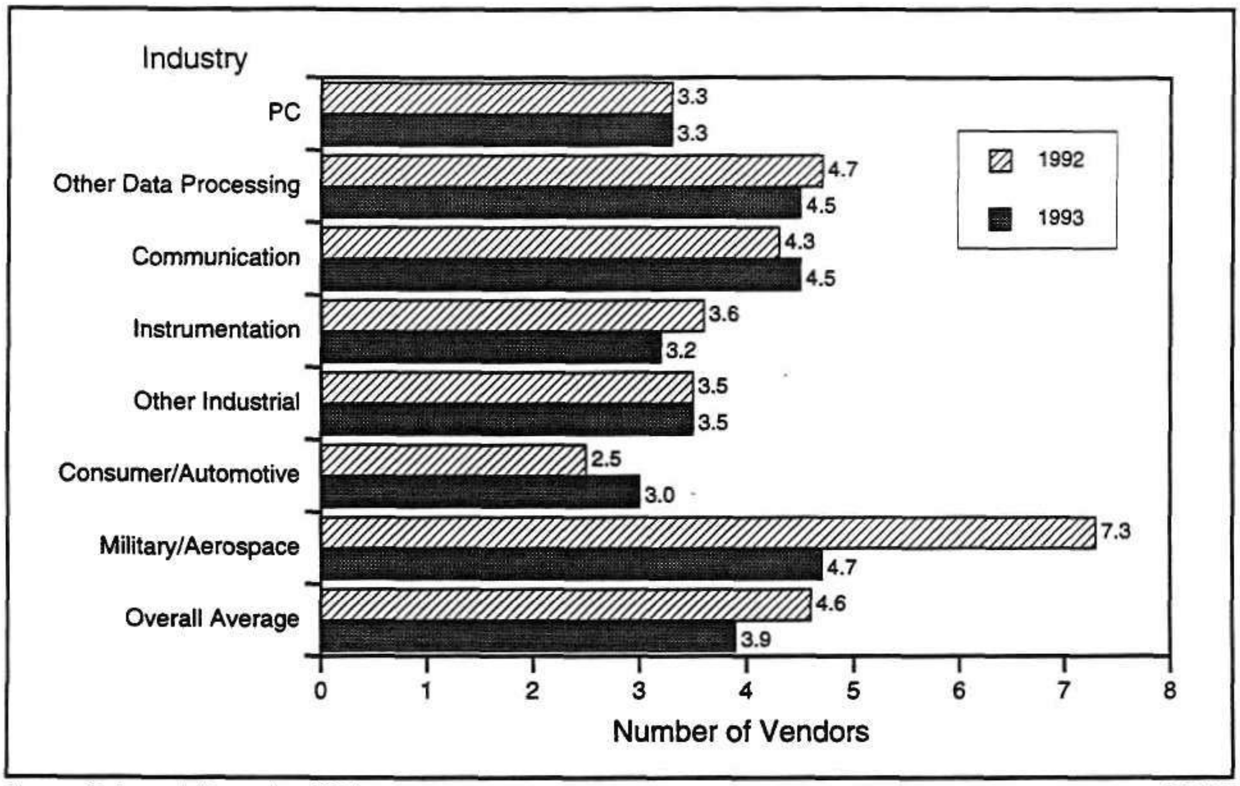


Source: Dataquest (December 1992)

G2001426

Higher-volume ASICs users such as computing and communications OEMs are requiring commensurate higher-quality levels.

Figure 5-24
Number of ASIC Suppliers

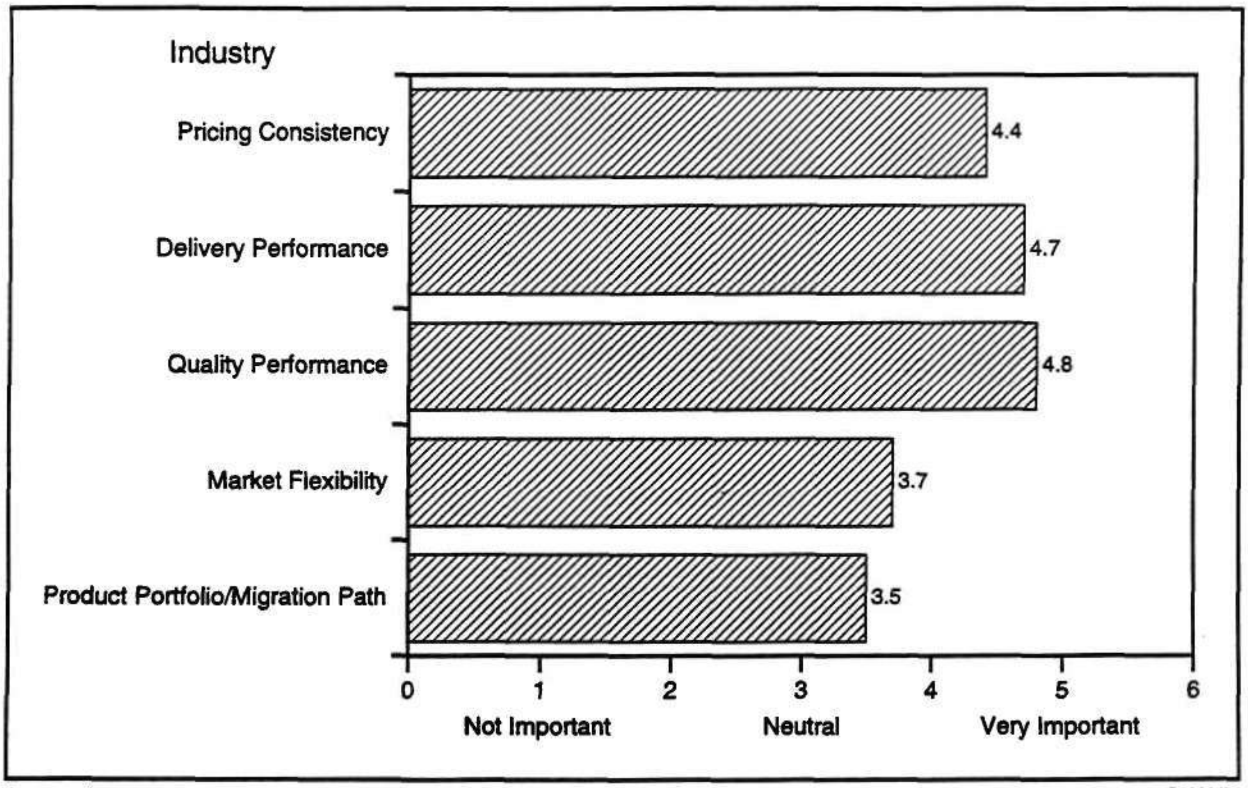


Source: Dataquest (December 1992)

G2001427

On average, ASIC buyers maintained about five separate suppliers in 1992, with plans to reduce that number in 1993 to four.

Figure 5-25
Standard Logic and Analog IC Supplier Selection Criteria: Overall

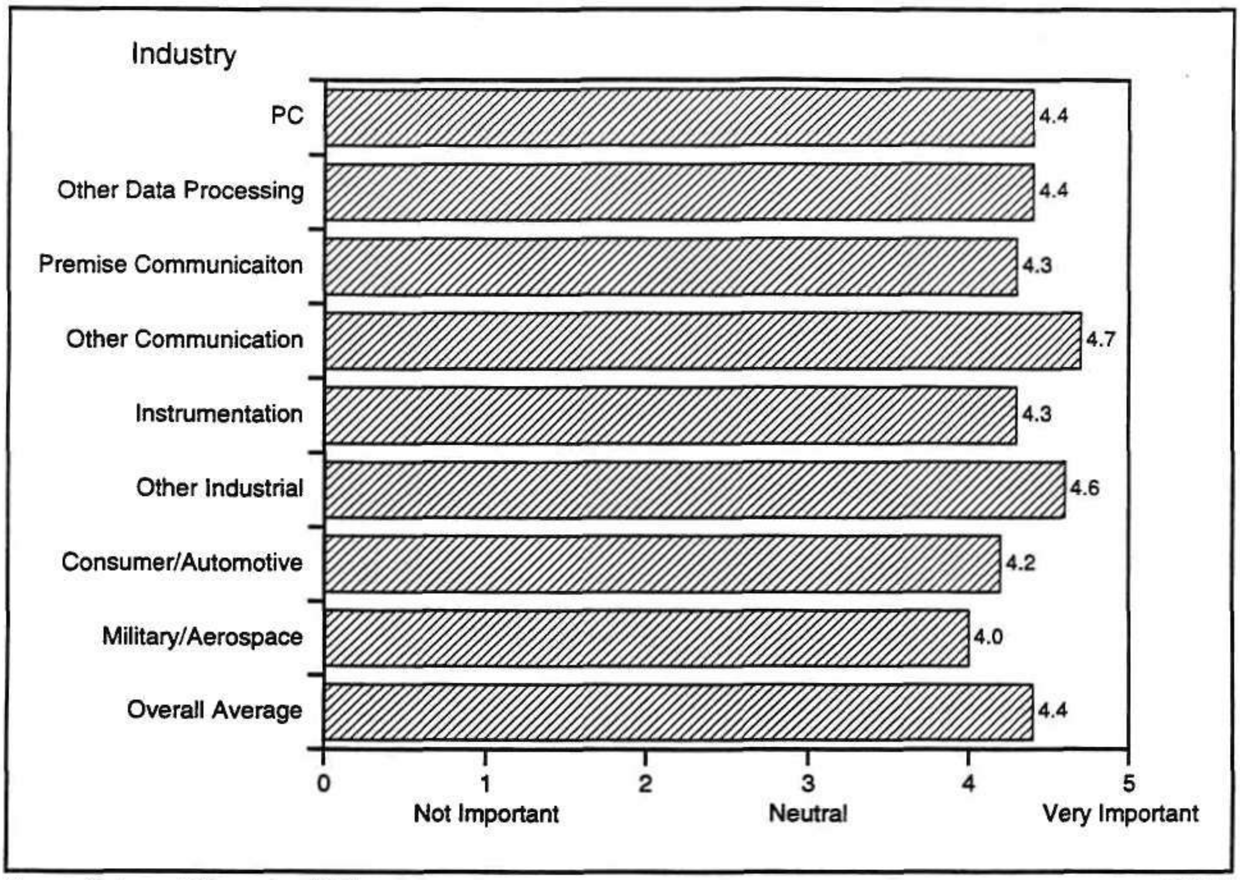


Source: Dataquest (December 1992)

G2001428

Delivery and quality performance share the spotlight in importance.

Figure 5-26
Standard Logic and Analog IC Supplier Selection Criteria: Pricing Consistency

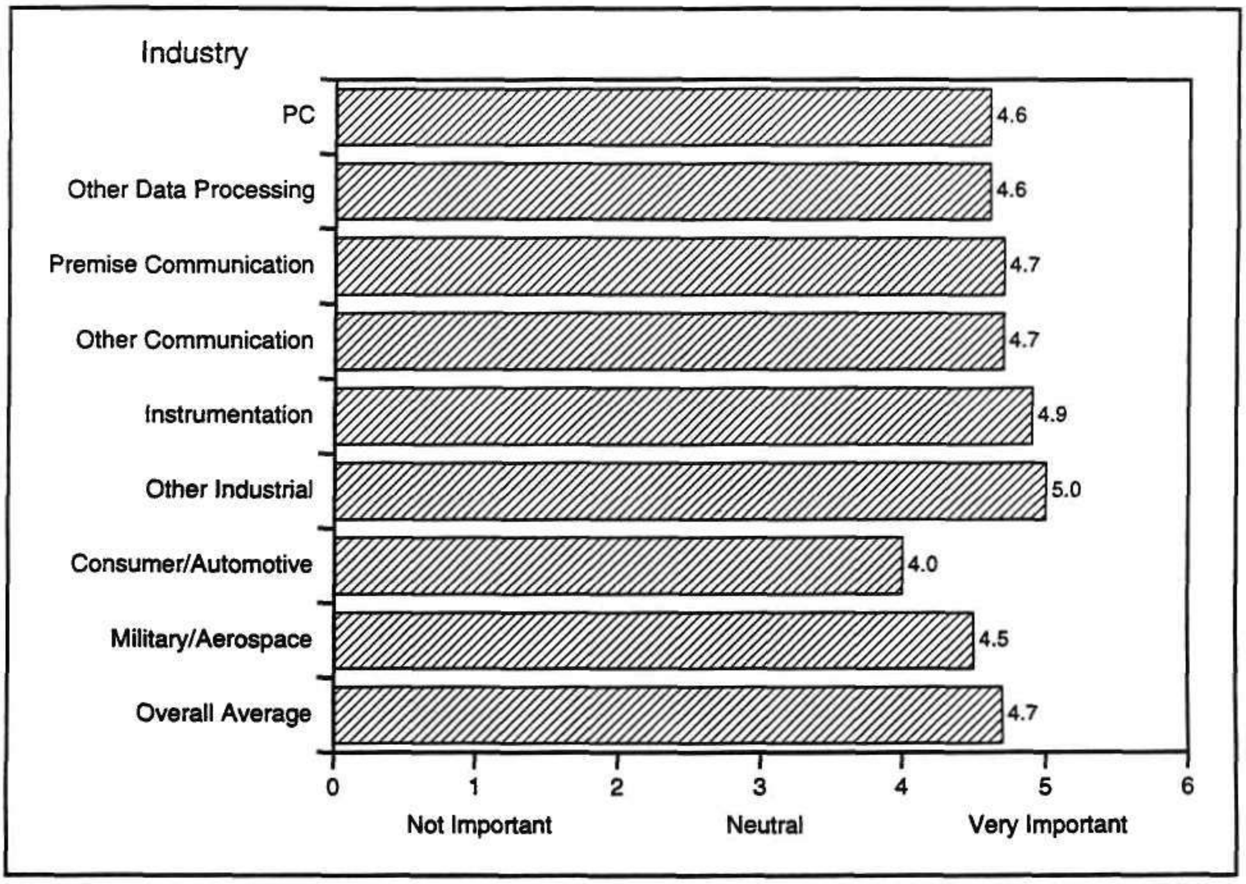


Source: Dataquest (December 1992)

G2001429

Analog-intensive categories such as communication and industrial are more sensitive to pricing issues.

Figure 5-27
Standard Logic and Analog IC Supplier Selection Criteria: Delivery Performance

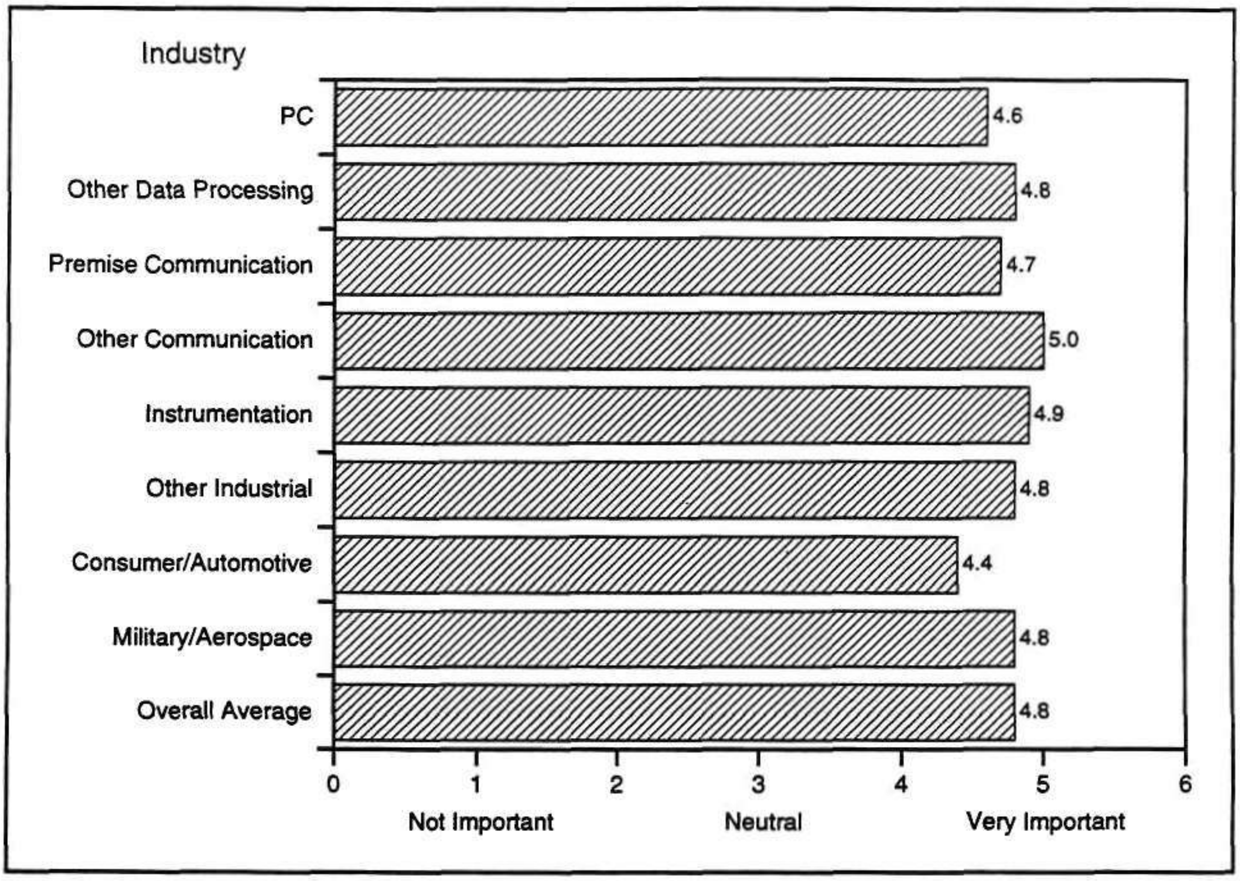


Source: Dataquest (December 1992)

G2001430

As with pricing, analog-intensive applications such as communication and industrial are more sensitive to delivery issues.

Figure 5-28
Standard Logic and Analog IC Supplier Selection Criteria: Quality Performance

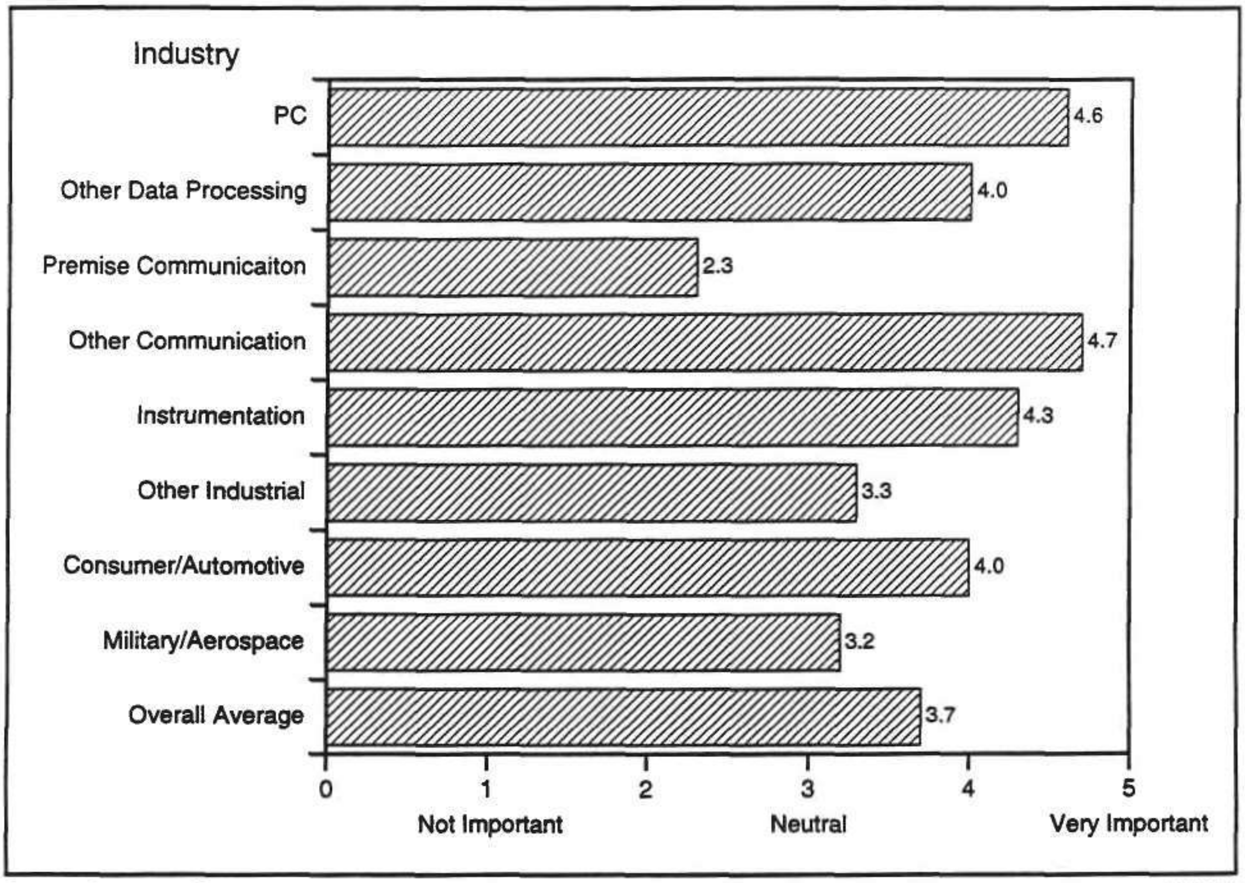


Source: Dataquest (December 1992)

G2001431

This criterion clearly is a prerequisite for doing business.

Figure 5-29
Standard Logic and Analog IC Supplier Selection Criteria: Market Flexibility

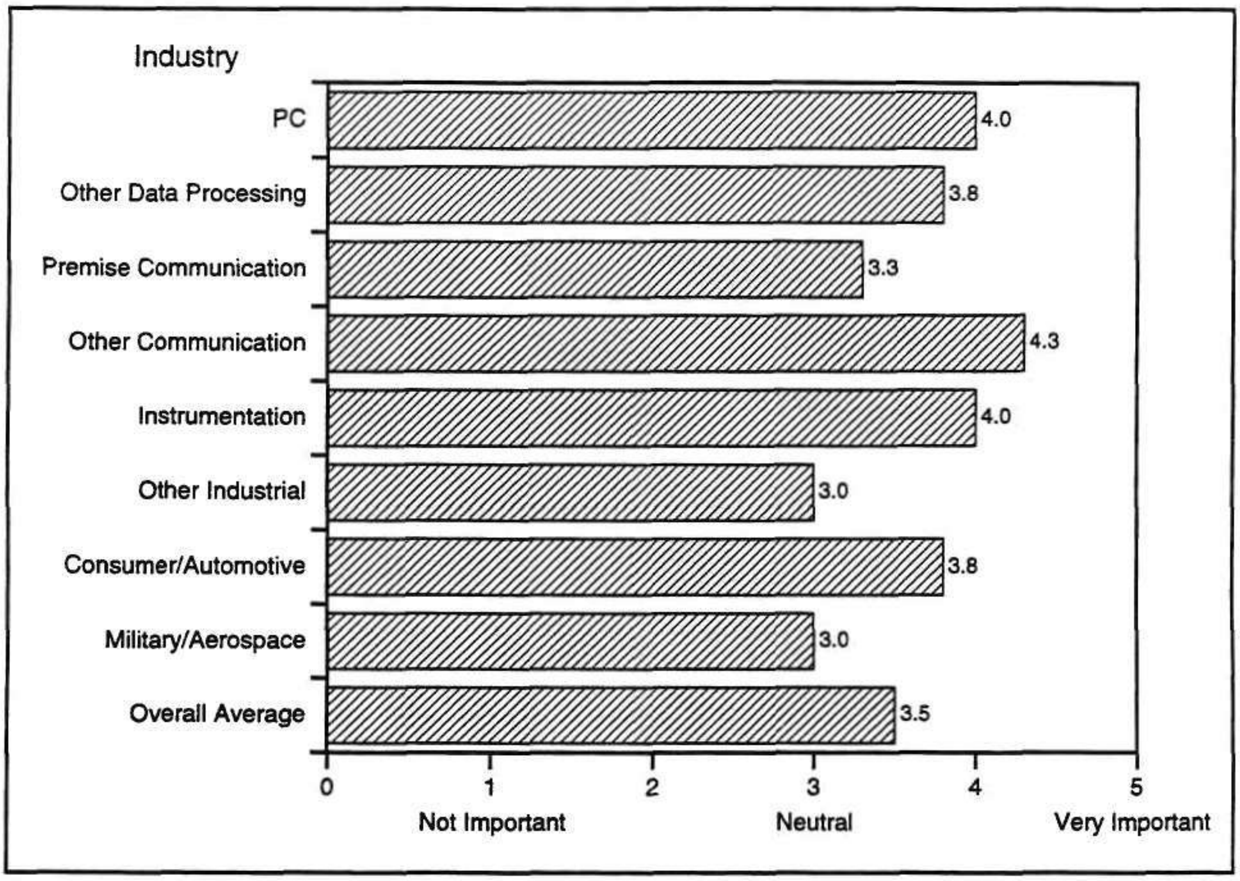


Source: Dataquest (December 1992)

G2001432

Communications and PC OEMs desire the most flexibility.

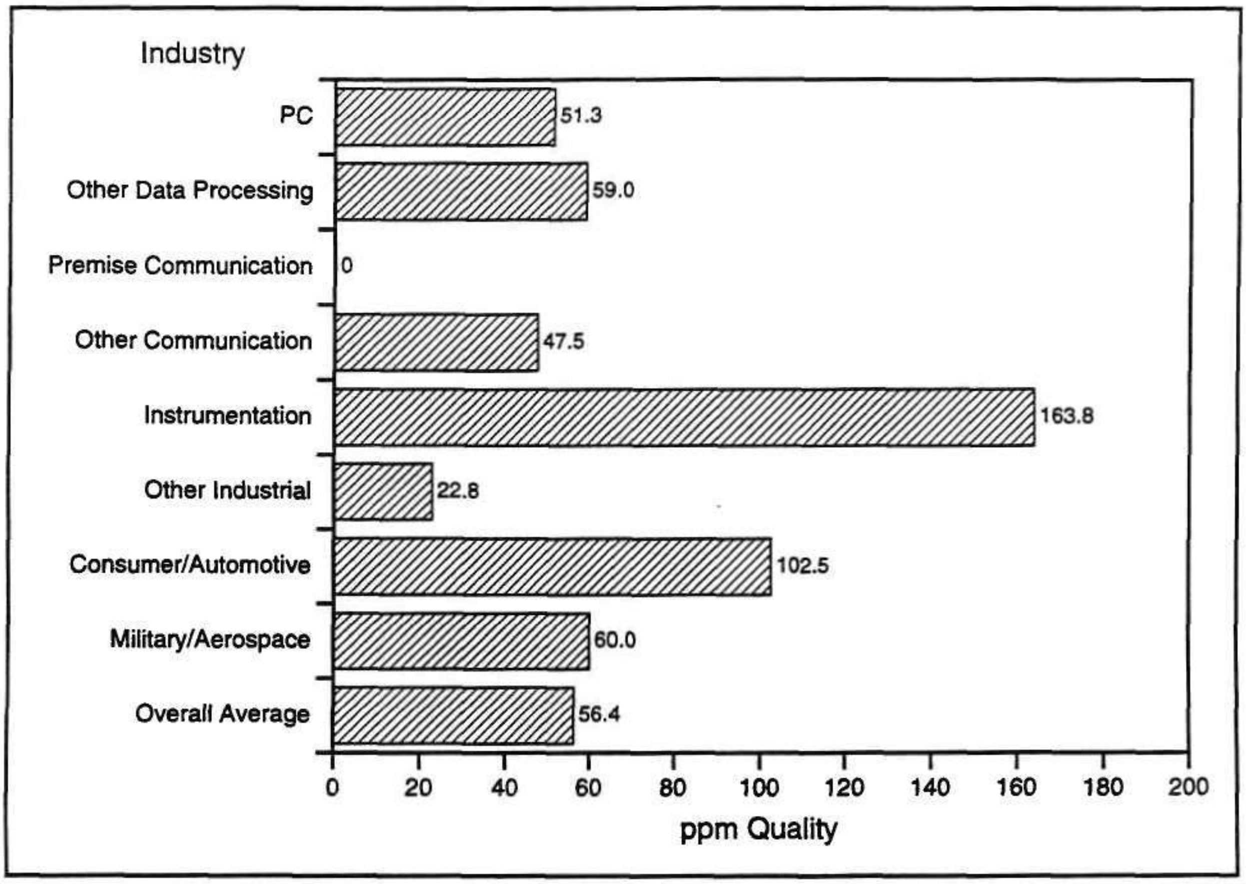
Figure 5-30
Standard Logic and Analog IC Supplier Selection Criteria: Product Portfolio and Migration Path



Source: Dataquest (December 1992)
G2001433

Product plans appear to be more crucial to performance-sensitive OEMs in computing and communication.

Figure 5-31
Minimum Necessary Quality for Standard Logic and Analog ICs (ppm)

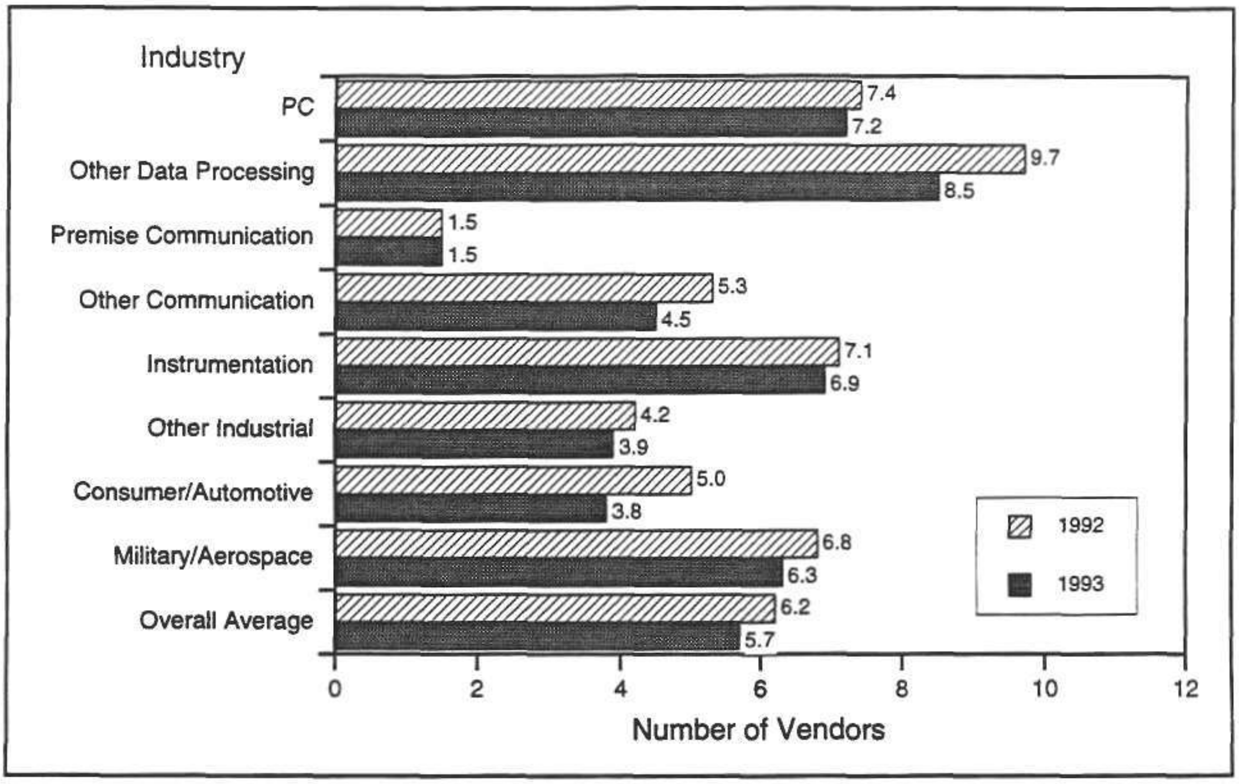


Source: Dataquest (December 1992)

G2001434

Higher-volume users such as computing and communications OEMs are requiring commensurate higher-quality levels.

Figure 5-32
Number of Standard Logic and Analog IC Suppliers



Source: Dataquest (December 1992)

G2001435

On average, standard logic and analog buyers maintained about six separate suppliers in 1992, with plans to reduce that number in 1993.

Chapter 6
Recommendations

Semiconductor Marketers

The primary picture that emerges from this report is that chip companies should be aware that relationships are not sacrosanct and eventually are subject to objective tests. OEMs are putting a substantial amount of rigor into managing their costs and hitting aggressive product development schedules, and suppliers that do not provide adequate service are left out. They want fewer, committed suppliers that will help share in the upside and downside phases of the business cycle.

Clearly quality is a go or no-go issue. Either a supplier has world-class, consistently delivered quality better than 60 ppm on average, or it is put on probation or disqualified as a supplier. Delivery performance, on the other hand, seems to separate the weak from the strong suppliers. Shipping to the customer the right product (no mis-shipments) within an acceptable JIT window (+5,-0 days, for example) is the goal to maintain. If anything is important today for OEMs, it is the vitality and speed of product development, and a consistent on-time supplier delivery track record will win a bigger share of annual requirements.

As a final recommendation, those that want to play in the big leagues had better be professional. The data from this survey indicate that high-volume markets such as PCs, peripherals, customer premise communications equipment, and consumer and automotive products demand a higher degree of commitment. In general, these markets require better quality, more exacting delivery, and rock-bottom pricing relative to other markets. In other words, a supplier that wants big volume had better be prepared with benchmarkable programs in process control and outgoing quality, minimal manufacturing cycles, inventory investment to buffer release fluctuations, and a general commitment among its personnel to get the job done.

Semiconductor Users

This study answers many questions regarding what is meant by high quality, on-time delivery, average use of a contract manufacturer, and the like, based on responses from some of the largest or most prominent electronics companies in the United States The process of benchmarking operations against regional competition involves the use of impartial parameters to gauge performance. Semiconductor users can make this information work for them by using it as a basis for comparing themselves against averages in the industry in which they compete, and in efforts to improve semiconductor supplier performance.

The major issues of semiconductor price, availability, and lead time continue to require excellent forecast communication between user and supplier. Both parties are reminded that these issues involve two-way sharing of information. The two main areas that require supplier maintenance (supplier discipline)—high quality and meeting delivery commitments—tacitly imply that semiconductor suppliers now are adequately meeting customer needs in these areas. Pressure should be kept on suppliers to keep quality and delivery commitments.

This report has presented many detailed parameters that should be coordinated and prioritized on an individual company basis in order to get the best use from them. If a little groundwork is done, this information will provide a solid foundation for growth in 1993 and beyond.

Chapter 7
Biographies

Gregory L. Sheppard
Director and Principal Analyst, Semiconductor Group

Role at Dataquest

Mr. Sheppard is responsible for coordinating worldwide semiconductor applications research for Dataquest. Besides his own areas of research, he oversees the research of the Semiconductor Application Markets Worldwide (SAM) service. In addition, he has participated in various custom research projects concerning semiconductor applications.

Program Responsibilities

Specific areas of expertise include:

- Workstation, midrange, high-performance applications
- Multimedia applications
- Communications applications
- Military/aerospace and automotive applications

Mr. Sheppard is a specialist on the end use or application of semiconductors. His scope of analysis includes both economic and technical trends regarding the semiconductor content of electronic equipment.

Professional Experience

Prior to Dataquest, Mr. Sheppard was Worldwide Business Analysis Manager at Fairchild Semiconductor Corporation. In that position he coordinated the worldwide product and market plan that drove investment decisions. He has also been a participant in the World Semiconductor Trade Statistics (WSTS) organization and the American Electronics Association. Previously, he worked in engineering management at GTE Corporation, specializing in communications systems design and decision aid systems.

Education

University of Colorado: B.S., Electrical Engineering/Computer Science, 1979

University of Southern California: M.S., System Management, 1982

Mark Giudici

Director/Principal Analyst, Semiconductor Procurement Service

Role at Dataquest

Mr. Giudici is responsible for tracking and analyzing emerging semiconductor procurement issues and trends. He also covers regional semiconductor prices and cost modeling issues. In addition, he has participated in various custom research projects involving procurement needs and regional price differentials.

Program Responsibilities

Specific areas of expertise include:

- ASIC product/trend analysis
- Worldwide regional price trends
- Cost modeling of semiconductors
- Strategic semiconductor procurement practices

Mr. Giudici is a specialist in the trend analysis and cost-based pricing of semiconductor procurement. His scope of analysis involves both macroeconomic and tactical trends that affect the availability and procurement of semiconductors.

Professional Experience

Prior to joining Dataquest, Mr. Giudici spent eight years in both the computer and semiconductor industries, where he held a variety of financial and marketing positions. Most recently, he was a Product Marketing Engineer with Gould-American Microsystems, where he was responsible for cost modeling and marketing semicustom and foundry-custom semiconductor components.

Education

California State University, Chico: B.S., Business Administration

University of Oregon: M.B.A., Business Management

Eric K. Shigemoto

Market Research Associate, Research Operations

Role at Dataquest

Mr. Shigemoto is a Market Research Associate in the Research Operations Group at Dataquest. Focusing on end-user research, he is responsible for designing and implementing primary research studies. His other responsibilities include questionnaire design, programming, and data analysis. The scope of projects Mr. Shigemoto manages includes Dataquest's User Wants and Needs surveys, custom consulting projects, and Dataquest's syndicated SCORE Customer Satisfaction product.

Program Responsibilities

The end-user research areas that Mr. Shigemoto is responsible for within the Research Operations Group include the following:

- User Wants and Needs—Examination of buying patterns and budgets, and future product and purchase plans
- Custom consulting studies—Custom end-user research, often involving conducting interviews worldwide
- SCORE Customer Satisfaction—A syndicated product analyzing customer satisfaction of desktop computers. Users of desktop computers are contacted on a quarterly basis.
- Surveys for *Dataquest Perspectives*—Event-driven analyses of various technology markets

Professional Experience

Prior to joining Dataquest, Mr. Shigemoto worked as a Market Research Analyst focusing on custom and syndicated research studies at OmniTrak Group Incorporated. His primary responsibilities at OmniTrak included questionnaire design, programming, data analysis, and report writing.

Education

San Jose State University: B.S., Marketing, Minor in Advertising

Mario Morales

Senior Interviewer, Field Interviewing, Research Operations Group

Role at Dataquest

Mr. Morales is the senior interviewer of Field Interviewing in the Research Operations group at Dataquest. With a staff of up to 39 interviewers, including 13 permanent interviewers and a flex staff of 25, Mr. Morales is responsible for assisting the supervisor with scheduling, coordination, and data collection of end-user surveys, vendor shipments, pricing, and market share statistics. The scope of these projects varies from small, specific studies targeting a population of 15 respondents to large quarterly studies with as many as 5,000 end-user interviews. Mr. Morales also acts as a project leader for international projects that require surveys conducted in Spanish, in which he is fluent. In addition, Mr. Morales has responsibility for monitoring and managing the networked computer-aided interviewing system.

Program Responsibilities

Mr. Morales assists with scheduling and training for the field interviewing area within Research Operations. His responsibilities include the following:

- Monitoring 39 telephone interviewing stations
- Twenty eight computer-aided telephone interviewing stations, with automated sample management, online monitoring, and quota updating
- Paper and pencil surveys checked for quality and accuracy to accommodate open-ended interviews
- Quarterly customer satisfaction surveys with end users
- High-level executive and technology-specific interviews
- Monthly and quarterly panels interviewed for semiconductor pricing surveys
- Focus group recruitment for our on-site focus group facility

Education

Mr. Morales attends Evergreen Valley College in San Jose, California, where he is completing an A.A. degree in Business Marketing. He will pursue a B.S. degree in Marketing and Economics at San Jose State University in spring 1993.

Appendix A
Survey Questionnaire

General Information

Hello, this is ______________________ from Dataquest Incorporated. We're conducting a study on semiconductor purchasing and your input would be most important to us.

Would you be the person who is in charge of purchasing semiconductors that have been selected to be used in the last two or three years at your location?

If not, is there someone else at your location I might speak to who would be knowledgeable in this area?

Do you have a few minutes to answer some questions? The results of this study will be used by leaders of the semiconductor industry as an industry benchmark series from which to improve upon. (If needed: *this is not a sales call and your answers will be kept completely confidential.)*

Q.1 Do you purchase semiconductors for the entire company, a single division, or just your department/work group? (ONE RESPONSE)

- Entire company .... ❑
- Single division .... ❑
- Department/Work group .... ❑
- Refusal .... ❑

Q.2 Dataquest segments electronic equipment into six categories. Which of the following describes your company's main lines of business? (READ LIST; ALLOW MULTIPLE RESPONSES)

- Data processing .... ❑
- Communications .... ❑
- Industrial/Manufacturing .... ❑
- Consumer .... ❑
- Military/Aerospace .... ❑
- Transportation .... ❑

Q.3 Please list the 3 main types of equipment in which your company uses the semiconductors that you buy. What is the first main type? (ONE RESPONSE)

- Data Processing—Computers .... ❑
- PCs .... ❑
- Workstations .... ❑
- Midrange .... ❑

Mainframe .... ☐
Super .... ☐
Other ____________________
Data Processing—Data Storage .... ☐
Disk .... ☐
Optical .... ☐
Tape .... ☐
Other ____________________
Data Processing—Input/Output .... ☐
Optical scan equipment .... ☐
Plotters .... ☐
Printers .... ☐
Terminals .... ☐
Other ____________________
Data Processing—Dedicated Systems .... ☐
Banking .... ☐
Office automation .... ☐
Point-of-sale terminals .... ☐
Smart cards .... ☐
Other ....
Data Processing—Graphic/Video Add-In Boards .... ☐
Data Processing—Other ____________________
Communications—Customer Premises Communications .... ☐
Business communications systems .... ☐
Data PBX .... ☐
Facsimile .... ☐
Local area networks .... ☐
Modems .... ☐
Single-line phones .... ☐
T-1 multiplexers .... ☐
Video teleconference .... ☐
Other ____________________
Communications—Public Telecommunications .... ☐
Switching equipment .... ☐
Transmission equipment .... ☐
Other ____________________
Communications—Radio .... ☐
Amateur .... ☐
Broadcast receive/transmit .... ☐
Cellular radio/telephone .... ☐
Mobile system .... ☐
Other ____________________

Communications—Studio ❑
Audio equipment ❑
Video equipment ❑
Other ____________________

Industrial/Manufacturing—Security/Energy Management: Alarm Systems ❑
Other ____________________

Industrial/Manufacturing—Manufacturing Systems ❑
Automated material handling ❑
Robot systems ❑
Semiconductor production ❑
Test equipment ❑
Other ____________________

Industrial/Manufacturing—Instrumentation ❑
Analytical/scientific ❑
Geophysical ❑
Meteorological ❑
Other ____________________

Industrial/Manufacturing—Medical Equipment ❑
All ❑

Industrial/Manufacturing—Miscellaneous Equipment ❑
Laser (not communications/medical) ❑
Power supplies ❑
Vending machines ❑
Other ____________________

Consumer Products ❑
Appliance ❑
Audio equipment ❑
Garage door opener ❑
Color TVs ❑
Personal electronics ❑
VTRs (VCRs) ❑
Consumer products ❑
Other ____________________

Military/Aerospace—Military Defense ❑
Avionics ❑
Communications ❑
Electronic warfare ❑
Missiles/weapons ❑
Shipboard ❑
Space ❑
Commercial aerospace ❑
Other ____________________

Transportation—Auto/Light Truck ☐
Body controls ☐
Power train ☐
Auto/light truck ☐
Other ____________
Don't know/refusal/no response ☐

(IF QUESTION 3 IS "Don't know/refusal/no response," THEN SKIP TO QUESTION 6)

Q.4 What is the second main type? (ONE RESPONSE)
Data Processing—Computers ☐
PCs ☐
Workstations ☐
Midrange ☐
Mainframe ☐
Super ☐
Other ____________
Data Processing—Data Storage ☐
Disk ☐
Optical ☐
Tape ☐
Other ____________
Data Processing—Input/Output ☐
Optical scan equipment ☐
Plotters ☐
Printers ☐
Terminals ☐
Other ____________
Data Processing—Dedicated Systems ☐
Banking ☐
Office automation ☐
Point-of-sale terminals ☐
Smart cards ☐
Other ____________
Data Processing—Graphic/Video Add-In Boards ☐
Data Processing—Other ____________
Communications—Customer Premises Communications ☐
Business communications systems ☐
Data PBX ☐
Facsimile ☐
Local area networks ☐
Modems ☐

Single-line phones ☐
T-1 multiplexers ☐
Video teleconference ☐
Other____
Communications—Public Telecommunications ☐
Switching equipment ☐
Transmission equipment ☐
Other____
Communications—Radio ☐
Amateur ☐
Broadcast receive/transmit ☐
Cellular radio/telephone ☐
Mobile system ☐
Other____
Communications—Studio ☐
Audio equipment ☐
Video equipment ☐
Other____
Industrial/Manufacturing—Security/Energy Management: Alarm Systems ☐
Other____
Industrial/Manufacturing—Manufacturing Systems ☐
Automated material handling ☐
Robot systems ☐
Semiconductor production ☐
Test equipment ☐
Other____
Industrial/Manufacturing—Instrumentation ☐
Analytical/scientific ☐
Geophysical ☐
Meteorological ☐
Other____
Industrial/Manufacturing—Medical Equipment ☐
All ☐
Industrial/Manufacturing—Miscellaneous Equipment ☐
Laser (not communications/medical) ☐
Power supplies ☐
Vending machines ☐
Other____
Consumer Products ☐
Appliance ☐
Audio equipment ☐
Garage door opener ☐

Color TVs ❑
Personal electronics ❑
VTRs (VCRs) ❑
Consumer products ❑
Other____________
Military/Aerospace—Military Defense ❑
Avionics ❑
Communications ❑
Electronic warfare ❑
Missiles/weapons ❑
Shipboard ❑
Space ❑
Commercial aerospace ❑
Other____________
Transportation—Auto/Light Truck ❑
Body controls ❑
Power train ❑
Auto/light truck ❑
Other____________
Don't know/refusal/no response ❑

(IF QUESTION 4 IS "Don't know/refusal/no response," THEN SKIP TO QUESTION 6)

Q.5 What is the third main type? (ONE RESPONSE)

Data Processing—Computers ❑
PCs ❑
Workstations ❑
Midrange ❑
Mainframe ❑
Super ❑
Other____________
Data Processing—Data Storage ❑
Disk ❑
Optical ❑
Tape ❑
Other____________
Data Processing—Input/Output ❑
Optical scan equipment ❑
Plotters ❑
Printers ❑
Terminals ❑
Other____________

Data Processing—Dedicated Systems ☐
Banking ☐
Office automation ☐
Point-of-sale terminals ☐
Smart cards ☐
Other ______
Data Processing—Graphic/Video Add-In Boards ☐
Data Processing—Other ______
Communications—Customer Premises Communications ☐
Business communications systems ☐
Data PBX ☐
Facsimile ☐
Local area networks ☐
Modems ☐
Single-line phones ☐
T-1 multiplexers ☐
Video teleconference ☐
Other ______
Communications—Public Telecommunications ☐
Switching equipment ☐
Transmission equipment ☐
Other ______
Communications—Radio ☐
Amateur ☐
Broadcast receive/transmit ☐
Cellular radio/telephone ☐
Mobile system ☐
Other ______
Communications—Studio ☐
Audio equipment ☐
Video equipment ☐
Other ______
Industrial/Manufacturing—Security/Energy Management: Alarm Systems ☐
Other ______
Industrial/Manufacturing—Manufacturing Systems ☐
Automated material handling ☐
Robot systems ☐
Semiconductor production ☐
Test equipment ☐
Other ______
Industrial/Manufacturing—Instrumentation ☐
Analytical/scientific ☐

Geophysical ☐
Meteorological ☐
Other ______
Industrial/Manufacturing—Medical Equipment ☐
All ☐
Industrial/Manufacturing—Miscellaneous Equipment ☐
Laser (not communications/medical) ☐
Power supplies ☐
Vending machines ☐
Other ______
Consumer Products ☐
Appliance ☐
Audio equipment ☐
Garage door opener ☐
Color TVs ☐
Personal electronics ☐
VTRs (VCRs) ☐
Consumer products ☐
Other ______
Military/Aerospace—Military Defense ☐
Avionics ☐
Communications ☐
Electronic warfare ☐
Missiles/weapons ☐
Shipboard ☐
Space ☐
Commercial aerospace ☐
Other ______
Transportation—Auto/Light Truck ☐
Body controls ☐
Power train ☐
Auto/light truck ☐
Other ______
Don't know/refusal/no response ☐

Q.6 What is the average market life cycle of your principal product?

______

Q.7 In days, what is your definition of on-time delivery? (e.g., +2 -0, or ±2 days)

______

Q.8 Do you currently use a contract manufacturer?
Yes ☐
No ☐
Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 8 IS "No," THEN SKIP TO QUESTION 10)

(IF THE ANSWER TO QUESTION 8 IS "Don't know/refusal," THEN SKIP TO QUESTION 11)

Q.9 How many years have you used one?

____

(PLEASE ANSWER QUESTION 10 IF ANSWER TO QUESTION 8 WAS "No")

Q.10 Do you plan on using a contract manufacturer in the next year?
Yes ☐
No ☐
Don't know/refusal ☐

Q.11 Does your company design its own circuit boards?
Yes ☐
No ☐
Don't know/refusal ☐

(IF THE ANWER TO QUESTION 11 WAS "No" OR "Don't know/refusal," PLEASE SKIP TO QUESTION 16)

Q.12 What percentage of the circuit boards were made in-house in 1992?
______________________________(percent)

Q.13 What percentage of the circuit boards will be made in-house in 1993?
______________________________(percent)

(IF THE ANSWER TO QUESTION 8 IS "No" or "Don't know/refusal," THEN SKIP TO QUESTION 16)

Q.14 Does your company purchase the semiconductors used by the outside contractors?
Yes ☐
No ☐
Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 14 IS "No" or "Don't know/refusal," THEN SKIP TO QUESTION 16)

Q.15 Are terms decided by the contractor?

- Yes ❑
- No ❑
- Don't know/refusal ❑

Q.16 Of all the purchasing issues you expect to face next year, what would be the major one? (ONE RESPONSE)

- ASICs ❑
- Availability ❑
- Cost control ❑
- Develop key supplier/user relationships ❑
- Government regulations ❑
- Just-in-time inventory control ❑
- Memory products ❑
- New products/obsolescence ❑
- On-time delivery ❑
- Packaging standards ❑
- Pricing ❑
- Quality/reliability ❑
- Lead time ❑
- Development schedules ❑
- Allocation ❑
- ASICs design tools ❑
- Flexibility/service ❑
- Other (specify)________
- Don't know/refusal ❑

(IF THE ANSWER TO QUESTION 16 IS "Don't know/refusal," THEN SKIP TO QUESTION 22)

Q.17 What would be the second major purchasing issue you expect to face? (ONE RESPONSE)

- ASICs ❑
- Availability ❑
- Cost control ❑
- Develop key supplier/user relationships ❑
- Government regulations ❑
- Just-in-time inventory control ❑
- Memory products ❑
- New products/obsolescence ❑
- On-time delivery ❑
- Packaging standards ❑
- Pricing ❑
- Quality/reliability ❑
- Lead time ❑

- Development schedules ☐
- Allocation ☐
- ASICs design tools ☐
- Flexibility/service ☐
- Other (specify)________
- Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 17 IS "Don't know/refusal," THEN SKIP TO QUESTION 19)

Q.18 What would be the third major purchasing issue you expect to face? (ONE RESPONSE)

- ASICs ☐
- Availability ☐
- Cost control ☐
- Develop key supplier/user relationships ☐
- Government regulations ☐
- Just-in-time inventory control ☐
- Memory products ☐
- New products/obsolescence ☐
- On-time delivery ☐
- Packaging standards ☐
- Pricing ☐
- Quality/reliability ☐
- Lead time ☐
- Development schedules ☐
- Allocation ☐
- ASICs design tools ☐
- Flexibility/service ☐
- Other (specify)________
- Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 18 IS "Don't know/refusal," THEN SKIP TO QUESTION 19)

Q.19 On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important is (response to Q.16) to you?

- Not at all important ☐
- Not very important ☐
- Neutral ☐
- Somewhat important ☐
- Very important ☐
- Don't know/refusal ☐

Q.20 On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important is (response to Q.17) to you?

- Not at all important ☐
- Not very important ☐
- Neutral ☐
- Somewhat important ☐
- Very important ☐
- Don't know/refusal ☐

Q.21 On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important is (response to Q.18) to you?

- Not at all important ☐
- Not very important ☐
- Neutral ☐
- Somewhat important ☐
- Very important ☐
- Don't know/refusal ☐

Q.22 Does your company have a regular, ongoing procedure of supplier evaluation?

- Yes ☐
- No ☐
- Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 22 IS "No" OR "Don't know/refusal," THEN SKIP TO QUESTION 24)

Q.23 On what parameters does your company evaluate suppliers?

- Quality ☐
- Delivery ☐
- Technical support ☐
- Price ☐
- Other (specify)____________________
- Don't know/refusal ☐

Q.24 What are one or two key factors ("cardinal sins") that can cause a current supplier to lose business from your company?

____

____

Q.25 Do you have a strategic partnering program in place?

- Yes ☐
- No ☐
- Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 25 IS "No" OR "Don't know/refusal," THEN SKIP TO QUESTION 27)

Q.26 Would you consider the program critical, beneficial, or nice to have?

- Critical ☐
- Beneficial ☐
- Nice to have ☐
- Don't know/refusal ☐

Q.27 Do you have a quality improvement program in place?

- Yes ☐
- No ☐
- Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 27 IS "No" OR "Don't know/refusal," THEN SKIP TO QUESTION 30)

Q.28 Is it an internal or a supplier program?

- Internal ☐
- Supplier ☐
- Both ☐
- Don't know/refusal ☐

Q.29 Would you consider the program critical, beneficial, or nice to have?

- Critical ☐
- Beneficial ☐
- Nice to have ☐
- Don't know/refusal ☐

Q.30 Who are your three major suppliers of semiconductors?

____

____

____

Q.31 Which one of these suppliers do you prefer to do business with?

____

Q.32 What percent of your 1992 semiconductor purchases were used in _____
(FIRST MAIN TYPE IN QUESTION 3) (TOTAL OF ALL TYPES MUST = 100%)
(DK = Don't know; REF = Refusal)

(IF "No Second Type" IN QUESTION 4, THEN SKIP TO QUESTION 35)

Q.33 What percent of your 1992 semiconductor purchases were used in _____
(SECOND MAIN TYPE IN QUESTION 4) (TOTAL OF ALL TYPES MUST = 100%)
(DK = Don't know, REF = Refusal)

(IF "No Third Type" IN QUESTION 5, THEN SKIP TO QUESTION 35)

Q.34 What percent of your 1992 semiconductor purchases were used in _____ (THIRD MAIN TYPE IN QUESTION 5) (MUST = 100%) (DK = Don't know; REF = Refusal)

Q.35 What percent of your 1992 semiconductor purchases were used in "Other types of equipment" _______ (MUST = 100%) (DK = Don't know; REF= Refusal)

Q.36 What was your company's (entire company/division/work group) total dollar value of semiconductor purchases for 1992? (ENTER IN HUNDRED THOUSANDS, e.g., 1=100,000)

____

Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 36 IS NOT "Don't know/refusal," THEN SKIP TO QUESTION 38)

Q.37 What would you estimate your company's total dollar value of semiconductor purchases was for 1992?

- Less than $1M ☐
- $1M - $9.9M ☐
- $10M - $24.9M ☐
- $25M - $49.9M ☐
- $50M - $99.9M ☐
- $100M - $249.9M ☐
- $250M or more ☐
- Don't know/refusal ☐

Q.38 Of your semiconductor purchases, what percent of your manufacturing needs will be physically assembled on to circuit boards in the following four regions: USA, Japan, Europe, and Other? (TOTAL MUST EQUAL 100%)

USA____

Japan____

Europe____

Other____

Q.39 What would you expect your company's (entire company/division/work group) total dollar value of semiconductor purchases to be for 1993 ? (ENTER IN HUNDRED THOUSANDS, e.g.,1=100,000)

____

Don't know/refusal ☐

(IF THE ANSWER TO QUESTION 39 IS NOT "Don't know/refusal," THEN SKIP TO QUESTION 41)

Q.40 What would you estimate your company's total dollar value of semiconductor purchases will be for 1993?

- Less than $1M ☐
- $1M - $9.9M ☐
- $10M - $24.9M ☐
- $25M - $49.9M ☐
- $50M - $99.9M ☐
- $100M - $249.9M ☐
- $250M or more ☐
- Don't know/refusal ☐

Q.41 On a dollar basis, what percent of your total 1992 semiconductor purchases were in each of the following three categories: Integrated Circuit, Discrete, Optoelectronics? (TOTAL MUST = 100%)

- Integrated Circuit ________
- Discrete ________
- Optoelectronics ________
- Don't know/refusal ☐

(IF ANSWER TO QUESTION 41 IS "Discrete + 1-100%" CONTINUE, OTHERWISE SKIP TO QUESTION 43)

Q.42 What percent of your discrete purchases were for power devices?

____

Q.43 On a dollar bases, what percent of your 1992 integrated circuit purchases were in the following four technologies?

- Memory ________
- General-purpose microcomponents/ASSPs ________
- ASICs ________
- Standard logic/linear/analog ________

(FOR THOSE WHO ANSWERED 1-100% FOR "Memory" IN QUESTION 43, ASK QUESTIONS 44 THROUGH 53, OTHERWISE SKIP TO QUESTION 54)

Q.44 What percent of MOS "memory" are the following four products? (MUST = 100%)

- DRAM ________
- VRAM ________
- SRAM ________
- Nonvolatile ________
- Don't know/refusal ☐

On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important are the following criteria when selecting a memory vendor.

Q.45 How important is pricing consistency?
Not at all important____________________
Not very important____________________
Neutral____________________
Somewhat important____________________
Very important____________________
Don't know/refusal.. ☐

Q.46 How important is delivery performance?
Not at all important____________________
Not very important____________________
Neutral____________________
Somewhat important____________________
Very important____________________
Don't know/refusal.. ☐

Q.47 How important is quality performance?
Not at all important____________________
Not very important____________________
Neutral____________________
Somewhat important____________________
Very important____________________
Don't know/refusal.. ☐

Q.48 How important is market flexibility?
Not at all important____________________
Not very important____________________
Neutral____________________
Somewhat important____________________
Very important____________________
Don't know/refusal.. ☐

Q.49 How important is product portfolio and migration path?
Not at all important____________________
Not very important____________________
Neutral____________________
Somewhat important____________________
Very important____________________
Don't know/refusal.. ☐

Q.50 What is the minimum necessary level of quality for memories, in PPM or AQL?

____

Q.51 How many memory vendors did you have in 1992?

____

Q.52 How many memory vendors do you expect to have in 1993?

____

Q.53 What new memory IC product features do you need for your next-generation products?

____

(FOR THOSE WHO ANSWERED 1-100% FOR "General-Purpose Microcomponents/ASSPs" IN QUESTION 43, ASK QUESTIONS 54 THROUGH 64, OTHERWISE SKIP TO QUESTION 65)

Q.54 What percent of general-purpose "microcomponents" are the following four products? (TOTAL MUST = 100%)

Microprocessors (MPU)______________________________

Microcontrollers (MCU)______________________________

Microperipherals______________________________

DSP MPUs______________________________

Don't know/refusal .... ❑

Q.55 What percent of your ASSP purchases were in each of the following categories? (TOTAL MUST = 100%)

System logic chip sets______________________________

Graphics/video______________________________

Communication______________________________

Storage______________________________

Other______________________________

On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important are the following criteria when selecting a general-purpose microcomponent/ ASSP vendor?

Q.56 How important is pricing consistency?

Not at all important______________________________

Not very important______________________________

Neutral______________________________

Somewhat important______________________________

Very important______________________________

Don't know/refusal .... ❑

Q.57 How important is delivery perfomance?
Not at all important__________
Not very important__________
Neutral__________
Somewhat important__________
Very important__________
Don't know/refusal .... ☐

Q.58 How important is quality performance?
Not at all important__________
Not very important__________
Neutral__________
Somewhat important__________
Very important__________
Don't know/refusal .... ☐

Q.59 How important is market flexibility?
Not at all important__________
Not very important__________
Neutral__________
Somewhat important__________
Very important__________
Don't know/refusal .... ☐

Q.60 How important is product portfolio and migration path?
Not at all important__________
Not very important__________
Neutral__________
Somewhat important__________
Very important__________
Don't know/refusal .... ☐

Q.61 What is the minimum necessary level of quality for general-purpose microcomponents/ASSPs in PPM or AQL?

____

Q.62 How many general-purpose microcomponent/ASSP vendors did you have in 1992?

____

Q.63 How many general-purpose microcomponent/ASSP vendors do you expect to have in 1993?

____

Q.64 What new general-purpose microcomponent/ASSP product features do you need for your next-generation products?

____

(FOR THOSE WHO ANSWERED 1-100% FOR "ASICs" IN QUESTION 43, ASK QUESTIONS 65 THROUGH 74, OTHERWISE SKIP TO QUESTION 75)

Q.65 What percent of ASIC purchases were in each of the following categories? (TOTAL MUST = 100%)

Bipolar gate arrays, cells, etc.______

Bipolar PLDs______

MOS gate arrays______

Mixed analog and digital______

MOS cell-based/custom______

MOS PLD/FPGA______

On a scale of 1 to 5, with 1 being not at all important and 5 being very important, how important are the following criteria when selecting an ASIC vendor?

Q.66 How important is pricing consistency?

Not at all important______

Not very important______

Neutral______

Somewhat important______

Very important______

Don't know/refusal......❑

Q.67 How important is delivery perfomance?

Not at all important______

Not very important______

Neutral______

Somewhat important______

Very important______

Don't know/refusal......❑

Q.68 How important is quality performance?

Not at all important______

Not very important______

Neutral______

Somewhat important______

Very important______

Don't know/refusal......❑

Q.69 How important is market flexibility?

Not at all important__________

Not very important__________

Neutral__________

Somewhat important__________

Very important__________

Don't know/refusal .... ☐

Q.70 How important is product portfolio and migration path?

Not at all important__________

Not very important__________

Neutral__________

Somewhat important__________

Very important__________

Don't know/refusal .... ☐

Q.71 What is the minimum necessary level of quality for ASICs, in PPM or AQL?

____

Q.72 How many ASIC vendors did you have in 1992?

____

Q.73 How many ASIC vendors do you expect to have in 1993?

____

Q.74 What new ASIC product features do you need for your next-generation products?

____

(FOR THOSE WHO ANSWERED 1-100% FOR "Standard logic/linear/analog" IN QUESTION 43, ASK QUESTIONS 75 THROUGH 84, OTHERWISE SKIP TO QUESTION 85)

Q.75 What percent of standard logic/linear/analog purchases were in each of the following categories? (TOTAL MUST = 100%)

Standard logic__________

Data conversion__________

Amplifiers__________

Regulators/reference__________

Interface__________

Other__________

Q.76 How important is pricing consaistency?
Not at all important______
Not very important______
Neutral______
Somewhat important______
Very important______
Don't know/refusal .... ☐

Q.77 How important is delivery perfomance?
Not at all important______
Not very important______
Neutral______
Somewhat important______
Very important______
Don't know/refusal .... ☐

Q.78 How important is quality performance?
Not at all important______
Not very important______
Neutral______
Somewhat important______
Very important______
Don't know/refusal .... ☐

Q.79 How important is market flexibility?
Not at all important______
Not very important______
Neutral______
Somewhat important______
Very important______
Don't know/refusal .... ☐

Q.80 How important is product portfolio and migration path?
Not at all important______
Not very important______
Neutral______
Somewhat important______
Very important______
Don't know/refusal .... ☐

Q.81 What is the minimum necessary level of quality for standard logic/linear/analog, in PPM or AQL?

____

Q.82 How many standard logic/linear/analog vendors did you have in 1992?

____

Q.83 How many standard logic/linear/analog vendors do you expect to have in 1993?

____

Q.84 What new standard logic/linear/analog product features do you need for your next-generation products?

____

Q.85 Would you be willing to respond to a few additional questions about semiconductors?

- Yes .... ☐
- No .... ☐

(IF THE ANSWER TO QUESTION 85 IS "No," THEN SKIP TO QUESTION 100)

Q.86 Does your company produce semiconductors for captive use?

- Yes .... ☐
- No .... ☐
- Don't know/refusal .... ☐

(IF THE ANSWER TO QUESTION 86 WAS NOT "Yes," THEN SKIP TO QUESTION 89)

Q.87 What was the total market value in 1992? (ENTER IN THOUSANDS, e.g., 1=1,000)

____

Q.88 What types of semiconductors are you producing captively? (READ LIST; MULTIPLE RESPONSE)

- ASICs .... ☐
- ASSPs .... ☐
- DRAMs .... ☐
- Discretes .... ☐
- Microprocessors .... ☐
- Optoelectronics .... ☐
- Other (specify) ______________________________
- Don't know/refusal .... ☐

Q.89 At what sites are engineering decisions on semiconductor selections made for what types of equipment? (RECORD COMPANY NAME, CITY, STATE, AND WHETHER IT'S A CORPORATE OR MANUFACTURING SITE)

____

____

Q.90 What percent of your 1992 semiconductor procurement was from distributors?

____

Don't know/refusal .... ☐

Q.91 The next few questions concern your electronic equipment production. Did your 1992 equipment sales increase, decrease, or remain the same compared to 1991?

Increase .... ☐
Decrease .... ☐
Remain the same .... ☐
Don't know/refusal .... ☐

(IF THE ANSWER TO QUESTION 91 WAS "Increase," PLEASE ANSWER QUESTION 92)

(IF THE ANSWER TO QUESTION 91 WAS "Decrease," PLEASE ANSWER QUESTION 93)

Q.92 What percent increase?

____

Don't know/refusal .... ☐

Q.93 What percent decrease?

____

Don't know/refusal .... ☐

Q.94 Do you expect equipment sales in 1993 to increase, decrease, or remain the same compared to 1992?

Increase .... ☐
Decrease .... ☐
Remain the same .... ☐
Don't know/refusal .... ☐

(IF THE ANSWER TO QUESTION 94 WAS "Increase," PLEASE ANSWER QUESTION 95)

(IF THE ANSWER TO QUESTION 94 WAS "Decrease," PLEASE ANSWER QUESTION 96)

Q.95 What percent increase?

____

Don't know/refusal .... ☐

Q.96 What percent decrease?

____

Don't know/refusal .... ☐

Q.97 Next, I would like to ask you a few questions about your semiconductor inventory levels. Currently, what is your actual inventory level (USAGE RATE) in days?

____

Don't know/refusal .... ☐

Q.98 In terms of number of days, what level of semiconductor inventory would you like to have (targeted)?

____

Don't know/refusal ☐

Q.99 Do you expect your target semiconductor inventory levels to increase, decrease, or remain the same over the next 12 months?

Increase ☐
Decrease ☐
Remain the same ☐
Don't know/refusal ☐

I just have a few demographic questions and we will be finished with the survey.

Q.100 What it your job title?

Administrative Support/Clerical ☐
Analyst ☐
Educator/Trainer ☐
Engineer ☐
Executive/Owner ☐
Laborer ☐
Manager/Supervisor ☐
Operator/Fabricator ☐
Production Worker (assembly and process) ☐
Professional (Lawyer, Doctor, Consultant, Broker) ☐
Programmer/Software Developer ☐
Sales/Marketing/Customer Representative ☐
Scientist ☐
Service Provider (Nurse, Social Worker) ☐
Technician and Technical Support ☐
Tradesperson (Craft, Repair) ☐
Senior Buyer ☐
Buyer ☐
Purchasing Manager ☐
Procurement Manager ☐
Component Engineer ☐
VP Operations ☐
Other (specify)____________________
Don't Know/Refusal ☐

Q.101 What is your organization's primary line of business?

- Agriculture/Forestry/Fishing ❑
- Mining/Construction ❑
- Manufacturing: Durable ❑
- Manufacturing: Nondurable ❑
- Communication ❑
- Transportation/Utilities ❑
- Wholesale Trade ❑
- Retail Trade ❑
- Finance/Insurance/Real Estate ❑
- Services: Business/Legal/Engineering ❑
- Services: Other ❑
- Health or Social Services ❑
- Education ❑
- Government ❑
- Other (specify)________________
- Don't Know/Refusal ❑

Q.102 How many employees are there in your company?

- 1 to 9 ❑
- 10 to 19 ❑
- 20 to 49 ❑
- 50 to 99 ❑
- 100 to 299 ❑
- 300 to 499 ❑
- 500 to 799 ❑
- 800 to 999 ❑
- 1,000 to 1,999 ❑
- Greater than 2,000 ❑
- Don't know/refusal ❑

Q.103 Approximately, what is your organization's annual sales revenue?

- Up to $99,999 ❑
- $100,000 to $499,999 ❑
- $500,000 to $999,999 ❑
- $1M to $4.9M ❑
- $5M to $9.9M ❑
- $10M to $49.9M ❑
- $50M to $99.9M ❑
- $100M to $499.9M ❑
- $500M or greater ❑
- Nonprofit (Banking/Government/Education) ❑
- Don't Know/Refusal ❑

THAT CONCLUDES THIS STUDY. THANK YOU VERY MUCH FOR YOUR COOPERATION. I WOULD JUST LIKE TO CONFIRM YOUR NAME AND ADDRESS SO THAT I MAY SEND YOU YOUR SUMMARY RESULTS OF THIS STUDY.

Enter your interviewer number: (2 DIGITS)____________________

Respondent's Name:____________________

Company:____________________

Address:____________________

City: State: Zip Code:____________________

Phone Number: (XXX-XXX-XXXX) (Date) Int. No.____________________

Date: (6 DIGITS—MMDDYY)____________________

Enter your interviewer number: (2 DIGITS)____________________

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Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

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Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

List of Figures

List of Tables

Chapter 1
Introduction to Personal Information and Communications Devices

Overview

This report on personal information and communications devices (PICDs) is a collection of *Dataquest Perspective* articles that focus on what promises to be a market with a high growth potential. In an attempt to provide a balanced perspective, we have included articles from the Semiconductor Application Markets and the Personal Computers groups.

Definition: PICDs

PICDs (pronounced PicDees) describe small form factor personal computers that rely heavily on communication and use a pen-centric operating system and a pen as the primary input device. PICDs are meant to be portable and self-sufficient for extended periods.

Introduction

PICDs—What Are They?

There appears to be no consensus for a name that properly describes future small-size portable PCs: Apple calls such devices PDAs (personal digital assistants) and AT&T calls them personal communicators. Of course, other names—palmtop, subnotebook, and companion—all more or less describe similar products. Both Apple and AT&T are attempting to describe a new device that, even though it is an evolutionary computer product, may in fact combine into one appliance the capabilities now found in our telephone, fax, PC, and daytimer. It is envisioned that products with all or part of these capabilities will appeal to both mobile professionals as well as consumers who thus far have not really embraced PCs.

The Roots

Thanks to advances in semiconductor technology, we have shrunk the desktop PC down to a size that fits in our palm. A product from Hewlett-Packard, the HP 95LX, is a good example of a PICD. It operates on two AA-size batteries, runs DOS and Lotus 1-2-3 (both embedded), and has 1MB of main memory. It is a significant achievement, even though most likely it will seem ancient history in 10 years' time. Until now we have used our computers to "compute"—that is, they calculate things for us and thus can be considered "overgrown calculators." Sociologists, however, tell us that the need to calculate is secondary for humans; the need to communicate is undeniably more necessary. So why all this fuss with the overgrown calculators? For one thing, computers help us do much more than calculate. They help us communicate, they manage our information, and to some extent they entertain us. Common to both Apple's and AT&T's vision is the need to easily manage information and communication.

Chapters 1 through 5 of this report will describe overall portable computing needs and discuss Apple's Newton, GO's operating system, and the recent AT&T-GO alliance. Chapters 6 through 10 present a portable computer forecast, a discussion of the elements that make up today's hand-held PC, and future trends in MPUs, storage, and communication.

Project analysts: Nicolas Samaras
Andrew Seybold

Chapter 2
Portable Computing Today

Present standards in portable computers include the full-function notebook systems, soon-to-be released subnotebook (companion) PCs, hand-held DOS-compatible systems such as the HP 95LX, and handheld organizers.

Each form factor will soon be available with either keyboard input (as they are now) or pen-based input devices. Each will continue to be important, but it is the movement toward sub-$1,000 hand-held machines that will enjoy the fastest growth over the next few years. This product group is where many innovations and new designs will be found. Until mid-1993, pen-based systems will be implemented by large companies and organizations in vertical markets with little or no retail sales of a horizontal nature available for start-up companies. It is important to note that the end-user community will view this area of subnotebook and hand-held computers not so much as computers but more as appliances.

The Need for Communication

As the trend evolves for smaller and lighter portable computers, the one shortfall hindering acceptance of these systems is in the area of communication. Notebook computers became popular after the capabilities of desktop systems were incorporated: an Intel 386SX processor, VGA compatibility, backlit screens, large hard disks, and better battery life.

One reason for the fast market growth of fully functional notebook systems is that a user can now duplicate the desktop on a notebook (operating system, applications, and file storage). This is a mandatory requirement because there is a lack of easy-to-use communications links among the worlds of portable computers, desktops, and networked systems. Moving data between platforms using a product such as Traveling Software's LapLink is not easily accomplished by a computer nonexpert. Programs such as LapLink assume that the user knows exactly which files need to be moved, where they are located on the desktop system, and where they should be located on the portable. Once moved, data need to be translated to the format of the receiving application. This usually requires reformatting. Further, when applications are moved from one platform to another, video drivers sometimes need to be changed and parameters for communications and printing need to be reset.

Subnotebooks

Many hardware vendors are designing subnotebook or companion PC products that will soon come to market. These units will have a smaller form factor, and for the most part will not include an internal floppy drive. Some will follow the Phoenix Technology reference model and, at first, be based upon CPUs with less power than the Intel 386-based notebooks.

Other vendors, however, will move directly to this form factor with a 386-based system, again, with no internal floppy drive. Instead, these machines will rely on communications links to transfer data to and from remote computing platforms. This will be accomplished by way of wired modem, infrared, and soon, RF communications links.

We believe that these links will be a viable form of communication, but they will represent no more than a transport layer for the data that must be moved across them. For the most part, we have seen no real evidence to date that software companies really understand the requirement for true ease of use in data communication for this class (subnotebook and smaller) of computers. End users will not tolerate the arcane data transfer software applications now available, nor will they tolerate having to know which programs and files need to be moved from one system to another.

On-board operating systems and applications will be used extensively in these recipient machines. The Phoenix-Lotus model will become a standard, but many such machines will rely instead on MS-DOS 5.0 and Windows 3.1 in ROM for their operating environment. Additional applications will either be part of this on-board suite of programs or will be available to the user by way of Personal Computer Memory Card International Association (PCMCIA) cards. And here again, the built-in communications links we have seen do not address ease-of-use issues. They will not be easier for end users to figure out and make work. Consequently, acceptance of such units will be delayed until these communications issues are appropriately addressed.

Hand-Held Computers

In response to the demand for ubiquitous, carry-everywhere computers, we will see a large number of diverse entries during the course of the next two or three years.

The first "true" entrant into the hand-held market was the HP 95LX. This machine has been successful for HP not just because it is DOS-compatible; it is a financial modeling tool first, a personal information manager (PIM) second, and a DOS-compatible system last. However, even more important than DOS compatibility is its ability to move data from the hand-held platform to the desktop and back again. Fully 75 percent of all HP 95LX systems are connected to desktop systems at one time or another. Other units, such as the Sharp Wizard, Casio Boss, and PSION hand-helds that are not DOS-compatible have also been successful, but many have ended up in a desk drawer after a few months of attempted use. These machines only partially meet the requirements of the mobile computerist. Until recently, moving data between these hand-helds and the desktops has been a difficult operation.

The Next-Generation Hand-Held Systems

The industry is on the verge of a major change in how it views hand-held computing. Many vendors have discovered that being DOS-compatible is not an important selling point in the hand-held world. What is important is the ability to move data quickly and easily back and forth between the hand-held platform and the desktop world.

Recognition of the relative importance of communication as compared to DOS compatibility has led to many new designs, some based on pen input and some still making use of a keyboard for data entry. We expect to see announcements of many other new technologies within the next six months. The resulting products will forever change end-user expectations of hand-held computing.

As one example, Apple announced a technology concept at Consumer Electronics Show (CES) in Chicago on May 31 that we believe will change the perception of hand-held computing for all time. The new hand-held, called Newton, is a total departure from what we have known in the world of hand-held computers (see Chapter 3) This unit is the first of what is supposed to be a series of products that include a built-in infrared communications link. This link is being designed to permit instantaneous and easy communication not only between like units, but also between Newton and both Intel and Macintosh desktop systems.

One feature is the ability to transmit and receive business cards from one Newton to another with a single keystroke. Other communications features include the use of in and out boxes for storing items to be sent and received once connection is established. This connection, which is made automatically once a Newton comes into the range of an infrared transmitter/receiver, will then intelligently handle all communication into and out of the unit with no additional end-user intervention required. It is our belief that the first communications links built into Newton will not be as easy for the user community to operate. Products of this ilk have begun to use in and out boxes for remote communication, but all we have seen so far still require the end user to format the document for the type of output: fax, word, or e-mail, among others. Wide acceptance of this type of unit will only occur once remote communications links are automatic and can take care of document and file formatting. The end user will not have to be concerned with it.

Formatting, merging, and reconciliation should be able to be preconfigured by the end user in the second generation of these products. The user should also be able to change the configuration simply by selecting from menus. An example of this type of preconfiguration might be as follows: The end user purchases a hand-held machine from Dell Computer. The system installed on the desk will be an Intel-based processor system running Windows 3.1, Excel, Word for

Windows, and PackRat, and will be connected to a LAN running CC:Mail. The network will have a fax server installed, as well as several different HP and PostScript-compatible printers. The end user will turn on the hand-held device and select setup (most software is already installed in ROM and the balance is available through PCMCIA cards). The Menu Selector will ask the user to indicate the types of programs and/or devices with which the companion unit will communicate. The user selects Excel, Word, CC:Mail, MCI Mail, and several printers from the menu, chooses the type of connection to be used most of the time (infrared, wireless, or direct connect) and then will move to the record and field mapping section of the setup. Here the user will spend only a few minutes determining which fields used in the local applications will map to which fields on the desktop and network systems. Once this is done, the information is stored and may be updated at any time either in sections or completely.

As part of the setup, the user may also choose to invoke "filters" for the data to be automatically received. These filters might include the types of e-mail to be downloaded (priority, or from whom, among others). It will be possible for the user to receive a listing of all mail and documents waiting on the system and then to point and click on the ones to download. Upon connecting to the desktop system, the two systems will "talk" to each other, exchanging the data placed in the in and out baskets of each. Messages received can then be reviewed and answered without having to close the message and open a word processor.

Calendar, To-Do, and Phone Messages

The premise of these systems is that once information has been entered, it never needs to be recorded again. If a secretary enters a new appointment and several phone messages in a desktop-based calendar, they are then placed in the out box, waiting for the portable device to connect to the system.

Once the portable system is connected to the "base station" (a term we will use for desktop PCs and/or networks—each portable will be assumed to have a main base station but be connectable to any number of substations by any number of different means), information will be automatically transferred to the portable system and information stored in the portable will be sent to the base station as well. The system should be user-selectable to provide the following features when a connection is made:

- Place the new information in the proper format in the proper file (appointments in the calendar, phone messages in the to-do list, among others, checking for duplications and overlaps in the process)
- Build an "incoming review file" from all of the sources

This review file would be used as follows: The user could open this file and read through the new incoming information, review each entry (or make mental note of it), and then choose to have it stored in the appropriate section of the portable, answer it, or take some other action as it is being reviewed. We believe that this type of "new" file is important in this environment because in a truly automatic transfer of multiple kinds of data, a user might not be aware of new information that has been sent. If, as in most systems we have seen, the data are merely placed into the calendar or to-do list with no notification, it is possible that it will be missed by a user that does not take the time to review all of the files each time input is downloaded. Fully automatic data transfer is important, but we believe that notification and review are equally as important. Such a feature would also be valuable for use in the one-way paging marketplace.

We have been working with the Motorola EMBARC paging system for the past few months. One shortcoming of this system is that the user has to download a new appointment transmitted to the pager and then move it to the proper area for storage. Automating this process so that the end user receives notification of the incoming message, reviews it for content, and then, with only a single keystroke or pen motion, stores it in the appropriate place for future reference would be a major enhancement.

"Act-Upon" Software

One requirement for mobile computer systems will be the ability to create, edit, mark up, and otherwise work with diverse types of information. Such categories are calendar, to-do, phone, fax, word processor, spreadsheet, and database.

The idea of act-upon software is that each type of document or file can be created in the portable computer, and then sent to the base station for final formatting and distribution action, instead of having to burden the portable with formatting, reformatting, and storing multiple copies of a single document (for example, a letter that is to be faxed to one person, sent via MCI mail to another, printed and mailed to yet another, and stored in the native format of the base station's word processor). Act-upon software provides a way to encapsulate a document within a folder. The folder would contain the formatting information, destinations, and other information required to remotely handle the document. In this case, documents would be stored in machine-native format in the portable (suggesting also compression techniques that could be employed for memory savings). The portable user would be able to prepare a file or document for transmission by simply instructing the system to "attach" one or more headers to the document that, upon receipt by the base station, would then command the base station to format and send one or more copies of the file to one or more locations by one or more methods.

The advantages of these transmission features become obvious. Because the system does not have to transmit information in formatted form, it provides a faster transmission capability. If new formatting requirements are needed, it is only necessary to add the formatting capabilities to the header files. If a document is to be formatted in a number of different ways, it is only necessary to send the information once, accompanied by multiple headers. Address books could then be built that would identify each person and the way they can be reached. For a memo to be sent to several people, it will be possible to look up the person and attach a formatting header to the document based on the information stored in that person's file (there could be multiple ways to reach the same person, which could lend itself to automatic follow-up file transmissions—send this by fax to John Q. Public and then confirm the fax transmission by mail, among others).

The Future

It is assumed that by year-end 1992 several new hand-held computers will be available from major manufacturers with capabilities that exceed the HP 95LX in communications and personal information management. These systems will have a mix of pen and keyboard user interfaces and will include software such as is described in "The Age of Appliance Computing," by Gerry Purdy of Phoenix Technologies Ltd. (*The Outlook*, Vol. 10, No. 9) and other similar designs. Communication will be limited to RS-232 serial cables, pagers, and infrared. The hand-held PIM software will be fairly unsophisticated. Pen-based computing will be limited to pilot programs in large corporations. Hand-held computer mass storage will be limited by cost.

It is assumed that more hand-held computers will emerge with 386SX chips and more sophisticated PIM software in 1993. The new PIM software will be aware that communications applications need to be notified of changes to the data. Pen-based applications will begin to proliferate. Two-way mobile radio will become one communications option, although still expensive. Hand-held computer storage will become less of a limitation because of lower cost. In 1994, hand-held computers should be fast and cheap enough that many processing and storage options will be affordable. Hand-held PIMs will be powerful and easy to use, and will cooperate with communications applications. Limitations will be screen size and keyboard usability. Pen-based applications will be quite usable. Two-way mobile radio will become reasonably priced.

Hand-Held Computer Vendor Dependencies

One trend we see unfolding, especially with the advent of the personal digital assistants such as Newton, is that operating systems, CPUs, and applications programs will not necessarily be compatible as we move forward. If data that arrive in the proper format can be received and sent among various platforms, then compatibility becomes a nonissue. Vendors of the software in hand-held computers must develop their PIM software with facilities to share data with communications/translation applications developers so that translators and formatters will be written to move data seamlessly between diverse platforms.

Several vendors have already taken steps to provide this type of "smart" communications links. Contact Software ACT has desktop software for both the Intel and Macintosh desktop systems. It offers a separate HP 95LX version that includes data integration and a Zapcards wireless business card exchange feature.

Goldmine, an advanced contact management software product from Elan, includes filters and import/export routines, not only to permit data to be moved intelligently to and from portables, but also to allow users to import data that already exist in another desktop software program. Traveling Software, LapLink Pro, and LapLink Mac are also moving in the proper direction. These products at present permit a user to not only move files but also to compare files between systems and then move the latest version to both systems. LapLink also provides interconnection capabilities that include direct connection and modem sessions. Adding the capability to communicate via wireless will not be a difficult task.

IntelliLink is perhaps the company—and the product—that is the farthest along. It routinely handles data translation on the fly, reconciliation, and merging. Its present product includes the communications links between the desktop and the hand-held world, but it has designed its product so that the intelligent data transfer portion can be separated from its own transport layer, giving it the advantage of being able to easily move the "smarts" of its program to any and all types of data transmission methods.

Conclusions

The good news is that the industry is beginning to recognize the need not only to move data, but to move information in an intelligent manner. The bad news is that we are still a long way from having the tools available that will make the end-user community flock to the small hardware devices that will become so pervasive, and useful, over time.

We have established the need, and end users are willing to spend the dollars. It is now time for the industry to respond with products that work.

Chapter 3
Apple's Newton

At CES, Apple provided the world with its first look at a hand-held computer product that we believe will revolutionize both hand-held computing and the consumer electronics industry.

This specific device in and of itself may not have this effect (although it could), but this class of device, with this genre of "smart" operating systems, will. The Apple product, Newton, is (will be) a hand-held device with pen input. A demonstration to analysts prior to CES focused more on the operating system than the hardware device, and what was shown at CES was not a standalone Newton, but rather a Newton that used a Macintosh as its "mother ship" to demonstrate the principles used in the conception and design of the product. Apple's preannouncement of this product, expected to be delivered sometime in early 1993 and priced at less than $1,000, has enough sizzle to get even the most staid computerist excited. Further, in keeping with the Apple tradition, it also delivers sizzle to the noncomputer user. In short, when Newton arrives next year, it will appeal to a wide audience.

Newton: What Is It?

Visually, Newton can be compared to the communicator used by Captain James Kirk on "Star Trek," complete with flip cover. Newton is not that small, but it does fit comfortably in the hand and the flip cover protects the combination screen/writing surface. Newton is designed to be used with a pen input device and incorporates an operating system that is tightly coupled to the hardware to provide an intelligent device.

To understand how Newton will work, we use the metaphor of carrying a roll of calculator paper with you wherever you go. This roll is never-ending and as you use it, "pieces" can be torn off and saved. The built-in programs can recognize and use the writing on the pieces. Alternatively, output can become a document that can be faxed or sent to another Newton or computer for transmission to its destination. The Newton is the first of a family of products; it makes use of an infrared link to move information between it and other computers. Future Newtons will likely use alternate forms of communication, including wireless (RF) devices that will be either built-in or attachable.

The Hardware

Newton's design around the ARM RISC chip itself is a departure of magnitude. It does not make use of a Motorola processor, as does the Apple Macintosh line of products, nor does it use either an Intel processor or an Intel-compatible CPU, as many popular systems do.

In truth, Newton extends the paradigm that began with the introduction of the HP 95LX. Yes, the HP 95LX is based on an Intel-compatible CPU, but this is not the main reason the product has met with great success. Rather, it is successful because it makes use of a series of applications contained in the basic system, and it provides the user with a solutions-oriented hand-held device that includes PIM capabilities. And, by the way, it is Intel- and DOS-compatible. Apple has realized that a hand-held device of this type will be attractive to users regardless of their desktop computer preference. Even those that may not use computers or are intimidated by them will be interested in this hand-held. Newton is a truly revolutionary and, in our opinion, intriguing product. The Newton design team was not hindered by having to give consideration to backward compatibility or any other limiting design considerations that might have resulted in a less than spectacular product.

It is hard not to get excited about Newton. Even though it is not "real," and even though we will have to wait for it, the concept and the marriage of hardware and software into a product such as Newton gets one's imagination going. Even if Apple's product never came to market (which is not the case), the vision behind it would have changed the expectations of hand-held computer users forever. We believe that Newton will become a "real" product under Apple's watchful eye and that it will appeal to the masses—not just the computer masses, but the masses in general.

The Software

The real excitement is in the software. At present, Apple is demonstrating the principles of the operating system and associated hardware using the power of a Macintosh. But we have to believe that Apple is confident that it will be able to retain all of the functionality and speed when Newton's tethers are loosed and it runs on its own.

The only word for the operating system is "smart." We have seen writing recognition demonstrated and have tried it. Newton is good and fast, and the action it takes when it recognizes words is almost uncanny. Typical of the actions Apple demonstrated at CES are the following: "Lunch with Isaac next Tuesday" is written on the screen. The text is recognized and Newton takes action based on its best understanding of the words. In this case, Newton would open the daybook and insert a lunch appointment with Isaac next Tuesday. Newton "knows" next Tuesday's date and "assumes" that lunch happens between noon and 1:00 p.m. The only thing that might puzzle Newton is exactly which Isaac is meant. If there is more than one in the database, choices are presented. Selecting the proper Isaac completes the transaction, and the calendar is updated. Write "call Isaac tomorrow," and Newton will put this note in your daybook—complete with Isaac's number(s). In this case, multiple numbers may be offered: office, home, mobile phone, and fax. However, if "fax Isaac" is written, the only number shown would be his fax number. Besides the entry, Newton will provide a dialing icon so that a touch of the pen can have Newton dial the proper number.

The Newton System

The basic, first Newton includes the display/writing screen, a built-in infrared communications link, a PCMCIA-compatible slot for PC cards (RAM, ROM, flash, modem, and more), and the basic PIM functions one would expect in such a device (notepad, scheduling, telephone, and address database). It even provides a graphics utility that is smart enough to recognize and replace crudely drawn circles on the screen with well formed and completely round circles.

This tight coupling of the operating system, a handful of small applications, and the hardware makes this product sizzle. The design team at Apple (or now Apple PIE) has come up with a winning combination of hardware and software. Its PDA term indicates that it understands that Newton is not simply a computer, it is a true appliance that can be used by anyone, either as a standalone device or in conjunction with existing computers. CES was a look into the not-too-distant future, and it signals the start of the war—not for the desktops of the world, but for the pockets and palms of the world.

The repercussion of unveiling the product concept at this time is that it will hurry along companies developing similar products. Several companies are rumored to be developing products that will use the AT&T "Hobbit" RISC processor, and some will use Intel or Intel-compatible processors. Several companies that were fairly far along in their own next-generation version of the HP 95LX have scrapped their current prototypes and design criteria and are starting anew, this time targeting Newton as their competition. Others are sticking to their guns and working on implementations of their own vision of hand-held computers, believing (and rightfully so) that the large market potential for these products will support not only multiple designs, but multiple paradigms as well.

Newton is being codeveloped with Sharp Electronics, which will be able to sell its own version. Apple has stated that it may, in some cases, license the technology to other vendors. Its motivation is for Newton to become the pervasive hand-held system over the next few years. By licensing the technology, Apple believes that it can create a bigger market in which to gain market share, and it can also keep others from encroaching on this type of product. It is not clear exactly how Apple will license this technology, or even exactly what it will license. We know only of its stated desire to do so.

Can Newton and/or Newton derivatives become the largest selling of the hand-held systems? Maybe, but, like everyone else, Apple is not working in a vacuum. Because it has preannounced its concepts and even demonstrated its smart operating system, it may be setting itself up for more, stiffer competition than it realizes. Apple is not alone in developing smart hand-held devices. We have heard about a number of these devices that either are on about the same schedule as Newton, somewhat ahead of Newton, or will be ready within a few months. The market, however, is large enough to provide a number of vendors with opportunities in the range of millions of units per year. Although a million sales of sub-$1,000 units may not be as profitable on a per-unit basis as 100,000 more expensive units, the volume possible with these products in itself will provide greater overall profit for each model. Obviously, Apple believes that Newton is unique and is so far ahead of the competition that it was not at RISC (pun intended) with this early announcement of the product.

From what we have seen, this may not be the case. Further, now that there is a known target looming on the horizon, other vendors may jump on the bandwagon and try to have their products available during the same period. Newton is a model to follow, imitate, and improve upon. Newton and its licensees may not have quite the open field they believe they will have. Part of Apple's strategy, it appears to us, is to use Sharp and several other licensees to meet the initial demand for Newton so it does not lose sales to non-Newton hardware. Even if a user buys a licensed Newton clone from Sharp or another vendor, Apple has not lost prospective customers, although, for the most part, non-Newton hardware vendors have. As Newton matures, Apple still will have the opportunity to convert a user from a non-Apple Newton to an Apple Newton with advances in technology and enhancements to the product. In addition, even if the non-Apple Newton user never buys an Apple Newton, Apple still benefits by collecting licensing and royalty fees.

Apple's game plan, then, must be to get Newton to market when promised (early 1993), and to handle (through licensees such as Sharp) the pent-up demand from those eagerly awaiting the product. Although this type of game plan might be compared to the SunSPARC licensing idea, we see it differently. First, Apple has stated that it will only license a "few" companies to build and/or market Newton. Second, the market for the Newton is 10 orders of magnitude larger than that for workstation products. Last, Apple knows that some of its licensed partners have far better access to the consumer channel than it does and therefore will pave the way for additional Macintosh sales.

Macintosh Sales?

As stated earlier, Newton will appeal both to existing computer users and to noncomputer users. Over time, the noncomputer user will be compelled to have a base station available for his or her Newton so that it can provide services not available using a standalone Newton without connectivity. Even when the wireless models become available, the user will not be able to take advantage of some of the true power of the system without a base station or home port for the Newton.

The standalone user will soon come to realize that Newton really shines when teamed with a base station. This will provide opportunities for many different types of vendors: e-mail providers, communications providers, and desktop and portable computer vendors. A non-computer user of a Newton, having mastered it and now ready to move into a connected world, makes a real (and much less expensive to find) Macintosh prospect. If the communications links are well established, the Macintosh will be the logical choice of the consumer that is soon to become a computer owner.

Missing "Links"

Missing are the links between the Newton and the rest of the world. In Newton, Apple has created a device that will work well in a standalone environment, but it will be more powerful and usable in conjunction with a base station or mother ship.

Without an umbilical cord of some kind (wired, infrared, or wireless), Newton at best is a much improved Sharp Wizard or Casio Boss. It provides the same functions as these and other electronic daybooks, and it goes a little further with its built-in dialing feature. It will be more fun and easier to use than a Wizard, and it will also be more expensive. When connected to the outside world, Newton becomes something much greater than the sum of the parts. Outside world connections give Newton availability to services it cannot provide on its own, provides reams of information it is not capable of storing all at once, and enables it to become a much more powerful work tool.

This electronic umbilical cord is both the strongest and the weakest link in the Newton chain. If the software running over this link is properly planned and implemented, the value of Newton rises substantially. However, if the state of the communications software art does not move ahead rapidly, Newton will be little more than a flash in the pan, ready to be replaced by any one of a score of new integrated hardware and software devices that may handle the communications issues in a better way. It is too early to tell if the design team and the rest of Apple really understands how dependent Newton will be on communication and how important it is to the success of the product. As we get more and more information from Apple over the next nine months, we will find out exactly how important systems integration is to the father of Newton, and how much it really understands. Although Apple has indicated that it realizes that communication is a key element in the PDA strategy, it has not yet been willing to discuss ideas and/or plans. Several companies are known to be working with Apple in this regard, with communications products planned for introduction shortly after Newton is available for sale early next year.

Sales Projections

According to a number of different sources, Apple's first Newton is expected to sell from 200,000 units to more than 1 million units in the first year. Apple has not commented on the figures nor has it indicated how involved its partner, Sharp Electronics, will be with the

Apple version of the product versus its own offering. Inconsistent sales projections across the various industry organizations have more to do with individual perceptions of the value of PDA-type products within the end-user community than any other factor.

The most bullish estimate comes from SRI International, while the most conservative estimates are from companies that generally watch the workstation and PC desktop markets and have little if any experience in consumer electronics areas. Further, without any real experience with this type of product, it is not possible to predict how successful it will be, and the demographics of the user community are difficult to determine. The two final issues that cloud the sales forecasts have to do with plant capacities and available communications interfaces.

It is safe to say that Apple and its partners will do well with this first PDA offering. However, they will not run away with the market, nor will they succeed in their stated objective of Newt (the Newton operating system) becoming the pervasive hand-held OS. There are too many highly qualified and highly skilled competitors lurking around the world and too many different approaches to solving the end users' problems and meeting their needs. Apple announced first, but another vendor may actually ship first. In either event, the size of the hand-held organizer/PDA/hand-held computer market is large enough to support many different players and offer the end-user community many choices. Newton has sizzle, it is functional, and it answers the needs of millions of people who want to be better organized no matter where they are, but it is not yet available. Between now and when Newton will be available, another product with more sizzle and more functionality could be introduced or, playing Apple's own game, shown well before it is ready to be brought to market.

Apple has captured everyone's imagination. Now it needs to produce Newton to capture pocketbooks as well. In the meantime, we too are captivated by Newton's promise. We see a hundred ways in which it could help make our lives easier each day. The concept is brilliant, it sizzles, and it is inventive. We trust Apple and look forward to it being able to deliver on its promise. If it cannot deliver, or if the PDA is delayed for any length of time, Apple's image will become tarnished, and the blow to its credibility will be difficult to overcome. It may not have bet the farm on Newton, but Apple has certainly bet John Sculley's reputation and ability to lead the rest of the computer industry into the age of consumer computing.

Newton: The Name

The name Newton is singularly appropriate because of Sir Isaac's involvement with an apple. He formulated the theory of gravity after an apple fell from a tree onto his head.

It is possible that today's Newton, or this family of products, will influence the industry to develop a new form of computing that is not computing at all but the adaptation of computing devices for the masses. Newton may hit the computer industry over the head just as the apple did Sir Isaac!

Chapter 4
Here Comes GO: PenPoint 1.0 Is Now Available

Pen-based computing has finally arrived! Or at least that is what the folks at GO Corporation would like us to believe. GO announced the availability of PenPoint 1.0 in April, its operating system for pen-based computer systems.

Just a week earlier, at COMDEX/Spring, Microsoft was on the floor with Windows for Pens, and GRiD, CIC, and Momenta have all had pen operating systems on the market for some time. So why is GO's announcement considered to be the "true" start of pen-based computing?

First of all, GO's operating system has been designed from the ground up with the aim of being more than just pen-aware. It is fully designed to specifically take advantage of the pen as an input device. In addition, it has been hyped by the independent software vendor (ISV) community and the press as being one of two major operating systems that will become pervasive in the world of pen computing. (Microsoft's Windows for Pens is the other.) And finally, the GO announcement marks the beginning of the battle for the pen user.

The end-user community has been waiting for GO's offering (as well as Microsoft's) in order to see the differences between the two systems and how ISVs will provide software for these platforms.

Hardware and software vendors have been waiting for GO's PenPoint 1.0 to begin shipping because once it becomes available, these vendors can start shipping their products in volume. Additionally, these vendors have been waiting for PenPoint 1.0 to launch so that they can ship products that take full advantage of the pen, not just products that show its promise.

Pen-Based Computing: The Elements

This is the first time in the history of computing that all of the elements needed to create a computing environment—the hardware, the operating system, and the applications—have come together at the same time. It is also the first time in history when an operating system is pushing for state-of-the-art hardware.

GO's development efforts started in 1988, well before today's powerful CPUs were available. During the last four years, the improvements and enhancements that have been made to GO's first operating system model have been possible because of the increased speed and performance of the processors, and because of the increase in the amount of memory available in a system and the decrease in its cost. PenPoint 1.0 has been optimized for the world of 32-bit processors. It is a preemptive multitasking, general-purpose operating system uniquely suited for pen computing.

The preemptive multitasking abilities built into PenPoint are important: They let users' work take priority, even while background tasks such as handwriting recognition and communications are in process.

The system uses virtual memory that enables the system to make use of a hard disk as an extension of RAM, permitting more applications and larger documents to be open at the same time. This gives users the ability to switch between tasks more quickly.

Help for users is provided in three different ways: context-sensitive help, a help notebook, and quick-start tutorials. To use context-sensitive help the user needs only to draw a question mark on the item. The help notebook provides more complete topic-based help information, and the quick-start tutorials permit users to become conversant with the system in only a few minutes—typically 10 minutes or less.

PenPoint 1.0 Features

Handwriting Recognition

GO's handwriting recognition engine, GOWrite, includes features that GO claims permit excellent "walk-up" accuracy (no training or practice), robust recognition, tolerance for sloppiness and sharp handwriting variation, trainability, and broad coverage. GOWrite recognizes more than 25 punctuation characters and a wide variety of writing styles by using a database of more than 700,000 handwriting and gesturing samples.

Look and Feel

The first view of PenPoint is a Table of Contents page, with tabs along the side and some small icons at the bottom. The entire metaphor of the system is unlike any other type of desktop computing environment in widespread use. An application is never launched, and documents are not loaded on top of the application. In PenPoint, the applications are resident, but not visible. Instead there are pages in a notebook, with each page created by the application that controls it.

Easy to Learn

Learning to use PenPoint is easy. There are only a few basic gestures that users need to learn. Once users learn those gestures, they can move freely around within the system, doing productive work and learning more about gestures and movements as they proceed.

Compatibility

PenPoint can read and write MS-DOS-formatted disks directly and can import and export many standard file formats such as RTF and TIFF. Support is also provided for Novell NetWare, AppleTalk, and native TCP/IP. In addition, several software vendors have designed and are shipping other communications-related products.

Product Specifications

The present version of PenPoint 1.0 is designed for the Intel 386 family of microprocessors, but future PenPoint versions will run on other processor types. We expect to see some very powerful RISC-based systems become available before too long.

Two applications are shipped with the OS: MiniText and MiniNote. MiniText is a simple text-editing and word processing application, and MiniNote is a basic note-taking application that permits users to scribble notes on the screen.

Memory Configuration

GO recommends 2MB minimum memory when PenPoint is ROM-based, and 4MB if the OS is disk-based. PenPoint supports memory configurations up to 256MB of physical memory and up to 4GB of virtual memory. In addition, the OS supports IDE-based hard disks as well as silicon (solid-state) disks. The OS requires 3.5MB of disk space, and virtual memory requires an additional 4MB to 5MB of space.

File System

PenPoint 1.0 supports the MS-DOS file system. The maximum number of documents that can be opened at the same time is limited only by the amount of memory available. The maximum file and volume size as well as the maximum files per volume are unlimited, but are dependent on the amount of disk space available.

PenPoint reads and writes to floppy disks in MS-DOS 720KB, 1.44MB, and the new 2.88MB formats. It also supports an external keyboard, external disk drives, floppy drives, and even some SCSI devices, depending on the hardware vendor's implementation of the system.

Display Support

PenPoint's display support is hardware-independent. If a VGA-compatible controller is used, PenPoint displays eight shades of gray based on 3-bit planes. A 1-bit plane is used for the ink annotation layer of the PenPoint interface.

Software

The software applications shown at the announcement included Slate's Day-Timer, and LapLink Pro for PenPoint (a collaborative product from Slate and Traveling Software). The Numero spreadsheet by

PenMagic Software was also demonstrated. Ink Development showed off InkWare Photo and Notetaker. Pensoft was there with its Perspective 1.0, a very robust (PIM) based on a relational database model. Many companies demonstrated vertical market packages designed to provide pen-based solutions to a variety of function-specific users. In addition, some companies demonstrated their own connectivity ideas, like Sitka with its PenCentral connectivity options, and Photonics with its infrared transceiver connections.

Operating System Summary

PenPoint 1.0 is a robust operating system that has been specifically designed for pen interface and interaction. PenPoint 1.0 includes its own handwriting support that can be replaced if another recognition system is preferred by the user. It supports embedded document architecture (live documents can be embedded within documents). It is display-scalable (runs on any size screen from very small to very large), and it has been designed to provide a new way of working with computer documents.

PenPoint is an object-oriented operating system that uses true 32-bit architecture and supports virtual memory. It is as compatible with MS-DOS as possible while retaining its own look and feel.

Dataquest Perspective

Dataquest does not believe that the average end user will beat a path to the retail stores of the world to purchase his or her very own pen system this year, or even well into next year. Instead, Dataquest believes that those hardware companies that will be successful are ones that invest the time, effort, and money to work on pilot programs with the corporate world. The first implementations of pen computing will come in vertical markets, where fully integrated hardware and software platforms are designed to provide specific solutions to current, identifiable business problems.

Companies that are already working with their corporate clients to find ways to integrate their pen-based offerings into the corporate computerized and, more important, noncomputerized operations—companies like IBM, NCR, and GRiD—will sell hardware this year. They will not sell just one and two units, but hundreds of units. Companies that do not have contacts with the corporate world will struggle through the next 12 to 18 months.

GO's announcement marks the true start of pen computing, a beginning that will change the way most of us regard computers and the way we interact with them. It is an exciting time and one that will be marked in the history books along with the introduction of the Apple II and the IBM PC. To the venture-funding organizations of the world we offer the following advice: Have patience and do not push too hard, for if you do you can only further delay the acceptance of pen computing. Putting pressure on companies to turn a quick buck can only hurt them and the industry as a whole.

Partnering and long-term strategies are going to be very important in this market segment. But the understanding of how people work, and how to integrate this technology with work habits, is the most important factor and will give many systems vendors a real advantage over the "box" shops. Finally, Dataquest believes that hooking the end-user community is more important than ever.

Congratulations to GO and to all of the vendors that are following GO into the market. Vendors have to be careful not to get into an "ours has to be the only one" position. Vendors need to earn their place in the market by providing solutions for users and accepting the fact that users may make other choices. The industry has to keep GO versus Microsoft from becoming as debilitating as Microsoft versus IBM has become to the desktop world.

Chapter 5
GO and AT&T Ally to Embrace Personal Communications

The world of personal communications devices, or personal information processors, or what Apple Computer refers to as PDA, is heating up. Apple announced its first PDA—called Newton—at the end of May, with plans to ship in the first quarter of 1993. Tandy, Casio, and GeoWorks announced plans for an alliance on May 27, and Day Runner and Texas Instruments announced a "cooperative development agreement" on July 14. Perhaps the most significant announcement, however, is the one from AT&T Microelectronics and GO Corporation on July 13 of plans to develop a personal communications platform.

None of these announcements involves products that exist to touch and feel today, although a prototype of the Apple hardware product was shown at Apple's Las Vegas launch. The AT&T-GO announcement did not include any hardware products, nor did the announcement hint at which vendors might be developing hardware for this integrated computing platform.

Tight Integration

Although the announcement did not include any hardware for the world to marvel at, or even a demonstration of what was being introduced, the announcement may turn out to be as important as—if not more important than—the Apple Newton announcement made a month and a half earlier.

At the base of this alliance is the coupling of GO's PenPoint mobile operating system and the Hobbit microprocessor from AT&T. This was not just a "here is the hardware platform, and over here is the operating system" announcement. It was, instead, "here is a very powerful, very low-powered microprocessor, and here is the operating system that will be integrated to form a powerful, portable communications and computing platform."

The Name

AT&T has chosen to name its future hand-held devices "Personal Communicators," which will be "rich in communication and will integrate voice, data, handwriting recognition, fax, electronic mail, still images, and in the future, full-motion video. These devices will provide anytime, anywhere communication to a whole new class of business users and consumers who need to constantly stay in touch," according to AT&T.

The Meat

In a nutshell, GO has optimized a version of its PenPoint operating system for both the Hobbit architecture and communications applications. AT&T has developed a series of low-powered microprocessors that work with digital signal processors (DSPs) and other technologies required for communications-oriented devices.

Even the Hobbit chips were not announced this time around. Instead, AT&T addressed the near future and the power that its new C-language Rational Instruction Set Processor (CRISP) CPU line will bring to mobile computing and how tightly it will be integrated with the GO operating system.

For its part, GO Corporation talked about the configuration of its PenPoint operating system for the mobile communications market. Special support for mobile computing has been added to the operating system, and it now supports intermittent connections via wired and/or wireless links. In addition, the operating system permits multiple simultaneous communications links, and it can store and forward messages, files, and information when connections are established (or re-established).

Interesting, But...

AT&T and GO Corporation have fired a volley in response to Apple's Newton introduction. But if they are not showing a product, or even discussing specific products or delivery dates, then why is their alliance perhaps more important than the Newton announcement?

First the Hardware

Dataquest believes that companies such as EO (the hardware spin-off from GO), as well as several others, will announce and demonstrate their fully integrated products prior to the end of this year and that they may even ship a small quantity of their offerings by the beginning of next year.

However, both AT&T and GO acknowledge that the first hardware platforms to offer the combination of GO's PenPoint and AT&T's Hobbit processor will have a larger form factor than Apple's Newton. They discussed upcoming products in vague terms but indicated that we should expect to see larger, clipboard-size products first, followed over time by smaller and lighter units.

These units will be "very powerful" (says AT&T) and—with the proper power management—battery life should be better than acceptable. Although AT&T did not, in fact, announce the Hobbit chip except to acknowledge that it does exist, AT&T did discuss the architecture of the chip and why it is "ideally" suited for the mobile computing environment.

Designed into the chip, according to AT&T, are the following capabilities:

- Fast context switching to move quickly from one process task to another is an important feature for personal communications devices, because the processor needs to service multiple processes—for handwriting recognition and several communications connections—simultaneously.
- Fast interrupt response allows personal communications devices to quickly respond to and service interruptions (such as incoming calls) while still allowing the operating system to provide a smooth, responsive interface.
- Low bus activity makes the system bus available for DSP or other communications hardware components to send communications process-handling information and other data to memory without interference from the main processor.
- Processing headroom to handle real-time communications tasks, especially those that involve rich data types—such as graphics, voice, and video—that require tremendous amounts of processing power. Hobbit represents a leap forward in providing this processing power at a cost low enough for consumer products.
- High code density allows products to be built with smaller memory systems resulting in lower overall system cost.
- Low power dissipation is achieved through an efficient power management architecture, which is controlled by GO's PenPoint operating system.
- Stack cache optimizes function call efficiency. Instead of operating with registers that are visible to the user, the Hobbit provides a run-time stack cache. This approach minimizes the overhead associated with procedure calls, which account for 1 out of every 20 instructions (or more in C language operating systems). PenPoint's object-oriented design allows an application programmer to send a single message that will result in the automatic performance of many functions by inherited classes in the system. The Hobbit stack cache makes resulting function calls highly efficient and fast.

All of these features of the Hobbit CPU, according to AT&T, make this platform the "perfect" fit for mobile communications and computing.

Systems, in addition to the main processor, that make use of the Hobbit chip can also include other low-power chips developed by AT&T Microelectronics, including a family of DSPs that AT&T claims will add a high degree of intelligence to both the product and its communications capabilities.

The Operating System

When GO's PenPoint operating system was first announced, the potential scalability of the system was one of the primary features discussed. The use of PenPoint on a hand-held platform has been a part of GO's plans since the inception of the operating system, and while scalability is important, the other features added to PenPoint during the past year are also a vital part of the package.

Because PenPoint uses object-oriented programming to provide a tightly knit core of reusable classes from which all applications and communications services are built, all types of documents, regardless of the application, become "communications enabled." This means that a document can be sent as a fax, printed material, an electronic mail message, a pager message, or a file to a desktop computer.

The other features of the operating system that have been specifically built in for mobile computing include automatic detection of device and media attachment and detachment (the ability to dynamically load and execute protocols in response to external hardware events, such as a wireless connection being made).

The AT&T-GO Vision

The press materials addressed the ways in which personal communicators will be used and how easy it will be to make a connection and take advantage of the built-in systems communications "smarts." AT&T and GO also envision a series of Hobbit-GO-based products, varying greatly from each other but all with a common focus: mobility and communication. Some of the ideas that they presented include pocket-size cellular telephone and notepad devices and notebook-size multipurpose communicators that include both data and voice communication and interaction.

AT&T and GO believe that this combination of tightly integrated hardware and software will provide their customers (who will be designing and selling the end-user products) the ability to differentiate their products and, as a result, help prevent the price wars that are now thinning out the ranks of PC vendors.

Several statements were made both during and after the press event indicating that hardware products based on this combination of the Hobbit chip and the PenPoint operating system will be introduced by the end of this year. Certainly, there has been much speculation regarding the GO spin-off EO, which is reported to be building a product based on this architecture.

The Real Deal

The press event was held just prior to the start of the Mobile '92 trade show and was well attended. A short time was spent discussing the "real" reason that people should be excited about this announcement, but not much attention was really drawn to the total communications picture.

Both AT&T and GO talked briefly about communication, indicating that they understand the need for robust communications links. Their

joint statement regarding communication seems to sum up their approach to the importance of moving information from one point to another: "If personal communications are to be successful, they will need to work hand-in-hand with today's existing wired communications infrastructure and be poised for the emerging wireless revolutions. Together, AT&T Microelectronics and GO will work with third-party partners so that the new platform will connect to key network resources and services."

The press release also reveals plans to incorporate features to make the Hobbit-based systems "wireless ready" using any of the wireless choices that are, or will be, available. Current choices are wired, infrared, and wireless connections, with the wireless option including cellular, packet radio networks such as RAM Mobile Data and Ardis; paging networks such as SkyTel and Embarc; and future networks such as those that rely on satellites.

Missing from this discussion, however, is the fact that AT&T owns and operates the largest wired communications system in existence and is involved in many cellular systems, paging, and point-to-point networks. Dataquest believes that AT&T has not yet played its trump card in this area.

If personal communications devices are to become as important as many people in the industry believe that they will, then it is the networks (as much as the technology and magic contained within them) that will enable these devices. AT&T understands this perhaps better than any other company. During its long history of being *the* telephone company before the divestiture, and even since its breakup, AT&T has been a provider of the network used for communication, and AT&T wants to continue to use this network. When it was the only provider, it rented telephone instruments to customers to plug into its networks. When customers first developed a need for radio paging or mobile telephone service, they purchased or leased equipment from AT&T and used its network.

Shortly before and certainly after the divestiture, AT&T was faced with competition in all areas. Many other companies moved in to provide the hardware necessary to connect to their own networks, and several other companies have even emerged to challenge the supremacy of AT&T's networks. However, it is still true today that AT&T's main strength is its networks, especially now that access to information is key to corporate success. The challenge still remains the ability to move information from one place to another.

The Hook

AT&T does not just own networks, it also owns services—such as AT&T Mail—that run on top of the networks. At present, AT&T Mail competes with MCI Mail for electronic delivery of e-mail on a worldwide basis. Some companies are using either AT&T Mail or MCI Mail to virtually run and coordinate their operations.

AT&T Mail, as well as AT&T's other communications networks, can serve as the point of contact for many personal communications devices. Users would not have to make decisions about the type of communications network that they needed—access to AT&T Mail could provide a gateway to any of the other services.

Access to AT&T Mail can be accomplished by wire, direct phone connection, LAN computer systems, and other networks. Access through wireless systems is easy enough to accomplish. After all, the wireless connection is an extension of the network, running through the air instead of on a pole, but part of the network nonetheless.

If AT&T couples the power of the Hobbit with the power of PenPoint and then provides easy access to its own network, the combination is one that will give it a decided advantage in the personal information processor field. AT&T will have the opportunity to sell the chip sets, help OEMs build the products, and then sit back and collect the rent for the use of its networks from all of the Hobbit users.

Dataquest believes that AT&T will work with all of the other service providers but that its main thrust will be to provide the missing link: the communications path from the hand-held device to the desktop or network device—as an integral part of the rollout of products.

Dataquest Perspective

As with the Apple Newton announcement, the AT&T-GO press event left as many questions unanswered as it answered. The two companies did not elaborate on exactly what vendors will provide hardware, or when the products will become available, or about the type of "seamless" communication that the products will offer.

Both AT&T and GO gave the distinct impression that they intend to handle every piece of information that goes into and comes out of the personal communicator as a document of one form or another. The operation to move a document from a remote base station to a hand-held system, as it was explained, involves having the document arrive at the personal communicator and be exposed to all of the applications in residence, and then have each application alert the user as to whether it can or cannot provide a home for the document. In this way, information can be sent to and received from the personal communicator, recognized by an application, and "attached" to that application.

What AT&T and GO did not discuss or demonstrate is an understanding that communication goes way beyond the transmission and reception of documents. Much of the information that will be received by and sent from personal communications devices will not be isolated or standalone but will be a piece of a larger pie that needs to be integrated with other information that often exists in a different form.

It is not clear that AT&T and GO have taken the communications metaphor far enough yet. There is still time, and AT&T does understand how to move enormous amounts of data from anywhere to anywhere. It will be interesting to discover whether or not the combination of AT&T and GO will be able not only to move the information but also to move it smartly, seamlessly, and quickly.

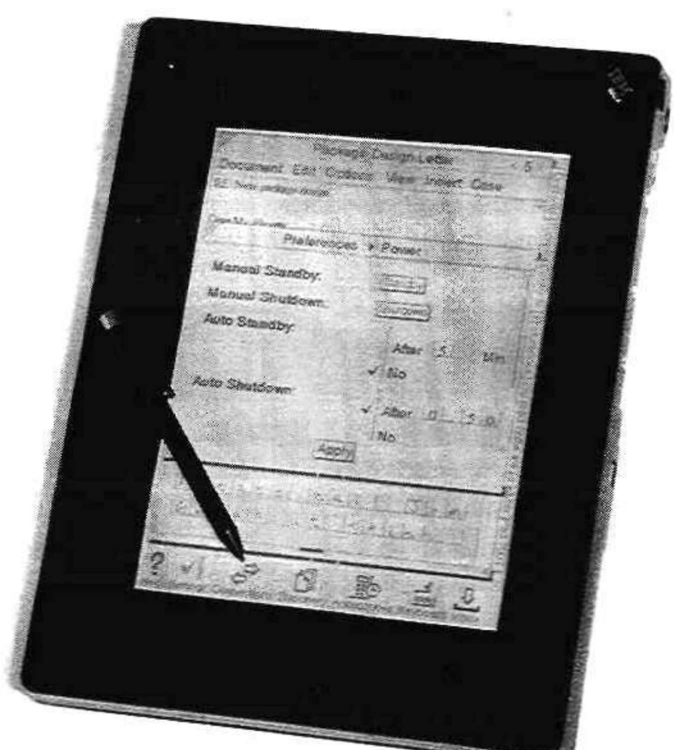
Without having seen the software or the hardware, it is impossible to declare the AT&T and GO alliance a success. In some ways, Apple has set higher expectations within its potential user community because it has demonstrated its concept of mobile computing on a hardware platform that is supposed to become real in the first quarter of 1993. On the other hand, AT&T and GO have announced an alliance that, when coupled with a third-party hardware supplier, will provide a product with just as much sizzle and even "more functionality" (their words) than the Newton. If the first efforts are not quite right, then the alliance has a chance to work with hardware vendors to correct problems while continuing to work with other vendors to improve existing products.

All of these personal communications/information devices are still evolving. AT&T and GO have provided a hardware and operating system platform that hardware vendors can add value to and bring to market—and probably connect to an AT&T network.

Chapter 6
Convergence to a New Form Factor

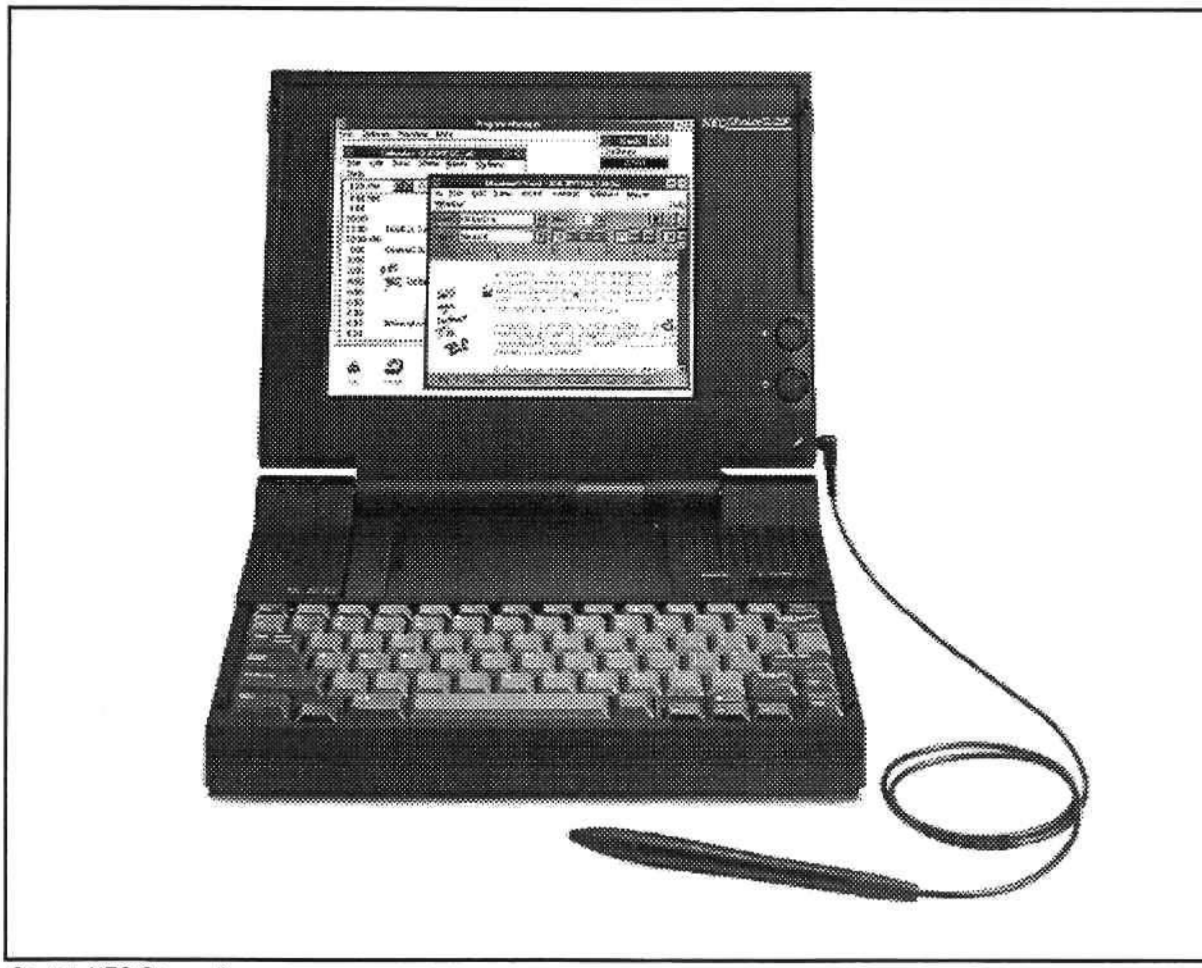
Current-generation notebook PCs are built around the 386 or 486 Intel MPU, have a 2.5-inch hard disk, a floppy, and fax/modem communication capabilities built-in. With respect to form factor, pen-based PCs today are similar to notebook PCs, and even though current-generation notebook and subnotebook PCs use a keyboard for information entry, they can easily be converted so that they run a pen-based operating system such as the Microsoft's Pen Windows using a "pen" instead of a mouse. Figures 6-1 and 6-2 show examples of pen-based systems, the IBM Thinkpad 700T and the NEC UltraLite SL/20P. The NEC model includes dual interface with both a stylus and a keyboard, and has mouse emulation via touch or stylus input.

Figure 6-1
IBM Thinkpad 700T



Source: IBM Corporation

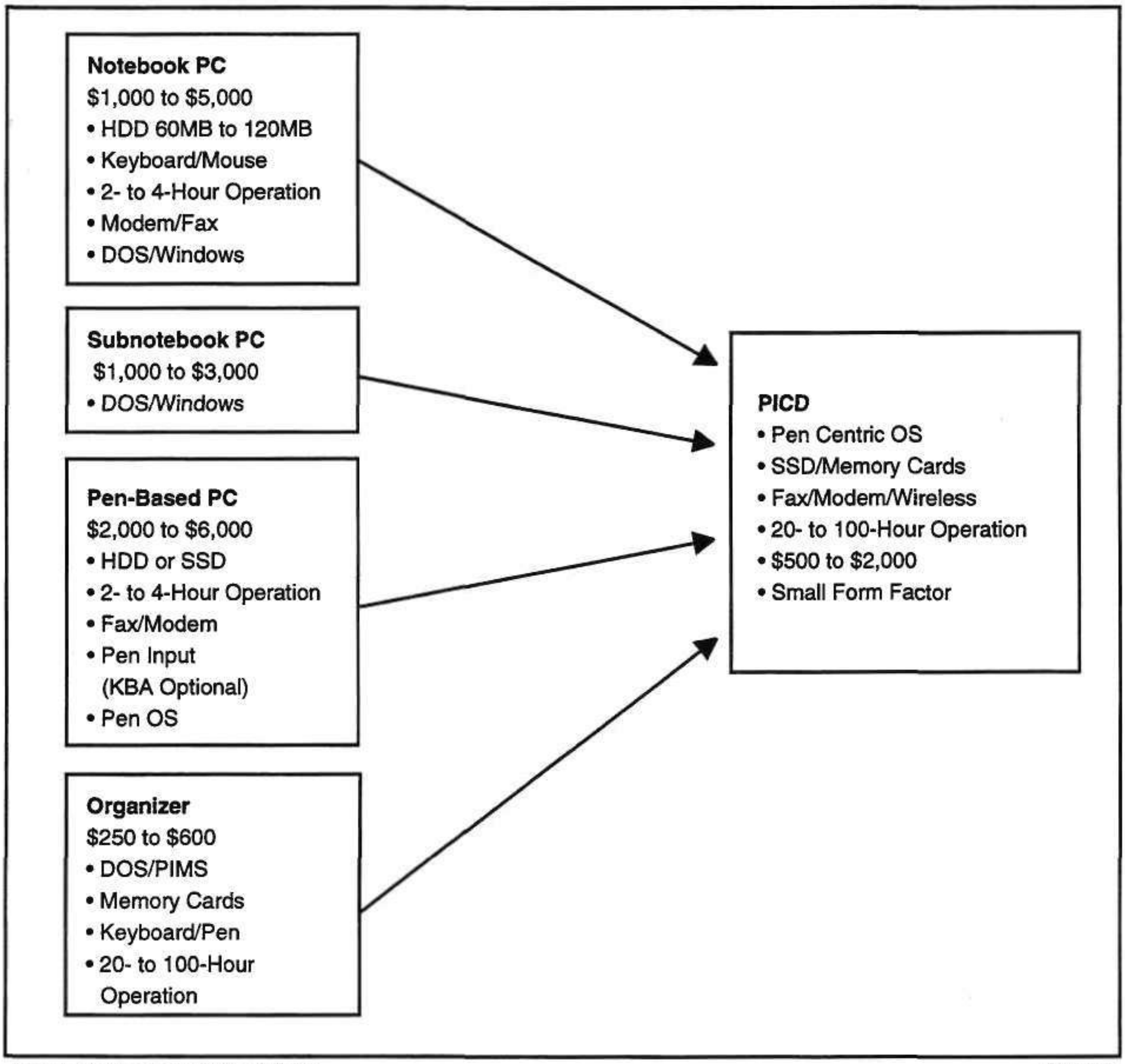
Figure 6-2
NEC UltraLite SL/20P



Source: NEC Corporation

This easy transformation of notebook PCs to pen-based PCs by simply replacing the mouse with a pen may indicate that the "pen-based PC" is not really a valid form factor, but perhaps a transient PC classification. Hand-held PCs such as the HP 95LX may acquire a pen to be used as an additional input device, and the same is true for organizers. As a matter of fact, Sony has offered one for the Japanese market, and Sharp has demonstrated a Japanese version of a pen-based organizer. All these form factors are in the process of experimenting with the use of the pen as an input device to replace or supplement the keyboard. In the process, they seem to be converging to a new form factor, as exemplified by Apple's Newton. Figure 6-3 shows that trend, which is being made possible by availability of low-power/high-performance semiconductor components and the emergence of new user-friendly and intuitive operating systems and software. Success of PICDs depends as much on the availability of new operating systems and software applications as it does on hardware.

Figure 6-3
Convergence to a New Form Factor



Source: Dataquest (October 1992)

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Microprocessor Wars Revived?

For PCs, the microprocessor issue has been mute for a while now. Simply stated, the majority use X86 architecture devices, currently in the migration path along the 386/486, and soon to be P5. The major exception to this is, of course, Apple using the Motorola 68000 family of devices for its products to date. Intel in essence has been a stabilizing force when it comes to MPUs for PCs. For its immense success, it has been rewarded recently with as much as 60 to 70 percent of the profit per motherboard sold! So far most challenges mounted against Intel and the CISC camp of MPUs have failed, at least as far as PCs are concerned.

What appears to be different now is that the most significant implementations of future PICDs are not scheduled to use an Intel X86 architecture MPU. Apple's Newton will use the ARM microprocessor from VLSI, while the AT&T/GO alliance has proposed an open architecture that uses AT&T's Hobbit microprocessor. Both ARM and the Hobbit are RISCs.

Is this a RISC-CISC war again? Not really. The lines between RISC and CISC have blurred sufficiently to make this a nonissue. The reason for not using X86 MPUs may be simple: PICDs do not need to run DOS or Windows, thus there is no need for backward software compatibility. That in turn opens the door to new possibilities because, for the first time in a while, it is open MPU season for an up-and-coming PC form factor.

Why ARM or Hobbit?

The tasks that Apple is envisioning Newton performing—handwriting recognition, speech and image processing, and communication, among others—are quite taxing for a 386 class of microprocessors. And even though a 486 or P5 may have an easier time, there is the issue of power; because PICDs need to be portable, watts of power are not available to the MPU anymore. Thus, the search for a powerful yet power-nimble MPU.

The MPU players are as follows:

- VLSI Technology Inc.: ARM
- AT&T: Hobbit
- Intel/AMD/Cyrinx/Texas Instruments: X86SL
- Motorola: LSC80018
- VADEM : VG-230
- NEC/Sharp: V20 and V30
- Chips & Technologies: PC/CHIP

Operating System Suppliers for PDAs, Personal Communicators, and PICDs

Suppliers expected to offer or attempt to offer operating systems for PICDs are as follows:

- Apple
- GO
- GeoWorks
- Microsoft
- Communication Intelligence Corporation
- Others

AT&T and GO Revisit the Past (in Search of Future Profits)

We may be revisiting history here. Not long ago many good microprocessors were around for building a PC. The two most successful were the 6502 used by Apple II and the Z80 used by everybody else. There were also at least two popular operating systems, one from Digital Research running Z80 machines, and Apple's proprietary OS running Apple II. Then came the IBM PC using the Intel 8088 microprocessor and a relatively unknown operating system, DOS, from Microsoft. The rest is history.

Microsoft grew into the largest supplier of operating systems on the planet, becoming a mammoth-size company overnight. Intel was thereafter established as the king of microprocessors for PCs, which in turn established PCs as the mainstream computer business. Apple did well following its own path, and led the way with some superb products that were soon emulated. To get the horsepower needed by new products, it replaced the 6502 with a line of powerful MPUs from Motorola, the 68000.

Where are we today? Apple is proposing a new visionary line of portable products (PDA), with Newton first in line. It will use its core expertise to provide a proprietary operating system. It chose ARM, which, by the way, is a 6502 RISC derivative! AT&T is proposing an open standard architecture with Hobbit as the core MPU running GO's pen-based operating system. GO is a relative newcomer in operating systems, the way Microsoft was 10 years ago. AT&T is where Intel was before IBM's endorsement. Does AT&T want to become Intel for the MPUs of PICDs? Does GO want to become the Microsoft of the next century? There is no question that GO would love to replace Microsoft, and that AT&T would welcome the opportunity to be the Intel of PICDs.

However, at this point both companies appear focused on the short-term objective: to provide useful hardware and software for Personal Communicators and similar classes of machines. The possibility of AT&T and GO replacing Intel and Microsoft at the top may be real for the first time in years.

Overview: Semiconductor Opportunities

PICDs will most likely be configurable at the user level, for two reasons, as follows:

- It makes for flexible systems, allowing the user, for example, to pick the size of the solid-state disk (mass storage) required at the time of purchase. The same holds true for other options such as PCMCIA fax/modem, Ethernet LAN cards, memory cards, expansion memory (PCMCIA form factor), and software packages (PCMCIA ROM cards).

- The basic system is low in cost, a must for PICDs to reach high volumes. As a result, opportunities for semiconductor vendors will be found in the following areas.
  - Mass storage
    - Memory cards
    - Solid-state disks
    - Small form factor rigid disk drives
  - Communication
    - Infrared (IR)
    - Radio frequency (RF)
    - Fax
    - Modem
    - Voice
    - Cellular
  - Data compression
  - Video
  - Audio

The following discussion examines a range of semiconductor opportunities, primarily for small form factor portable PCs, by presenting pertinent market size and growth data of selected areas as well as specific examples of current implementations and future trends. (It should be noted that a good treatment of trends and semiconductor opportunities in video, audio, and compression, among others, can be found in Dataquest's Multimedia report.)

Market Overview

Table 6-1 shows the portable computer subset of the PC market forecast provided by Dataquest's PC group. It is worth noting that handheld PCs are second only to pen-based PCs in terms of unit growth, and are expected to account for 23 percent of all PCs sold by 1996. Table 6-2 shows the worldwide portable PC market forecast by product type.

Figure 6-4 is our market estimate for PICDs, whose success will depend heavily on execution. As with all new markets, this market will take time to develop. After all, it took at least 10 years for the PC market to reach its present stage of maturity. Opportunities for this market are emerging in semiconductors, systems, and software.

Table 6-1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	2,764	3,101	3,392	3,669	3,933	4,114	8.3
Notebook	1,136	1,794	2,816	4,393	6,809	9,464	52.8
Pen-Based	41	122	800	1,759	3,289	5,098	163.0
Hand-Held	238	763	2,042	3,877	6,188	7,314	98.5
Total Portable	4,179	5,780	9,050	13,698	20,219	25,990	44.1

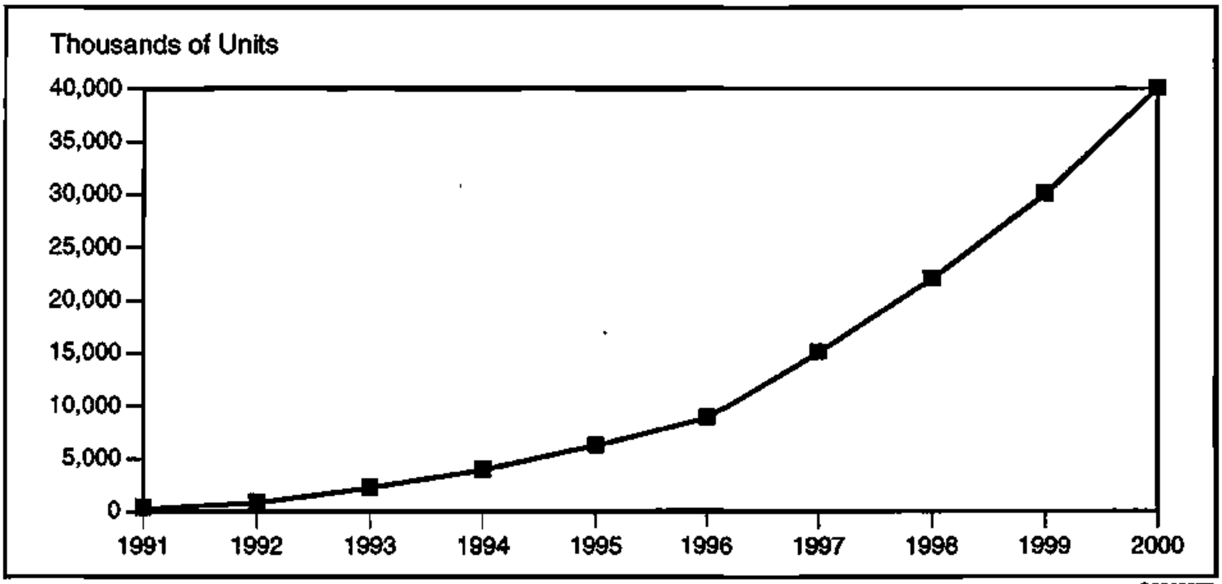
Source: Dataquest (October 1992)

Table 6-2
Worldwide PC Revenue Forecast, by Product Type (Millions of Dollars)

Type	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	4,852	5,256	5,513	5,980	5,860	5,965	4.2
NoteBook	1,795	2,857	4,369	5,798	8,238	10,410	42.1
Pen-Based	85	268	1,917	4,391	7,966	11,978	169.0
Hand-Held	86	254	653	1,193	1,832	2,083	89.2
Total	6,818	8,635	12,452	17,362	23,896	30,436	38.1

Source: Dataquest (October 1992)

Figure 6-4
Worldwide PICD Shipment Forecast (Thousands of Units)



Source: Dataquest (October 1992)

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Chapter 7
Nomadic Computing and Semiconductor Opportunities for Hand-Held PCs

Portable PC terminology is confusing. Definitions change with time as technology races to fit a Cray supercomputer in a shirt pocket! In this article, Dataquest provides basic definitions and then discusses trends and semiconductor opportunities in the portable PC industry.

Definitions

A notebook PC is a desktop PC shrunk to the approximate size of 8.5 × 11 × 1.5 inches; it weighs 4 to 7 pounds.

A subnotebook PC or companion PC is basically a smaller notebook PC that typically measures 10 × 6 × 1 inches and weighs less than 3 pounds. It may use a floppy and a hard disk or silicon disk for mass storage.

A hand-held is a desktop PC shrunk to at least a size of 8.5 × 4 × 1 inches (more often 6 × 4 × 1 inches) and weighs less than 1.5 pounds. Because of size and power constraints, hand-held PCs do not use a hard disk for mass storage. Instead they rely on PCMCIA-type memory cards to fulfill this function. The memory card here performs dual functions: that of a removable mass storage device (hard disk) and of a floppy that allows for information exchange. The term palmtop is often used to indicate a similar class of machines. For our discussion we will focus on machines that support a standard operating system (OS) such as DOS.

A personal organizer is a small portable device (6 × 3 × 1 inches or smaller) typically running a proprietary OS and a small set of personal information management (PIM) utilities such as appointment calendars and phone books. Personal organizers do not run general-purpose software. They can, however, communicate with PCs for data transfers.

Why Do We Need Hand-Held PCs?

Even though portable PCs are getting smaller and lighter by the day, they are still cumbersome for many applications and users. It is true that notebook PCs have brought the computing power of the desktop to an 8 × 10 × 1-inch form factor weighing just under 5 pounds. But even though they fit in briefcases, they are still limited in a number of ways.

Portable PCs depend on expensive nonstandard rechargeable batteries that allow for just 2 to 4 hours of operation, which creates a problem: It is nice that such powerful full-fledged PCs can be taken on the road, but they tend to become temporarily useless once they run out of power. Of course they can be brought back to life when an AC outlet is found, but then, this is not much consolation inside an airplane! Another problem is the AC adaptor, which is not lightweight and takes up space. At 4 to 5 pounds (adaptor excluded), notebook PCs are still heavy for most users, who would prefer something much lighter if given a choice. More importantly these PCs are not socially accepted in meetings, while paper-based daytimers and organizers are. Portable PCs also are not very rugged, the weak points being the hard disk and to a lesser degree the LCD display. Finally, there is the cost issue: Notebook PCs still cost $1,500 to $4,000, excluding software.

Enter the hand-held PC, which is much smaller, much lighter, runs on off-the-shelf batteries (often standard AA) for up to 100 hours, fits in a shirt or vest pocket, costs a third the price of a notebook, runs most (if not all) PC application software, and easily connects with desktops.

Because the hand-held PCs run off-the-shelf software, they become almost as useful as the desktops. The key word here is almost. Some choices had to be made to downsize a desktop to a hand-held. There is no space or power to use a hard disk, which means that some alternate form of mass storage is needed. The only viable—and in the short-term, expensive—alternatives were solid-state disks and/or memory cards. The solid-state disk based on flash memory is the hard disk replacement; the memory card is the floppy.

Solid-state storage is a blessing in disguise. Because it is more expensive than the equivalent hard disk drive (HDD), it mandates that only the necessary software be built-in or carried along. This fact, limiting as it may at first glance seem, forces examination of the utility of the software carried along. Only absolutely necessary software is embedded in hand-held PCs because semiconductor mass storage is not cheap. On a per-megabyte basis a hard disk drive costs $3 to $4, whereas a flash memory disk/card may cost $50 to $75. By year's end it is expected that the cost disparity between hard disks and solid-state storage (flash) will be reduced to 5:1 as memory cards reach $25 per megabyte.

A point often missed in cost-per-megabyte discussions is that just 3MB of hard disk storage cannot be bought for $9! Even if the cost issue is ignored, hard disks cannot be used in hand-held PCs because they consume too much power and their size, even at the 1.8-inch form factor, is a problem. This may not hold true if and when low-power 1-inch HDDs become available. At that size most problems inhibiting their use in hand-helds should disappear. A 1-inch hard disk would be reasonably rugged and power nimble. For now, however, solid-state is the only alternative.

Hand-held PCs are not meant to replace the office PC; instead, they are expected to act as adjunct computers.

To the extent that hand-held PCs can effectively be used as take-along computers, their compatibility with the user's desktop PC is essential. However the ability to run all the software as the user's desktop is a questionable quality. The hand-held is more of an outgrowth from the organizer camp as opposed to the downsizing of the notebook PC. Attributes other than full compatibility are more important. For example, are the PIMs adequate and well designed? Is the hand-held small and easy to carry along and use? Is the keyboard useful for a reasonably small amount of typing? Are the batteries easy to find and do they last 50 to 100 hours? Is the display quality acceptable? How easy is it for the average user to connect the hand-held to a desktop and upload/download data? Is connectivity expensive? Successful hand-held implementations should have plenty of yes answers for this set of questions.

Who Uses Hand-Held PCs?

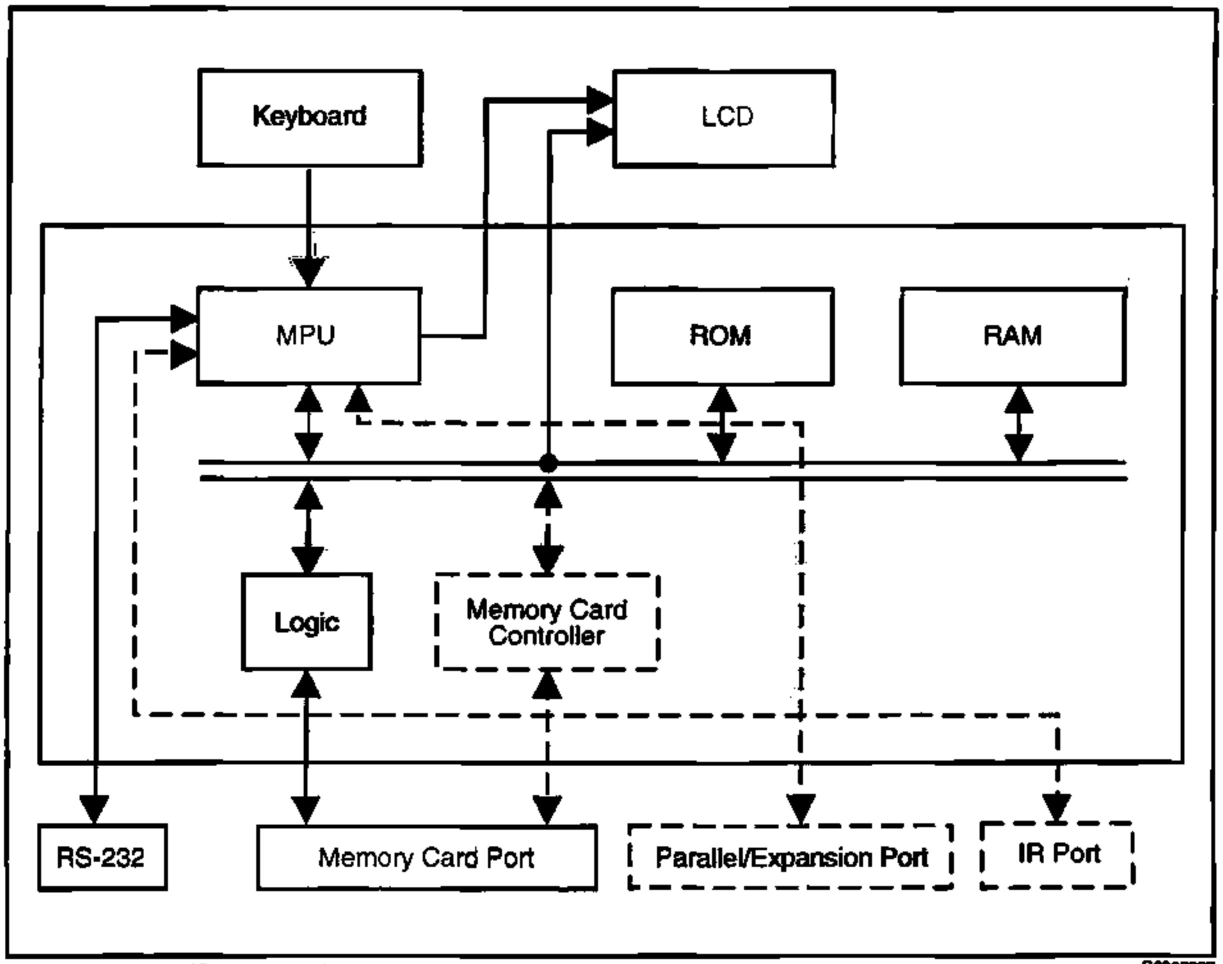
Beyond the on-the-go professional that needs something light for the road, a multitude of people use and will use these devices in a variety of environments. Weight, portability, and battery life are key features that make hand-held PCs attractive in industrial/commercial tasks on the factory floor to collect data, in shipping and receiving, for inventory and other tasks. Thus assuming that hand-helds deliver on the challenges at hand (ease of use, long battery life, and seamless connectivity), they stand to clearly dominate parts of mobile computing. Figure 7-1 shows a representative level of integration in today's hand-held PCs.

The trend in hand-helds is toward using a highly integrated MPU such as the NEC LH72001, the C&T F8680, the VADEM VG-230, or the Motorola LSC80018. The memory card port can be controlled in a number of ways. A memory card controller may be used if space and cost permit. Alternately, glue logic or even the MCU may be used for direct but less efficient control. This function will ultimately migrate to the MPU.

Table 7-1 shows hand-held unit projections based on Dataquest's Personal Computers group's forecast, which does not include personal organizers. Hand-held PC unit shipments are expected to grow at a compound annual growth rate (CAGR) of about 84 percent from 1992 to 1996. Both average selling prices and hand-held semiconductor content are expected to come down following reasonably well-defined learning curves. The total available market for semiconductor vendors is projected to grow at a healthy rate of 67.2 percent over the same period. It should be noted that the semiconductor TAM figures do not include the substantial semiconductor memory (flash, ROM, and RAM) opportunities arising from memory card sales.

Figure 7-2 shows projected hand-held PC market share for 1992 and 1996.

Figure 7-1
Hand-Held PC—Block Diagram



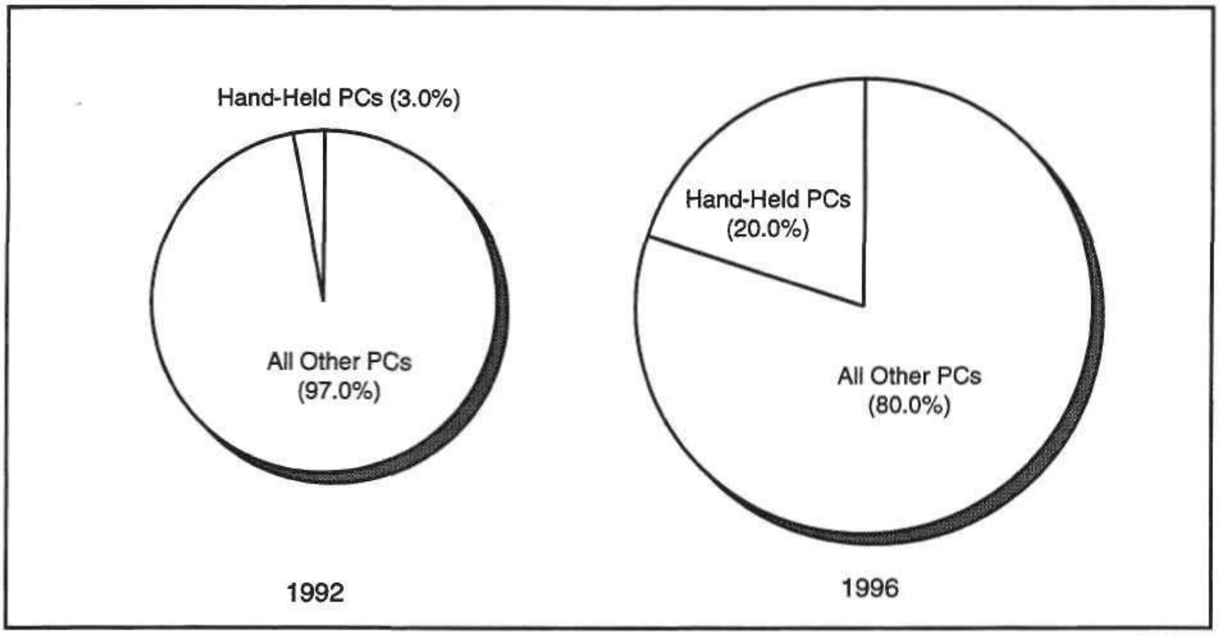
Source: Dataquest (October 1992)

Table 7-1
Estimated Total Available Market, Worldwide Hand-Held PCs

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Units (K)	238	763	2,042	3,877	6,188	7,314	98.45
ASP ($)	360	330	320	310	300	280	- 4.90
Semiconductor Content ($)	71	56	52	47	43	38	- 11.75
Semiconductor TAM ($M)	16.9	42.7	106.2	182.2	266.1	277.9	75.07

Source: Dataquest (October 1992)

Figure 7-2
Worldwide Hand-Held PC Market Forecast



Source: Dataquest (October 1992)

G2000100

Hand-Held PC Players

Players in the hand-held PC market, along with their status, are as follows:

- HP—In its second generation of product, HP 95LX 1MB.
- Poqet—In its second generation of product, Poqet PC.
- Sharp—About to enter the hand-held PC market with its PC-3000. Has participated in the organizer market with its Wizard product line.
- Casio—So far has offered a series of organizers (B.O.S.S. product line).
- Atari—Offers the Atari Portfolio. Sold close to 100,000 units in 1991.
- Sony—At present offers a line of hand-held PCs for the Japanese market that run a proprietary OS and accept pen input.
- PSION—Has offered a product that is similar to HP's 95LX but is based on a proprietary OS.

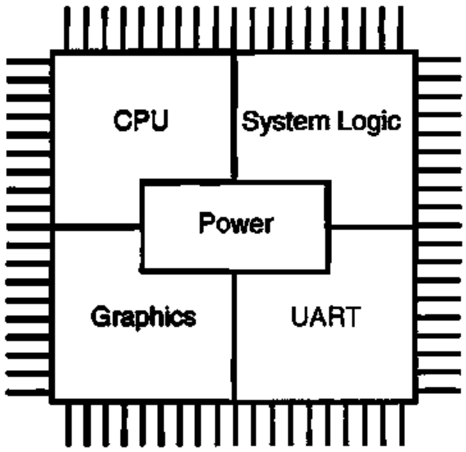
Semiconductor Opportunities and Trends

Opportunities and trends for semiconductors are described in the following paragraphs.

MPU

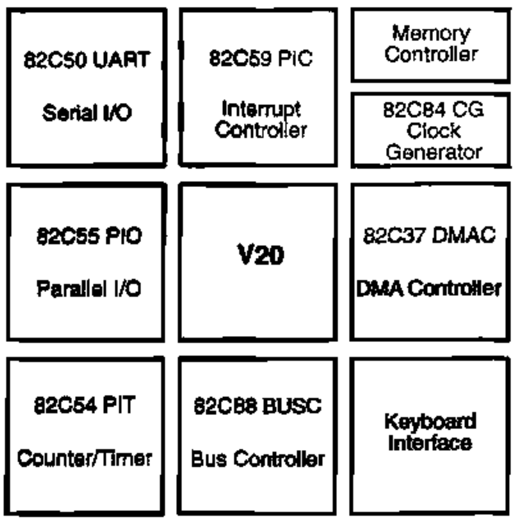
Because both space and power come at a premium, MPUs that integrate most if not all the functions needed to build a hand-held PC are now appearing to fill the gap. Figures 7-3, 7-4, and 7-5 are typical implementations. As high integration is achieved, board

Figure 7-3
Block Diagram of the Chips & Technologies F8680 (PC/CHIP)



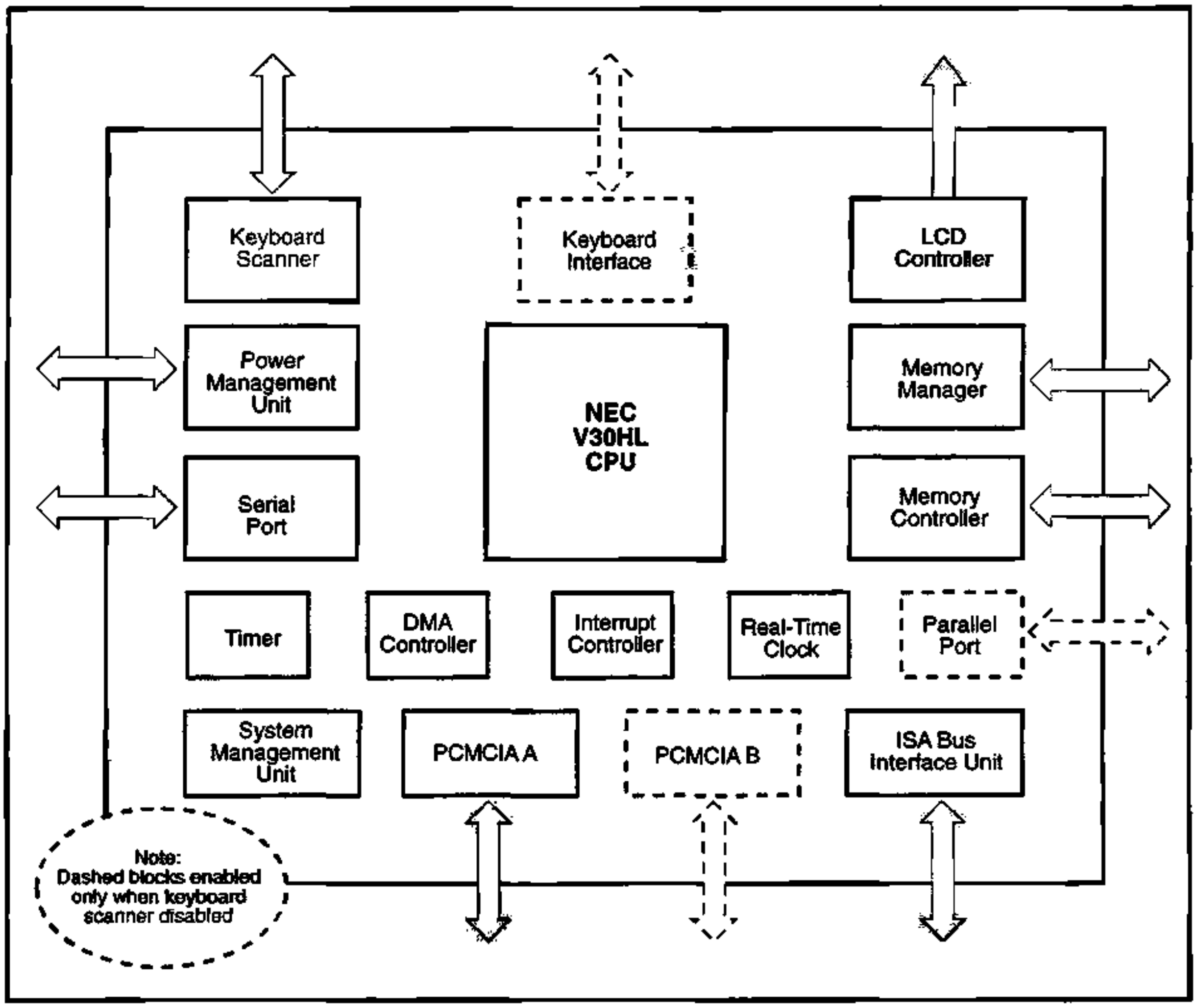
Source: Chips & Technologies Inc. G2000101

Figure 7-4
Block Diagram of the Sharp LH72001



Source: Sharp Corporation G2000102

Figure 7-5
Block Diagram of the Vadem VG-230



Source: Vadem

G2000103

space and cost will be freed for other functions such as speech and handwriting recognition, and IR and RF communications capabilities. MPU speeds will increase, primarily driven by handwriting recognition, algorithmic demands, data compression speech processing, and communications needs.

Main Memory

Today 1MB of SRAM/PSRAM (pseudo RAM) is typically used. PSRAM is preferred for cost reasons. Two 4MB, 3/5V devices do the job. If the execute-in-place (XIP) function is successfully implemented, then main memory may increase marginally to 2MB. Flash will be used in the future because of nonvolatility and low power consumption; most likely it will replace at least a part or all SRAM/PSRAM.

ROM

The 1MB typically used today most likely will be replaced by flash in the near future. In this area hand-held PCs store their operating system (for example, DOS) and programs such as Lotus 1-2-3 and PIMs. The problem with ROM is that it cannot be changed and thus the hand-held PC may be rendered obsolete in a short period. Flash memory is far more appropriate for this function. The expected memory size is 2MB to 4MB in the near term, increasing to 10MB by the end of the decade.

Mass Storage

Solid-state disks using flash memory with capacities on the order of 2MB to 5MB should be used in the near term; 10MB to 40MB should be used by 1995. Small densities should not be underestimated; by using software compression their size could be more than doubled, thus decreasing their apparent cost.

Data Compression

This function begs for eventual implementation in silicon, perhaps as part of a chip set at first, eventually to be integrated in the core MPU. Data compression is needed to offset the high cost of silicon-based memory used for mass storage.

Other Storage

Hand-held PCs will incorporate one or two PCMCIA-type ports supporting XIP. Flash and SRAM memory cards will be used as secondary storage devices. ROM memory cards will carry application software. Programming flash memory cards will become easy with the introduction of single-supply 5V devices now, and 3V in the future.

Connectivity

Connectivity is a key issue with devices such as hand-helds that tend to depend on the uploading and downloading of data to and from a desktop PC. Beyond the RS-232 type connections, infrared such as the one used by HP seems to be a very good alternative. An infrared connection with the desktop may simplify the chore of transferring data and programs between a desktop and the hand-held. In the long run, with PCMCIA ports finding their way into desktops and notebooks, the memory card will be used to transfer data between hand-held and desktop PCs.

Communication

The HP 95LX hand-held can mate with the NewsStream receiver from Motorola. It allows the user to receive e-mail over national, regional, or local paging services. Most products offer built-in terminal emulation software that allows the hand-held to be tied up to a network such as CompuServe by using a modem. Modem and or wired/wireless fax capabilities may be integrated into hand-held PCs in the near future.

Who Makes Microprocessors for Hand-Held PCs?

The NEC V20 MPU is used by the HP 95LX, the Poqet, and the Sharp Wizard series of products. It is by and large the microprocessor most commonly used in these IBM-compatible PCs.

A number of newcomer single-chip MPUs are poised to challenge this MPU. C&T introduced a single-chip highly integrated MPU, the F8680 (PC/CHIP), which also includes power management logic, a CGA-compatible LCD controller, a serial port, and IBM XT-compatible bus logic.

Newcomer VADEM will shortly introduce the VG-230, a device that incorporates the V30 MPU, a power management unit, serial port, timer, DMA and interrupt controllers, real-time clock, memory controller and manager, graphics LCD controller, and keyboard scanner.

Motorola is about to offer a highly integrated MCU, the LSC80018, to a small consortium of companies with the common goal of promoting a hand-held variant called PocSec for the Pocket Secretary. The LSC80018 features an 8-bit MCU that incorporates a graphics LCD controller, a real-time clock, an SPI, SCI, 3.5K of ROM, 448 bytes of RAM, and an 8MB MMU.

IC Peripherals for Hand-Held PCs

Table 7-2 lists memory card controller ICs, and Table 7-3 compares three hand-held computers. The Poqet has been around the longest. HP has been very well received, with sales on the order of 100,000 units for 1991. The Sharp PC-3000 is about to enter the market.

Dataquest Perspective

The need for portability must be balanced with the usefulness of a hand-held PC, which, depending on implementation, may be portable but not useful. A nagging problem in today's hand-held PCs is the human interface. A small hand-held with a tiny keyboard can fit in a pocket. Unfortunately, even the smallest amount of typing using such a keyboard becomes a chore. That makes the hand-held effectively an organizer that can be connected to a desktop PC.

Table 7-2
Memory Card Controller ICs

Intel	82365SL	Memory card controller	160-pin QFP
VLSI	VL82C107	Includes memory card Control function	128-pin QFP
Fujitsu	MB86301	Memory card controller	120-pin PQFP

Source: Dataquest (October 1992)

Table 7-3
Hand-Held PC Features

	HP95L × 1MB	Sharp PC-3000	Poqet
Size (Inches)	6.3 × 3.4 × 1.0	8.8 × 4.4 × 1.0	8.8 × 4.3 × 1.0
Weight	11oz	1.23 lbs.	1.2 lbs.
CPU/Speed	V20H at 5.37 MHz	80C88 at 10 MHz	80C88 at 7 MHz
System Memory	1MB SRAM 1MB ROM	1MB SRAM 1MB ROM	640KB SRAM 768KB ROM
Keyboard	60 + 10 FN + 10 Apps	77 + 12 FN	77 + 10 FN
Display Column/Emulation	40 x 16—MDA	80 x 25—CGA/MDA	80 x 25—CGA/MDA
Display Resolution	240 x 128	640 x 200	640 x 200
Batteries/Type	Two/AA	Three/AA	Two/AA
Memory Card Slot	1 PCMCIA-1.0	2 PCMCIA-1.0	2 PCMCIA-1.0
O/S	MS-DOS 3.22	MS-DOS 3.3	MS-DOS 3.3
Other Ports	3-wire RS-232 Infra-Red	RS-232-C Parallel I/O	RS-232-C I/O Bus (XT Comp)
Opt. Peripherals	NewsStream Receiver	1.44MB 3.5" Floppy	1.44MB 3.5" Floppy
Built-In Software	Lotus 1-2-3 Ver 2.2 Scheduler Address/Phone Book Memo Editor HP Financial Calc DataComm Filer Clock/Stopwatch To-Do list	Lotus compatible Scheduler Address/Phone Book Memo Editor Calculator LapLink File Manager Clock To-Do list	Scheduler Address/Phone Book Memo Editor Calculator File Manager Clock To-Do List

Source: Dataquest (October 1992)

On the other hand, if the minimum useful size keyboard (such as the Poqet/Sharp PC-3000) is used, the hand-held cannot fit in a pocket and its usefulness is again reduced. The solution may be a hybrid product such as the HP 95LX where the keyboard keys are enlarged to a size closer to those in the Poqet/Sharp PC-3000 (QWERTY without separate numeric keypad) and where the pen input is allowed to supplement the keyboard. Both Sharp and Sony have demonstrated products that incorporate such a pen-based input device. Even though these are not hand-held PCs that run DOS, they are a step in the right direction. Making such devices PC-compatible is rather simple.

The key to success for hand-helds may be semiconductor devices that allow for a good machine-human interface, which may be handwriting on the LCD screen, voice recognition, or a combination of both, and provide seamless connectivity. If hand-helds succeed in being easy to use, then their unit volume potential will exceed our expectations.

Chapter 8
Memory Cards

What Are Memory Cards?

A memory card is a portable semiconductor storage device that contains memory ICs. It resembles a thick credit card (3.3mm) with an edge connector at one end (see Figure 8-1).

Memory cards perform a function similar to that of a floppy disk. They store binary data.

As program or data storage media, memory cards are not new. They have been used in computer games, point-of-sale (POS) systems, photocopiers, and laser printers. More recently, electronic organizers such as the Casio BOSS and the Sharp Wizard along with palmtop PCs such as the Poqet and the HP 95LX have begun using memory cards for data storage.

Figure 8-1
Example of a Memory Card

Source: PCMCIA

The memory card form factor has not changed much over time, but the type of edge connector and the electrical/mechanical interface have. The edge connector of a memory card is the conduit that allows data to move to and from the card's memory ICs. It defines the card's capabilities. To date, we have seen cards with a variety of connectors including 38-, 40-, 50-, and 60-pin.

Memory Card Varieties

Memory cards contain mostly semiconductor memory ICs that belong to one of the following families: mask ROM, EPROM, OTP, SRAM, DRAM, EEPROM, and flash. DRAM memory cards are relative newcomers and are meant to be used as "extended/expanded" memory with no need for battery backup. SRAM cards with battery backup have been used as solid-state "floppies" in the current generation of electronic organizers. Until recently, SRAM cards (with battery backup) were the only nonvolatile memory cards. Flash memory cards today provide a promising alternative. Items such as language-translating software and dictionaries typically come in mask ROM cards, as they are the most dense and least expensive. Functionally, they are huge look-up data tables that need no change. Table 8-1 lists the various memory card alternatives.

Memory Card Standards

What inhibited memory card growth in the past was the lack of standards. In June 1989, the PCMCIA was formed in the United States, with a broad-based membership that included semiconductor companies along with software and hardware vendors. The PCMCIA's originally stated goal was to establish a standard for memory cards used with DOS-based PCs. It succeeded rather quickly as standards go. The first revision of a memory card standard was published in August 1990.

Revision 1.0 of the PCMCIA/Japan Electronic Industry Development Association (JEIDA) standard defined the following:

- The form factor—a device the size of a credit card, 3.3mm thick with a 68-pin socket connector
- The interface—parallel type bus, 8-bit/16-bit
- The address space—64Mb

Table 8-1
Memory Card Alternatives

Type	Density
ROM	128KB—16MB
EPROM/OTP	128KB—8MB
DRAM	64KB—12MB
SRAM	32KB—4MB
EEPROM	8KB—512KB
Flash	128KB—4MB

Source: Dataquest (October 1992)

The PCMCIA worked closely with the JEIDA and JEDEC. This close cooperation enabled the prompt international acceptance of the standard. Revision 2.0, as announced in September, addresses XIP (eXecute-In-Place) and I/O functions such as modems and LANs for PCMCIA bus cards. Intel Corporation also announced the Exchangeable Card Architecture (ExCA), a hardware and software implementation of the PCMCIA Revision 2.0 system interface. It is Intel's stated intention to make ExCA an industry standard so that different types of cards (memory, LAN, modem, and wireless communications) from different manufacturers will be interoperable.

Do Memory Cards Replace Hard Disks?

Strictly speaking, memory cards are not hard disk replacements. Rotating media have not been terribly successful with removable hard disks. A number of companies have tried that approach, but technology and costs kept it out of the mainstream. Thus, after a decade of using PCs, we are conditioned to think of hard disks as storage devices that belong inside the PC enclosure. This idea is a technology-dependent perception, and there is no reason why it should be so. On the other hand, memory cards, being a solid-state storage medium, are removable and portable. At a density of 20Mb, is a memory card acting like a "removable hard disk"? We believe that it is.

The Cost Issue—How Important Is It?

In 1991, the average selling price (ASP) of a 2.5-inch 40MB hard disk drive was $250.00, which translates to $6.25 per megabyte. The 3.5-inch floppy cost is close to $1.00 per megabyte. By comparison, a 1MB flash card costs approximately $300.00 or $300.00 per megabyte—a substantial disparity! Semiconductor memory certainly costs more.

The question is, "Can you put a floppy disk drive in a palmtop PC to take advantage of that cost disparity?" The answer is, "No." There is not enough power (or space). *The issue, then, is not cost.* Here the removable storage medium dictates the product's capabilities and its success or failure in the marketplace. Without a memory card, a palmtop is nothing more than an electronic organizer. It is the memory card that transforms a palmtop into a full-fledged personal computer.

Flash memory cards hold the promise of becoming the least expensive form of solid-state storage.

Cost Reduction

Flash memory cards hold the promise for becoming the least expensive form of solid-state storage. From a cell standpoint, flash rivals that of DRAM. Unlike DRAM or SRAM, it is nonvolatile, which means there is no need for battery backup. The need for bulk erasing of current-generation flash ICs creates a problem that requires clever solutions. With SRAM or DRAM cards, a single byte can be erased; EPROM-derived flash most often can be erased at the chip level (i.e., the whole chip). Recently, some vendors have announced products that allow erasure of particular memory segments. A prime example is the Intel 28F001BX 1Mb flash memory, which is segmented into areas of one 8KB, two 4KB, and one 112KB—all of which can be independently erased and programmed. EEPROM-derived flash is far more flexible at a cost premium (larger die). Flash EEPROM cells are larger than flash EPROM. Mask ROM memory cards will be the least expensive for the foreseeable future.

Data Compression ICs

Data compression ICs represent a key development for the electronic photography market and, to a lesser extent, for palmtop and pen-based PCs. Data compression ICs will be the subenabling technology devices. Without them, the future of electronic photography is in doubt. Thirty-six exposures (pictures) can be stored in a 2MB flash memory card in compressed form. If no compression were used, 40MB would be needed!

XIP

Simply stated, XIP allows a memory card to "plug-and-play." That is, once the card is plugged into the PC, program execution begins much in the way a program runs after one types in the program name and hits carriage return. That procedure is in contrast with current-generation PC architectures that need to copy the program code from secondary storage (hard disk or floppy) to main memory (DRAM) before execution. A palmtop PC with XIP capability needs just a single copy of a program, usually stored in the memory card, thus freeing up main memory.

The Players—Solid-State Disks

A number of companies are working on solid-state disk (SSD) replacement—a challenging task, to say the least. SunDisk Incorporated, located in Santa Clara, California, chose to focus primarily on hard disk replacement (solid-state disk) with a proprietary flash memory technology and architecture. The venture-capital-funded start-up launched three SSD products recently, all aimed at pen-based and palmtop PCs. The 2.5/5/10MB SSD plug-and-play subsystems come with an IDE industry-standard interface.

Toshiba announced a 4MB 5V EEPROM IC (TC58400) that is aimed at the SSD market. This device is by far the most dense EEPROM introduced to date. Architecturally, it is organized in a way that should facilitate SSD implementations. Toshiba uses a NAND cell structure that is 70 percent of its 4Mb DRAM cell; it is manufactured using a 0.7-micron double-poly CMOS process. The die size is $58.55mm^2$.

Hitachi announced a 5.25-inch form factor SSD based on 4Mb DRAM technology. This product is targeted at CAD/CAM, imaging, and graphics systems that demand a higher I/O throughput than what hard disk drives provide. The Hitachi SSD has access time of 0.35ns, incorporates an SCSI interface, and comes in 32MB or 64MB PC boards. The SSDs may be expanded to a capacity of 320MB. The data can be protected from power failures by using an optional battery-powered backup hard disk drive.

Recent Developments in Flash Memory and SSDs

AMD announced the first single-transistor cell 1Mb flash memory device that operates from a single 5V supply. The Am29F010 is by far the fastest flash memory chip with a 45ns read access time, a feature that may eliminate the need to download the flash data to SRAM in order to improve execution time. The Am29F010 is segmented into eight 16KB sectors that can be independently programmed/erased. Endurance is 100,000 cycles per sector.

Intel announced an 8Mb flash memory device and the series-2 flash memory cards based on this new flash chip. The 28F008SA can store 1MB of data or code, and by virtue of its pricing ($29.90) comes close to DRAM cost per megabyte. The device uses a 5V power supply for read operations and a 12V supply for write/erase. A 3.3V (read) version is available for portable applications. This traditional single-transistor cell-based design offers 100,000 cycles for endurance rating and 85ns access time. The memory array is segmented into 16 64KB blocks that can be independently erased/programmed. The 28F008SA is the highest-density flash memory offering to date. The series-2 memory cards are based on this new 8Mb flash memory and come in 4MB, 10MB, and 20MB densities priced at $163.50, $331.50, and $611.50, respectively. These cards are clearly aimed at mass storage applications.

AT&T entered the memory card and solid-state disk market by second-sourcing Sun Disk's IDE interface SSD subsystem and card architectures.

Microsoft announced the Flash File System (software), which supports Intel's 8Mb devices. The FFS-2 is now in beta sites and should be available later this year. Microsoft's Flash File software is a key component and necessary for solid-state disk subsystems that (unlike the SunDisk solution) will use off-the-shelf flash memory ICs.

The PCMCIA has ratified the technical content of two new standards for mass storage on memory cards. The PCMCIA-ATA (AT Attachment) specification incorporates the ATA mass storage protocol as a PCMCIA standard for mass storage on a memory card. The Auto Indexing Mass Storage (AIMS) specification is for memory cards that will be used in electronic imaging and multimedia applications.

Some Thoughts on the Future of Memory Cards and PCs

In the past, the computer was the expensive component and the storage medium (floppy disk) the inexpensive one. We've become accustomed to that oddity and do not seem to question it. However, the computer is just a machine that manipulates information. It is the information that is important and valuable, not the machine that manipulates it. So perhaps it is fitting that the information carrier, a memory card, may cost more than the computer it is attached to. In the future, we will be using platforms (palmtop PCs) that cost much less than the storage media (memory cards) they use. Imagine a $50 PC attached to a $100 memory card. At least losing the PC will not be a problem anymore!

Dataquest Perspective

Dataquest believes that memory cards represent an important enabling technology. They have the potential to transform still photography and to make the 35mm film and cameras that use it obsolete. In the process, they will change that industry and provide tremendous opportunities for growth in the consumer electronics market.

Memory cards will not eliminate rotating magnetic media any time soon. Instead, they will selectively replace them only when and where it makes sense. The bulk of the memory card growth will not come at the expense of rotating media. Growth will come from the creation of new markets. This should be good news for the semiconductor memory industry.

Ultimately, we believe, memory cards may revolutionize portable PCs by enabling them to become smaller, more rugged, lighter, faster, and perhaps user-friendly in a way that appeals to the vast majority of people who at present have no use for them. In doing so, memory cards may be the enabling technology that will make the PC of the future a true consumer item.

Chapter 9
Pen-Based PCs

This chapter looks at what are described as "pen-based" PCs. Whether the term is appropriate for a PC classification is debatable. After all, the "pen" is just a PC input device similar to the keyboard or the mouse, and we do not differentiate PCs on that basis. Having said that, we will let this argument be resolved in the future; perhaps the term pen-based will disappear. In this chapter we use this term as currently accepted.

Pen-based computers (PBCs) represent a new class of machines that quickly captured the spotlight in personal computing. These computers may evolve into something significantly different from today's PCs. It is safe to say that current advances in technology have allowed us to revisit the past, the past being the use of pen and paper as the primary form of communication.

Today's pen-based computer is a notebook PC minus the keyboard. The user interacts with the computer using a penlike device. The pen is the primary input device and as such it is no different than a mouse, except in its (familiar) ease of use. It is very difficult to sign or free-form write using a mouse, which is a pointing device.

The pen is much more. Together with the software and the hardware that drive it, the pen turns an ordinary PC into a useful, easy-to-use tool. At least, that is the expectation, which is partly derived from our familiarity with using pens and our belief that computers are useful tools. Combining the two makes sense.

The pen may or may not be connected to the computer by a cord in a pen-based system. There are basically three types of pens: The resistive type connects to the PC like a mouse; the capacitive and the electromagnetic types need no connection. There are pros and cons to any type of pen used. But the pen should not be considered by itself; the software and hardware that drive it form an entity that either works or renders the pen-based computer useless. Specific implementation is a key element in the design of pen-based systems.

The keyboard is an option; most pen-based computer manufacturers offer one because a keyboard is a far more convenient device for entering text of any length. Most people can type faster than they can write. Then again, a keyboard isn't necessary for the millions of people who never learned how to use one effectively. This is a subtle but important difference that differentiates pen-based computers from traditional PCs. A far greater number of people can use a pen than can use a keyboard. By using a pen as an input device instead of the keyboard, computer manufacturers can tap a much larger market than that served by traditional PCs.

Meeting Potential

Pen-based PCs represent a new field in computers and as such need a lot of polishing to reach their potential. The major stumbling block at present is the lack of operating systems, which in turn translates into a limited number of software packages that can run on any given hardware platform. Early hardware entries had to use operating systems developed in-house and thus limited or eliminated the possibility of using off-the-shelf software applications. So far vendors of hardware have taken one of the following approaches:

- Developed in-house proprietary operating systems (OSs) and applications—for example, spreadsheets, personal information management (PIM) software, and word processors
- Used beta-site OS for pen computers from software vendors such as Microsoft Corporation and GO Corporation to develop applications (however, this ties their hardware releases to the release of the OS; NCR Corporation is an example)
- Implemented both of the above (Momenta Corporation developed a proprietary OS that can run either off-the-shelf Windows applications or in-house-developed software such as a PIM, a word processor, and a Lotus-like spreadsheet)

Specifications

A typical pen-based computer today weighs 5 pounds and is about 8 × 11 × 1.5 in. It is able to run on batteries for three to six hours, depending on actual use and power management implementation. It is usually built around an Intel Corporation 20-MHz 386SX, 386SL microprocessor, or the newer 25-MHz 386SXL from Advanced Micro Devices Inc. (AMD). Main memory (DRAM) ranges from 2MB to 8MB for a standard configuration. The video graphic array (VGA) display is a 10-inch (diagonally measured) LCD with 640 × 580-pixel resolution and 16 to 32 shades of gray.

For mass storage the typical PBC uses a 40MB, 2.5-inch hard disk. Some PBCs use solid-state storage devices such as the 20MB solid-state disk from SunDisk Inc. or flash memory and flash cards. PBCs have no internal floppy and thus rely on communications software for uploading or downloading data. Alternately they use PCMCIA-type memory cards or docking stations for data transfers.

For communication PBCs typically offer an integrated modem/fax line, which simplifies connectivity. Some units offer modem/fax/voice capability.

The market for pen-based computers is relatively bright (see Table 9-1). Unit sales are expected to grow from 96,000 in 1991 to

Table 9-1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	2,764	3,101	3,392	3,669	3,933	4,114	8.3
Notebook	1,136	1,794	2,816	4,393	6,809	9,464	52.8
Pen-Based	41	122	800	1,759	3,289	5,098	163.0
Hand-Held	238	763	2,042	3,877	6,188	7,314	98.5
Total Portable	4,179	5,780	9,050	13,698	20,219	25,990	44.1

Source: Dataquest (October 1992)

about 4.4 million by 1995. The compound annual growth rate (CAGR) for pen-based computers is 159.75 percent from 1991 to 1995, the highest in the portable PC market. The expected revenue also is substantial, as the average selling price is at least similar to that of a notebook PC.

Figure 9-1 represents the worldwide market forecast for pen-based computers.

Figure 9-2 shows pen-based PCs over the same period (1991 to 1995) as a percentage of the total portable computer market. At 2 percent in 1991, the market is expected to grow to 15 percent by 1995.

The semiconductor content for a typical pen-based computer retailing of a $3,000 system is about $330. Figure 9-3 shows the cost distribution on a percentage basis. DRAM represents about 36 percent of the semiconductor content (in dollars). This amount is expected to increase, driven primarily by memory-hungry pen-based OSs.

Table 9-2 shows the semiconductor cost breakdown of a current-generation pen-based computer.

Figure 9-4 shows Dataquest's total available semiconductor market estimate. Semiconductor revenue derived from PBCs will exceed $1 billion by 1994.

Major players in pen-based computing that offer hardware products include GRiD Systems Corporation, Momenta Corporation, NCR, Samsung, Sanyo Electric Co. Ltd., and Sony.

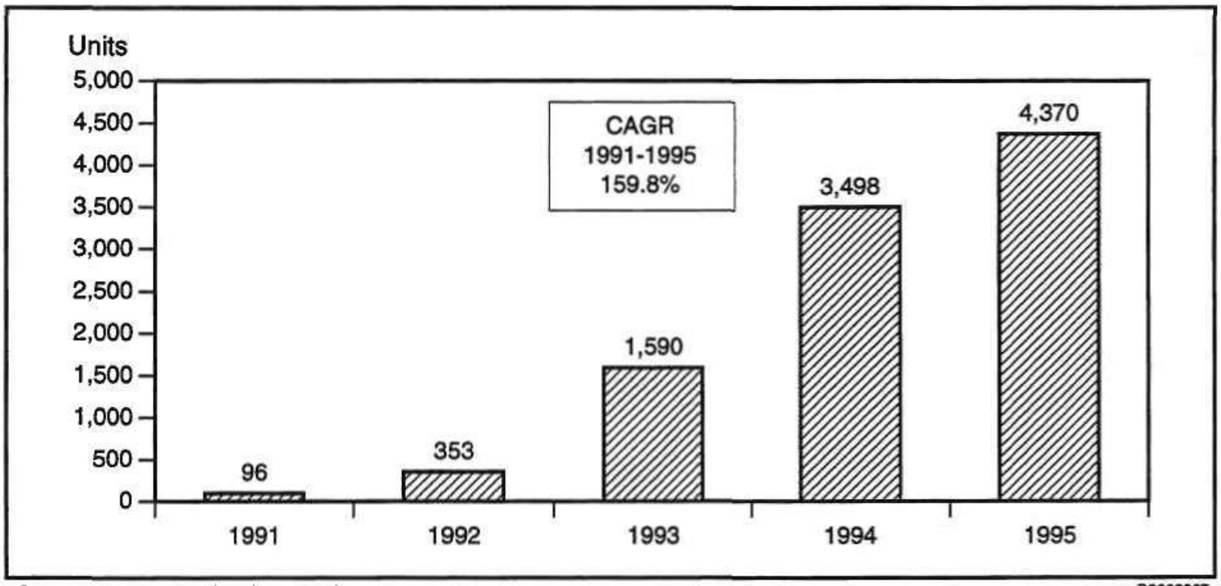
Major players in pen-based operating systems include GO Corporation (Pen Point), Microsoft (Pen Windows), and Communications Intelligence Corporation (PenDos).

Table 9-2
Semiconductor Content, Typical Pen-Based Computer

	Cost ($)
MPU	90.00
Main Memory (4MB DRAM)	120.00
System Logic	70.00
Graphics Controller	25.00
Video Buffer (PS-RAM)	8.00
Analog	10.00
Local Buffers (SRAM)	4.00
Logic	3.00
Total	330.00

Source: Dataquest (October 1992)

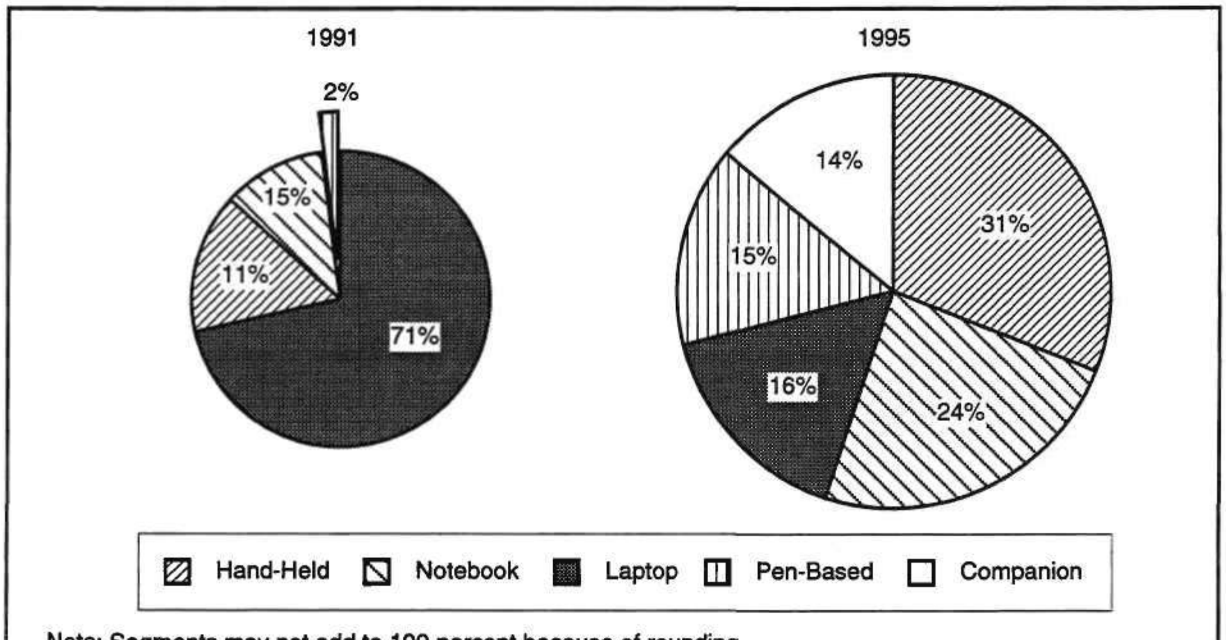
Figure 9-1
Worldwide Pen-Based PC Market Forecast (Thousands of Units)



Source: Dataquest (October 1992)

G2002267

Figure 9-2
Portable PC Market, 1991 and 1995

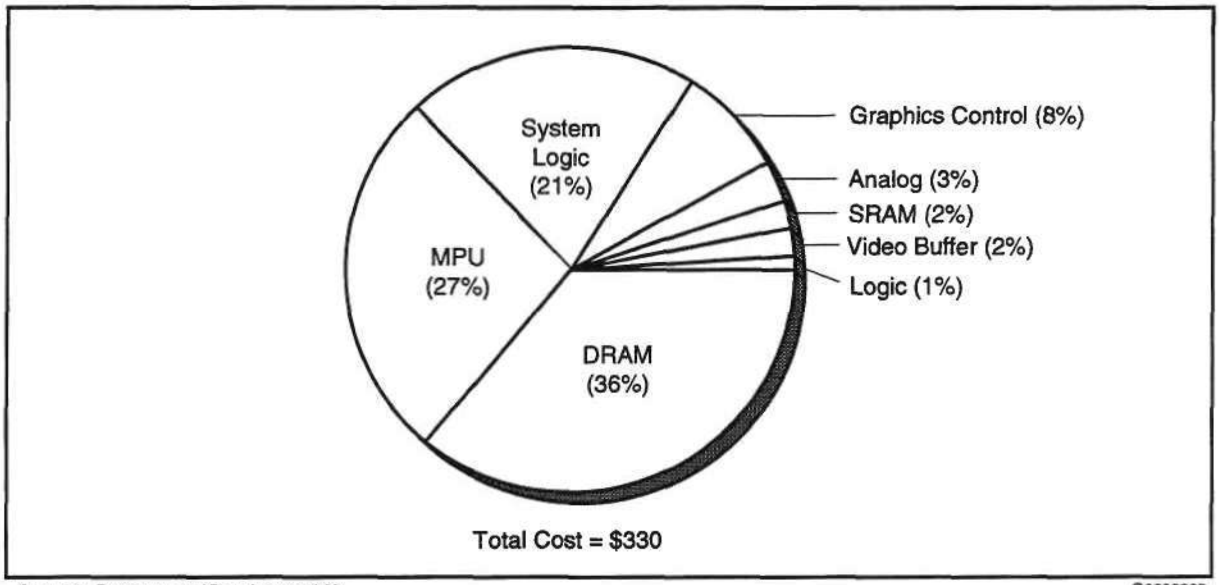


Note: Segments may not add to 100 percent because of rounding.

Source: Dataquest (October 1992)

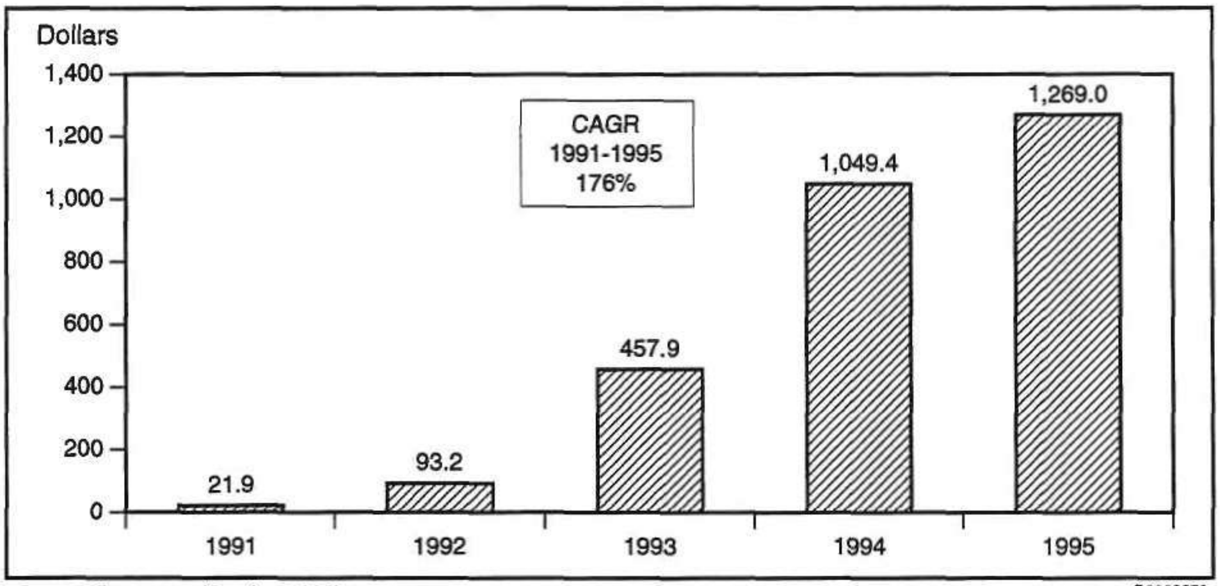
G2002268

Figure 9-3
Semiconductor Content Cost for Pen-Based PCs



Source: Dataquest (October 1992)
G2002269

Figure 9-4
Estimated Total Available Semiconductor Market, Pen-Based Computers (Thousands of Dollars)



Source: Dataquest (October 1992)
G2002270

Who is shipping OS? Both Pen Point and Pen Windows are at a beta-site stage right now. Both products are expected to be released by the second quarter of 1992. This delay in operating system introduction has retarded the availability of pen-based computers.

Handwriting Recognition

Even though handwriting (character) recognition is desirable for a pen-based computer, at present it is not a critical item. Momenta's approach is (and rightly so) that the computer does not need to recognize everything sketched onto the screen. This position follows the logic that notes entered into a daytimer are for private use and need not be transcribed; they just need to be stored for future reference/retrieval.

Connectivity/Docking

A PBC is quite effective as a field or factory floor instrument, but it needs to download the information captured to a mainframe or a PC. That can be accomplished in a number of ways: using a PCMCIA (68-pin) port and memory cards as the transfer medium, or by using radio frequency or infrared communication. A docking station is another alternative.

With respect to communication, current-generation pen-based computers typically offer an integrated modem/fax. The addition of the fax capability is quite handy because it allows a user to receive or send a fax from any place that has a phone jack or to use a cellular phone from practically anywhere.

Applications

Pen-based systems are already used in retail stores. Customers sign for credit card purchases right on the screen of the pen-based PC, which captures the signature in a digitized form and stores it in a hard disk for after-hours phone transfer to a credit card clearing bureau. The use of a PBC instead of the regular credit card imprinter for signing for a purchase speeds up the transaction. Future off-line signature verification will be possible using a smart card (where the customer's signature stored in the smart card's nonvolatile memory is in binary form).

PBCs are very good at applications that require filling out forms. A good example is their use by public utility companies for reading electricity, water, and gas meters. Police departments use them to replace paper forms for traffic violations. In manufacturing they are used to fill out inspection reports. Banks and investment companies use PBCs to fill out standard contracts. They also are quite popular with insurance adjustors and are finding their way into real estate sales.

Dataquest Perspective

As is the case with anything new, it will take some time for pen-based systems to reach their potential. Today lack of operating systems is retarding the growth of this segment. This situation should change in

1992. From a CAGR point of view, pen-based PCs stand out. Over time the distinction between palmtops and pen-based computers may become blurred as palmtops begin to incorporate a pen as an input device. The fax communications capabilities of pen-based computers make them extremely useful to a great number of people who are on the go, substantially enhancing the total available market for pen-based systems. Dataquest believes that pen-based computers offer a significant market growth opportunity for systems manufacturers, software developers, and semiconductor vendors.

Chapter 10
Winds of Change in Mass Storage

Emerging micro rigid disk drives (micro RDDs), as exemplified by the 1.3-inch RDD recently launched by Hewlett-Packard, are challenging memory cards and solid-state disks used in hand-held PCs.

Is there any evidence to suggest changes in the mass storage industry, and what sort of changes are we seeing? The answers to the first question depends on how a disk drive, or better yet a mass storage device, is defined. If the traditional definition is expanded to include flash memory (semiconductor)-based solid-state disks (SSDs), then the answer is yes. Further confusing the issue is what one considers to be a mass storage company. For example, is Intel also a mass storage company? What about SunDisk, whose products are silicon-based?

No one is taking chances, if the Intel-Conner Peripherals joint venture is any indication. It is very unlikely that Conner feels threatened by flash memory-based SSD alternatives to RDDs for the near future. However, it early on realized the potential of the new technology and opted to capitalize on the opportunities to expand sales. Besides, the chosen route (teaming with Intel) offered the most logical and symbiotic relationship, with each company contributing strengths to the partnership: flash memory technology from Intel and subsystems storage expertise from Conner. More such alliances should be on the way in an attempt to serve the needs of the mass storage marketplace, and should come as no surprise to the participants. For companies looking at entering the market, this is food for thought.

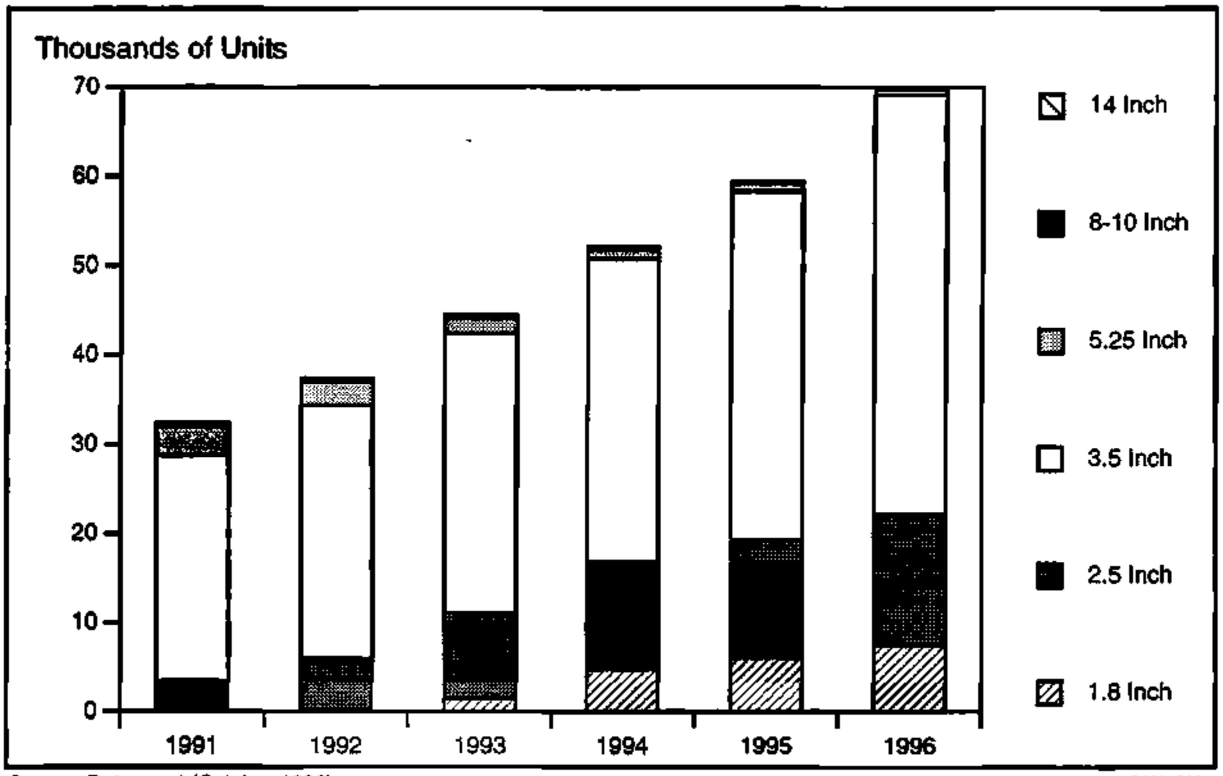
Forecast Uncertainties

The 3.5-inch hard disk drives represent the dominant form factor, at least through 1996 (see Figure 10-1). From a Semiconductor Application Markets group standpoint the wild card in this market forecast is the emergence and quick acceptance of the new small form factor hand-held computers, that is, the PICD.

As a category, PICDs describe hand-held PCs such as Apple's Newton and future HP 95LX type derivatives, as well as small pen-based machines. Will such devices be in volume production by 1996? If they are, what form of mass storage will they use? The answers may depend on one's point of view.

For PICDs to be successful, they must be small, light, easy to use (intuitive), and relatively inexpensive. They also must possess good communications capabilities. The need for portability and light weight

Figure 10-1
Worldwide RDD Market Shipments (in Thousands)



Source: Dataquest (October 1992)

G2001503

dictates the mass storage requirements. PICDs are not meant to replace desktop PCs and as a result are not required to incorporate excessive amounts of software. The bare minimum amount of mass storage is needed. Because PICDs will communicate over wireless (or wired) networks with mainframes, home, and office computers, embedding massive amounts of storage solves no problems. Indeed, it adds weight, power consumption, and cost. Forecast uncertainty results from the possibility of early PICDs' success, which may consume substantial volumes of 1.3-inch (or smaller) drives. In such a case, this forecast may be conservative because it does not fully address that new PC subcategory.

Cost Alternatives: Micro Drives versus Solid-State Storage

We know that at present semiconductor storage is a much more expensive form of mass storage than are RDDs, so why discuss the matter? The reason is that the new generation of PICDs may or may not use RDDs for mass storage, depending on the outcome of a head-on competition to satisfy the following conditions, which are seen as necessary for adopting a mass storage medium: Mass storage devices for use in PICDs must be rugged, small and lightweight, low in power consumption, and inexpensive.

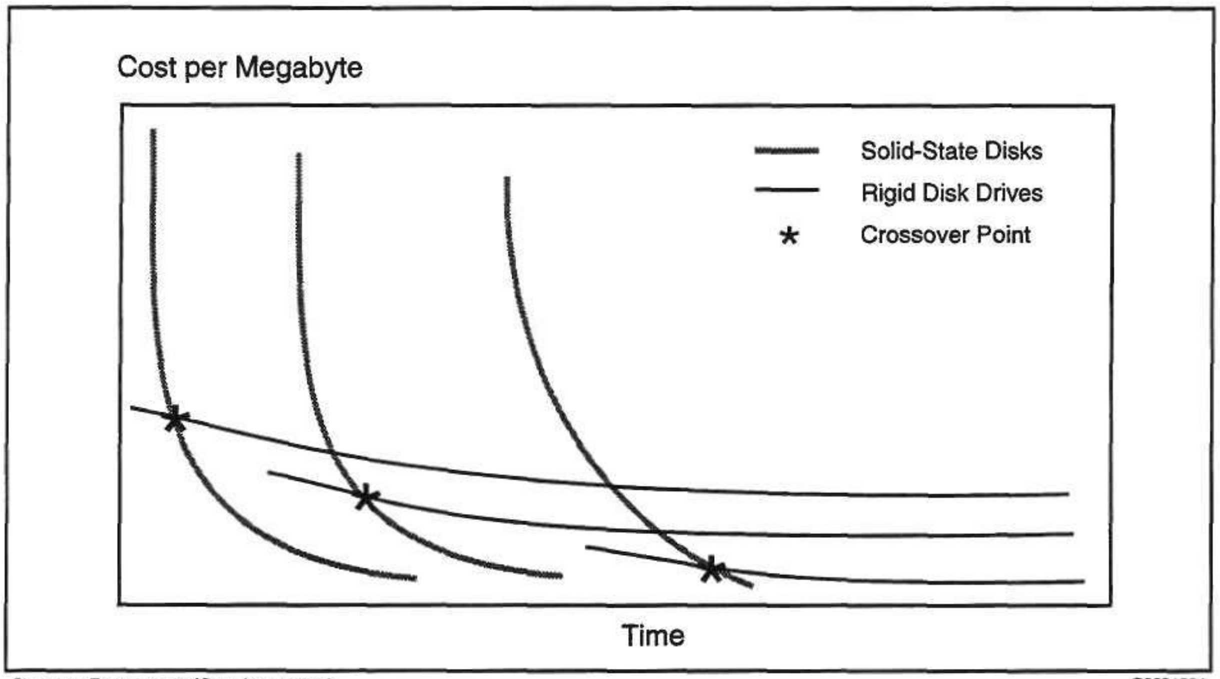
So far RDDs have not satisfied these requirements. SSDs do well with the first three, but are about five times the price of RDDs. The 1.3-inch RDDs are expected to do better addressing the conditions. But SSDs are expected to close the cost gap to 3.5 times that of the 1.8-inch drives by 1996 and perhaps to do even better when compared with 1.3-inch or smaller RDDs. Ultimately, of course, cost determines whether a particular technology gets used or not. But are we talking about the cost per megabyte or the overall system cost? This is the key question and it involves a bit of an understanding and prediction of the ways PICDs will be used.

Because PICDs are not going to replace desktop PCs but instead will be the take-along device, there is no need to duplicate the power of the desktop. Instead we need to tap into that power remotely, thus the emphasis on the communications capabilities of PICDs, which in turn dictates that only a small amount of mass storage may be needed for local processing. Thus, 10- to 20MB may suffice (effective storage of 20- to 40MB with compression). The SSD cost of the system should be $50 to $100 by 1995. It is unlikely that a 20MB, 1.8-inch drive will cost $30 (20 times $1.50), as such a cost is based on a much higher disk density. The most likely scenario is that the SSD and the HDD will cost the same for that density. If that happens, then solid-state storage will be the medium of choice, because it fares much better for the requirements delineated earlier.

So, is it time for semiconductor vendors to celebrate? RDD manufacturers offer formidable competition for anyone that ventures into the mass storage arena with SSD solutions. And so far RDD makers have been able to come up with substantial cost and technology breakthroughs whenever the requirements demanded. The infamous cost per megabyte curves for RDDs and SSDs have been drawn so as to cross over at some point, and that point has been moving forward for the past 20 years (see Figure 10-2), sparking many heated debates in the process. The real question is whether these two curves must cross. Given the preceding discussion, the answer may be no.

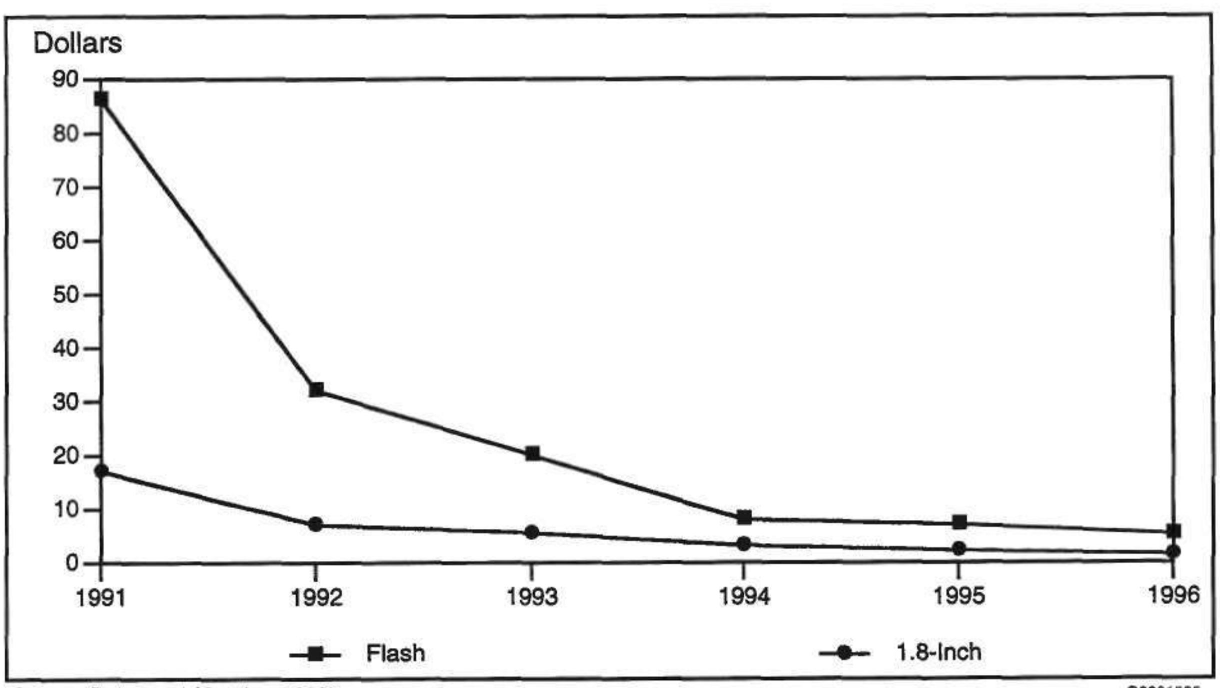
Figure 10-3 shows Dataquest's cost-per-megabyte estimates for flash memory-based SSDs and RDDs. The 1.8-inch drive is used for comparison because it represents the current candidate (along with the 1.3-inch) for head-on competition with solid-state storage in the emerging PICD market.

Figure 10-2
Cost per Megabyte, RDDs and Solid-State Disks



Source: Dataquest (October 1992) G2001504

Figure 10-3
Cost per Megabyte, 1.8-Inch RDDs versus Flash Cards



Source: Dataquest (October 1992) G2001505

Dataquest®

a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Offices in
Costa Mesa, Munich,
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Representative Agencies in
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Multimedia Computing—Unleashing the Market Opportunity

Focus Report

Part I

Semiconductor Application Markets
SAWW-SVC-FR-9201
September 28, 1992

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Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

List of Figures

List of Figures (Continued)

List of Tables

Chapter 1
Introduction

If the number of inquiries we receive about *multimedia* every day at Dataquest is any indication, this is *the* hot topic of the year—perhaps of the decade! First of all, there is a lot of confusion about multimedia in general. What is multimedia? What are its component parts and how do they interrelate? What hardware platform reigns supreme for delivering multimedia? Is it a home, education, entertainment, or business technology? Is there really any available multimedia software, or just development tools? What are the strategies of companies like Apple and Microsoft—not to mention most Japanese electronics firms—that seem to be aiming their futures toward the multimedia star?

From a market and strategic perspective, our clients usually ask how big the market is and where the best development opportunities lie. When they start getting down to specifics, they are generally coming from a particular business focus such as software, PC design and manufacturing, or CD-ROM manufacturing. Therefore, they want to know what multimedia trends will affect their product development efforts, what strategies they should adopt to penetrate the multimedia market, and what companies they should consider partnering with to achieve success.

When we started looking at multimedia technologies to help clients answer these questions, it became quickly apparent that multimedia is such a broad subject that no one Dataquest analyst or service could possibly provide all of the answers. Besides crossing many user boundaries—home, school, entertainment, business, and technical—multimedia crosses over *all* of the technology services provided by Dataquest—from semiconductors, to computer systems, to storage, to software, to telecommunications.

So to provide a thorough and authoritative look at multimedia, we assembled a team of analysts that specialize in each of these technologies and we began investigating what is going on in multimedia in their respective areas.

This report is the synthesis of our research. It is divided into two parts, with each part comprised of four chapters that review multimedia technologies, opportunities, markets, products, and players, as follows:

Part I

- Chapter 1: Introduction
- Chapter 2: Executive Overview—The Multimedia Market Begins to Emerge
- Chapter 3: Semiconductor Technologies and Opportunities in Multimedia
- Chapter 4: Multimedia Authoring Software and Applications

Part II

- Chapter 5: The Role of Computer Platforms and Upgrade Kits in Multimedia
- Chapter 6: Multimedia Storage Requirements
- Chapter 7: Multimedia Telecommunications
- Chapter 8: The Impact of Emerging Technologies on Multimedia

Dataquest intends to expand its coverage of these multimedia technologies and markets in the future. This report represents the foundation of our research.

Report Project Team:

Pamela Stone Bliss—Software
Patty Chang—CD-ROM
Robert Corpuz—PCs and Workstations
John Gantz—Telecommunications
Bill Kesselring—PCs and Workstations
Greg Sheppard—Semiconductors and Add-On Boards

Chapter 2
Executive Overview: The Multimedia Market Begins to Emerge

Introduction

The term *multimedia* has been the subject of multiple definitions, many interpretations, and accelerating interest during the past few years. This is quite understandable, given multimedia's cross-industry and cross-market implications. Computer systems, software, and peripherals providers see it as a tremendous market opportunity to develop and sell new products and services. Early-adopter users of new computing technologies are gravitating toward multimedia for its promise of exciting, new ways to bring information to the desktop through combining text, data, animations, still and moving images, voice and sound, and interactivity. In the home, consumers are also being tempted by a dazzling array of interactive games, gizmos, television programs, and online services that are beginning to make use of multimedia's capabilities. Multimedia is a natural extension of the entertainment industry, and cable TV is quickly embracing interactive programming.

Despite all the hype and hoopla, however, the multimedia market is still very young. We believe that multimedia will be an everyday reality by the end of this decade, but not before scores of complex platform, networking, standards, and software issues are resolved.

One cause of the current fragmentation of the multimedia market is that creating multimedia systems involves the collaboration of many industries that have been historically discrete, with their own target users. For many would-be players in the market, getting into multimedia involves forging new working relationships and learning new technologies far afield from the comfort zone.

Another major hurdle is the lack of standards. In this new market, like most others in the past, early developers created their own ways of doing things. From software to systems to semiconductors, battles rage over which file formats, interfaces, compression scheme, operating system, hardware platform, network delivery, and chip sets will reign as supreme multimedia delivery vehicles.

The lack of business-oriented multimedia applications further fragments this nascent market. Granted, there are a growing number of multimedia titles available on compact disc read-only memory

(CD-ROM) disks for the home market that provide games and reference/educational materials that can be played on a CD-ROM drive attached to a workstation. And optical disk-based information services provided on CD-ROM have become very popular for their quick and painless ability to sift through huge databases of information. In addition, there are a good many in-house training programs that have been developed by progressive end users using multimedia authoring systems. But looking around for off-the-shelf business or productivity applications that provide multimedia's quick information access and sensory appeal, the searcher comes up with only a handful of titles.

The opportunities are there. Information providers can leverage their archives of text, video, and sound into new business opportunities for interactive access to multiple information media. These companies will have to work closely with both computer hardware and software manufacturers that understand digital data processing. Cooperation with peripheral companies offering CD-ROM drives and videodisk players is essential to create standard platforms in order to fuel the development of rich multimedia offerings. Underlying this collaboration are two issues: networking and how critical the transport of multimedia information will be to the business world; and, the array of opportunities networking represents in the consumer market.

What Is Multimedia?

So, what is this diverse concept called multimedia? The definition, too, can be elusive. Dataquest's definition focuses on *multimedia computing* and the two key elements always found in multimedia applications that are missing from "traditional" applications. These are as follows:

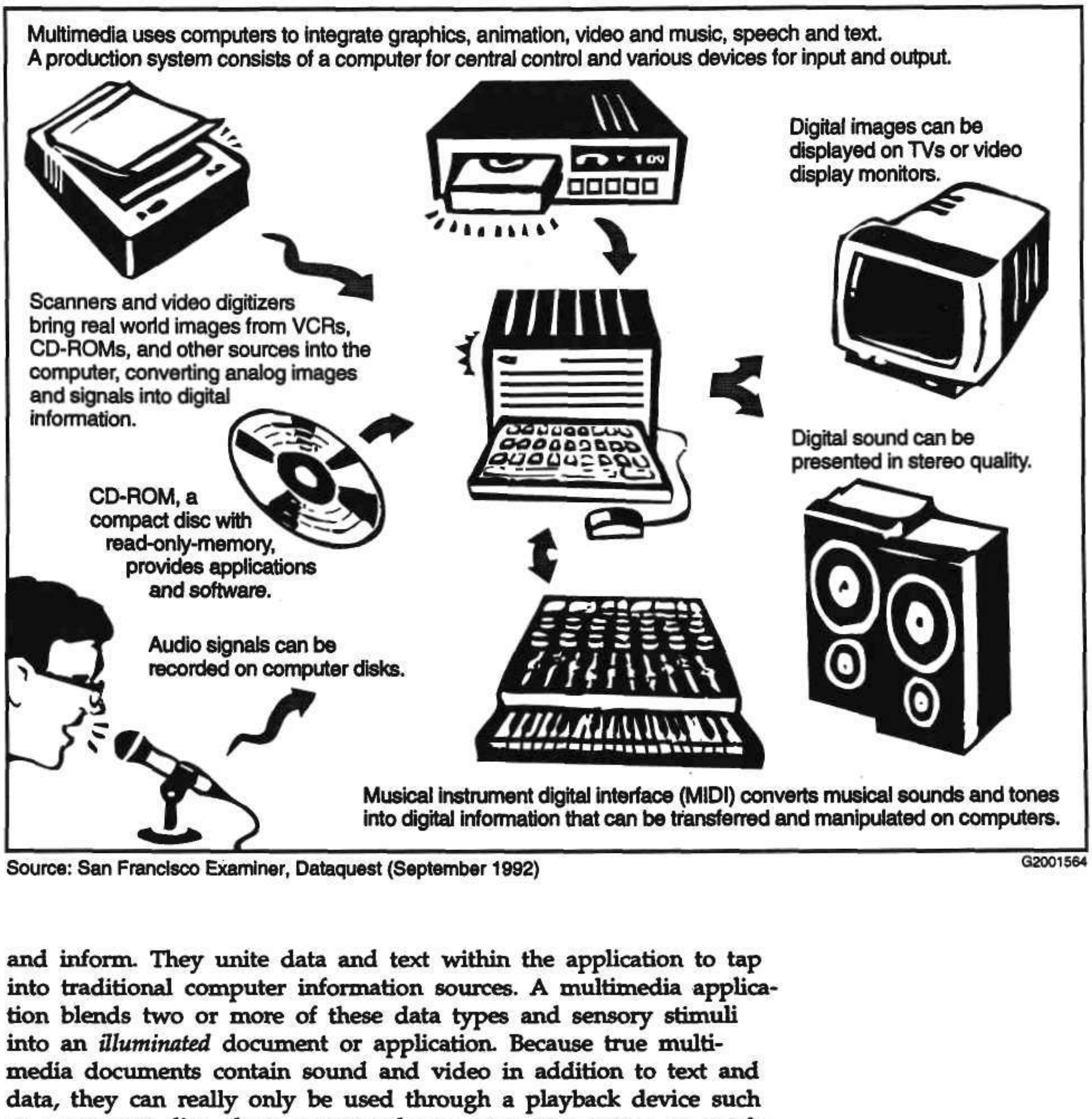
- The blending of multiple digital data types in a single application
- An appeal to a variety of human senses, especially sight, hearing, and touch

Definition

Multimedia computing blends a variety of digital information types including data, text, sound, voice, moving and still images, raster and vector graphics, and animation into a single system or application. This merging of static information with visual and auditory elements enhances communication by replicating the way that humans experience the world. Multimedia provides user interfaces that mimic the ways people communicate best—especially through sight, hearing, and touch. Multimedia applications usually provide navigational tools such as touch screens, mice, or pens so that users can interact with the system to control, guide, or respond to information presented (see Figure 2-1).

Multimedia applications simultaneously inform, educate, and delight by engaging several of the user's senses. They use color to stimulate the user's eyes and inner vision. They use sound to play back noises, spoken words, and music to add the depth of hearing. They blend photographic-quality moving and still images to spur the imagination. They merge animated pictures to illustrate, entertain,

Figure 2-1
Multimedia—A Blending of Many Technologies to Enhance Communication



Source: San Francisco Examiner, Dataquest (September 1992)

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and inform. They unite data and text within the application to tap into traditional computer information sources. A multimedia application blends two or more of these data types and sensory stimuli into an *illuminated* document or application. Because true multimedia documents contain sound and video in addition to text and data, they can really only be used through a playback device such as a compact disc player connected to a computer system or a television set.

Multimedia applications are found in two very different markets today: the business market and the consumer market. Business applications tend to run on PCs, Macintoshes, technical workstations, or other systems outfitted with multimedia hardware upgrades including video and audio boards, speakers, and a CD-ROM drive. Business multimedia applications are clustered in the training, presentation, information services (reference collections on CD-ROM), and information kiosk areas. (A kiosk is an interactive information "booth," usually equipped with a touch-screen monitor, that a user can query using touch or keyboard commands to obtain information, make reservations, or order goods and services.) Consumer multimedia applications tend to run on home entertainment devices such as television sets fitted with game players (from manufacturers including Nintendo and Sega), compact disc interactive (CD-I) players (Philips' offering for consumer multimedia), interactive descrambler devices (for cable TV programming), and/or home PCs equipped with multimedia upgrade kits. Consumer applications include games, interactive TV programming, and education and reference programs on CD-ROM.

There are two levels of multimedia systems: personal and collaborative. Personal systems are standalone systems that provide entertainment and information to individuals. Examples of personal multimedia systems include games, computer-based training, and CD-ROM reference collections. Collaborative systems enhance information-sharing and communication between individuals or groups of individuals. They combine multimedia applications with networked computing devices. Examples of collaborative multimedia applications include desktop conferencing, interactive television (for voting or polling, for example), training applications, information kiosks, and multimedia-enabled groupware applications that are beginning to emerge. Many multimedia products and applications fall into both categories, depending on how they are used.

The Business Opportunity for Multimedia

Most of today's multimedia applications are geared toward the consumer and home market rather than the business market. The majority of multimedia titles are CD-ROM-based games or interactive "infotainment" applications. The uses for multimedia in the business world are vast and significant, however. By the end of this decade, multimedia computing will pervade the average office worker's desktop as thoroughly as word processing does today.

If business is to better compete in the 1990s and into the 21st century, the ability to react quickly to changing business conditions will become its No. 1 priority. Corporations clearly are facing a crisis in human capital. Most business leaders agree that the best way to compete in a global market is with a well-trained, knowledgeable work force that has a superior ability to comprehend and satisfy customer needs. What such workers need are fast access to information, presentation of information in an easy-to-understand format, easy-to-use tools to analyze that information (analysis may require collaboration), and the ability to take informed, creative action. Multimedia holds great promise to deliver systems that can produce this type of worker productivity. If multimedia systems deliver, we believe that the business community will quickly embrace multimedia because of its heightened ability to effectively express information. In areas such as interactive training, where early successes are visible, multimedia has already taken off.

Our idea of information is changing to include anything that can be digitized. This radical change in the nature of what constitutes information means that companies should begin to look at their business applications with a broad perspective. A strategy for teams or groups of workers is necessary in order to take advantage of networked interactive multimedia globally. A major challenge facing corporations will be to find the breadth of talent—technical and artistic—that is needed to create well-executed, easy-to-use, yet visually compelling multimedia applications. The balance of artistic and technical skills needed to create such applications in one developer is a rare commodity.

Ultimately, multimedia and its ability to provide unlimited access to multiple information forms will be a catalyst in humanizing and personalizing all communication. The productivity benefits that it will bring to the business world are too vast to quantify.

Multimedia for Home and Entertainment

Multimedia for home and entertainment refers to multimedia-enabled products and services that vendors anticipate consumers will purchase. Vendors agree that the market from home multimedia products is very different from the business market. Products for the home must be small, light, portable, affordable, and very easy to use. They must fulfill a need in the home setting, such as to provide entertainment, assist the family in learning, or provide home office capabilities. Some recent product introductions geared for the home market give an advance taste of consumer-oriented products that manufacturers believe will be successful in this arena:

- Philips Consumer Electronics Company and Sony Corporation are betting that there is a large market for their Compact Disc-Interactive player, a $1,000 attachment to the home TV that is used to play interactive games and education features ranging in price from $25 to $200 each.
- The Eastman Kodak Company's Photo-CD system enables color photographs take by any camera to be transferred to CD-ROM disk and viewed using a Kodak's Photo CD Viewer. These digitized photographs can also be integrated into PC multimedia applications using authoring software.
- Sony's DiskMan is a portable CD-ROM player that is the size of a thick paperback novel that will cost under $1,000. Users can carry a bookshelf full of titles (stored on 3.5-inch compact discs) in a purse or pocket.
- Apple Computer Inc.'s Newton personal digital assistant (PDA) is a pocket-size combination of computer, personal organizer, and communications device that enables users to take notes by hand, sketch figures, check schedules, store addresses, review computer application files, and network with the office using wireless communications. Expected to sell for under $1,000 when available in early 1993, this mobile device is designed to help people compile and work with information more easily than using a standard PC.

The cable television (CATV) and wireless television industries are also betting big on the growth of multimedia interactive systems in the home/entertainment market. Most cable systems are being rewired to facilitate two-way communications to enable a host of cable TV services such as subscribing to cable programs, playing along with game and quiz shows, ordering products (for example, the Home Shopping Network, checking flight schedules and booking reservations, and so on), and dipping into information databases. Multimedia interactive promises to be a shot in the arm for the cable industry, which boomed in the early 1980s but has slowed down considerably in recent years.

An alternative definition of home entertainment might include products or services that require an evolving, higher level of technological fluency or curiosity among a sufficient number of consumers (such as existing PC owners) to support a more ambitiously detailed form of interactive programming. An example might be a real-time, customized interactive newspaper that would display news information and video clips according to a user's exact requirements. The user could navigate through the "paper," request deeper levels of information on any subject, and even select a favorite news personality to deliver the news. Entertainment and information will merge in products such as this. They will all probably be a reality by the middle of the decade.

Multimedia Technologies

The following sections outline the various hardware, software, and telecommunications components that, when blended together, comprise multimedia. Major components are discussed in detail in the chapters of this report.

Animation

Animation is a visual communication technique that uses a rapid succession of slightly shifted images of text, graphics, or models to create a sense of smooth, dynamic motion in the mind of the viewer. Although animation is traditionally associated with hand-drawn cartoons, recent advances in computer-based animation have opened up new possibilities for adding motion to a wide variety of real and artificial images. PC-based tools such as MacroMedia Inc.'s Director and Autodesk Inc.'s Animator allow moderately skilled creators to develop images that seem to move continuously on the screen.

Animation lies between sound-over-still images and full-motion video in terms of the complexity and technical demands it makes on both the creator and the display platform. The lower cost and increasing ease of use of animation tools suggests that they will play an increasing role in developing business, technical, educational, and entertainment applications.

Audio

Coming in just behind sight, audio adds the second-most important human element to multimedia programs—human hearing. Multimedia audio enables programs to contain the spoken word, noises and sound effects, and music. This dimension adds life and reality to applications that otherwise would be flat and mute.

There are two grades of audio. Voice quality audio (8-bit) reproduces the fairly limited range of tones produced by the human voice. It is sufficient for applications that play back the spoken word—voice annotations, voice conferencing, voice mail, training, and text-to-speech. Music or CD-quality audio (16-bit) is required for applications that replicate a higher range of tones and notes than the human voice can produce—music and sound effects. CD-quality audio is found mainly in the music and home entertainment industries today, but will play an increasing role in multimedia computing. Already making its way to the computer industry is Musical Instrument Digital Interface, or MIDI. This is a code-oriented control language for specifying the notes and timing of a computerized musical score. These codes can be generated and/or played back by MIDI-compatible electronic devices such as keyboards and synthesizers.

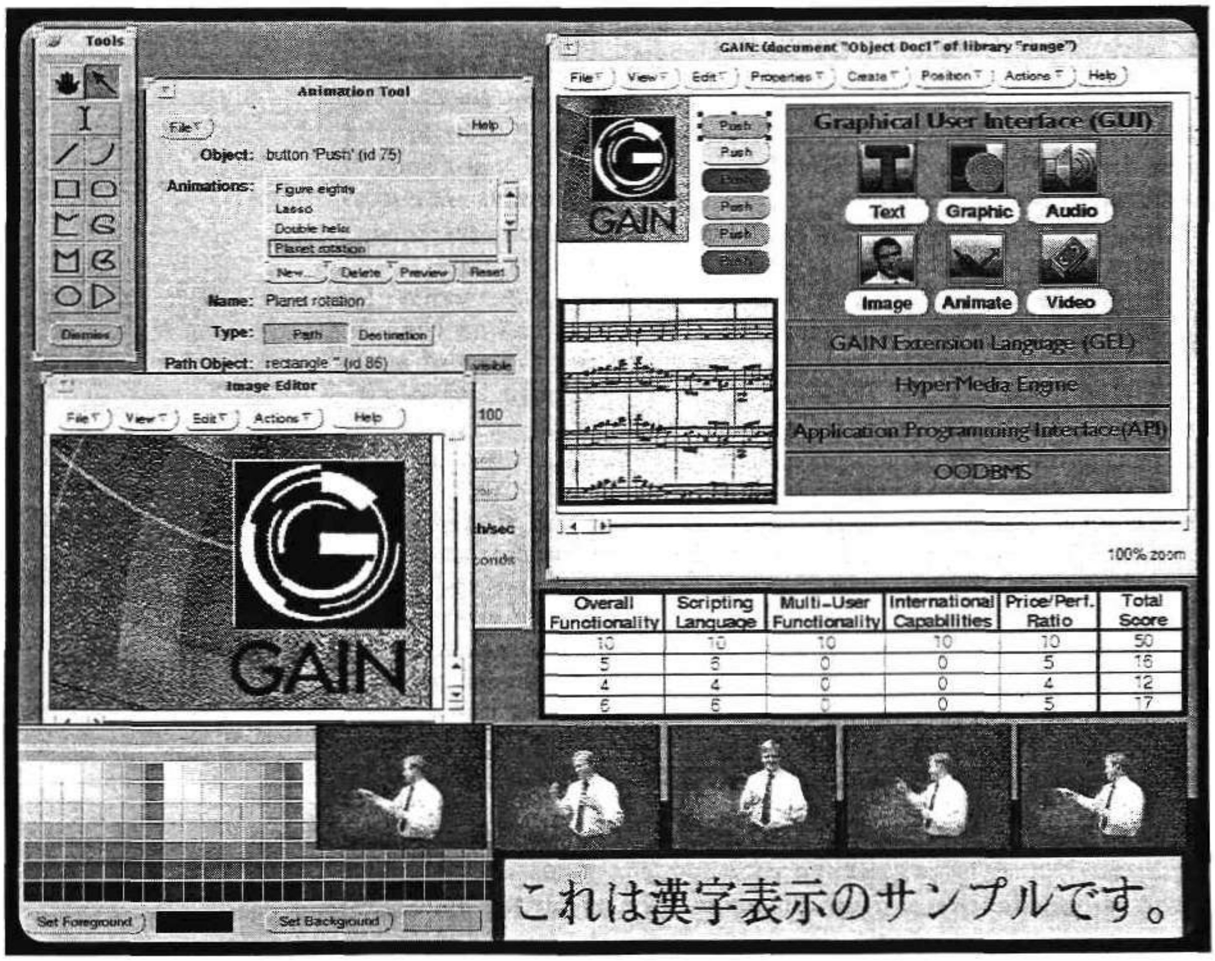
There are several elements involved with managing and storing audio data. The first is audio capture. Audio is analog data that have been created by some kind of input device such as a microphone or CD player. Graphically, audio looks like a long wave form. The audio signal is defined by its bandwidth, the highest frequency in cycles per second that can be represented in the wave form. This signal may be digitized by the combination of two processes, sampling and quantization. Analog audio signals are digitized by an analog-to-digital converter (ADC) chip component of audio digitizing equipment.

Once captured, audio can be stored as a data file for later use and playback. Audio files are stored with information about the data file including the sampling rate, the number of bits per sample, and the encoding algorithm used. Audio takes up a lot of storage—one minute of uncompressed CD-quality audio can consume close to 10MB of storage. One of the biggest challenges in dealing with audio information is developing efficient compression algorithms to minimize the amount of storage space, and building networks with sufficient bandwidth to accommodate audio efficiently.

Authoring Tools

The increasing interest in multimedia is fueled by the recent possibility of creating and displaying applications combining multiple data types on a relatively low-cost device, the desktop PC. The process of composing interactive multimedia applications and presentations is called authoring, and software that supports this process is called an authoring tool (see Figure 2-2). These tools span the gamut from application program interfaces (APIs) that only technical users can use, to graphical toolsets designed to allow nontechnical novices to create multimedia presentations and training programs. In addition, authoring tools range from simple to complex in terms of the capabilities and features they provide.

Figure 2-2
GainMomentum's UNIX Authoring Environment



Source: Gain Technology Inc.

Creating a multimedia application or program is not always as simple as sitting down at your PC with your favorite authoring tool, however. For one thing, most existing databases were designed to store and retrieve two data types: data and text. Fundamentally different techniques are required to describe and accurately link associated text, graphics, audio, and video data types within a single file system. The rise of object-oriented database programs and standards for object programming seek to address this issue.

In addition, searching multimedia databases can be a complex issue because digital information in the form of audio and video cannot be quickly scanned by the user or automatically categorized by software. Multimedia information retrieval will require richer models of information navigation than those provided by current text search and retrieval software. "Surrogate travel" is one of these models. It involves "virtual" movement within a 2-D or 3-D model of objects such as a city, a building, the human body, an aircraft, or any other subject that can be modeled and for which a database exists. Touching parts of the model with a mouse or pointing device retrieves information relevant to that part of the model.

CD-ROM

CD-ROM uses standard audio laser disk technology to publish digital data in a low-cost form that can then be retrieved by a CD-ROM drive connected to personal computer or workstation. CD-ROM technology has accelerated the growth of the multimedia market by providing voluminous storage capacity at a low cost per megabyte for storage. One CD-ROM disk can store 600 to 800MB of text or graphics, several hours of sound at high or low fidelity, thousands of high-resolution still images, and/or 72 minutes of moderate resolution, compressed full-motion video. In addition to providing high-capacity storage, CD-ROM disks are economical. Audio-only CD-ROM disks (music) sell for around $15. CD-ROM disks containing multimedia titles such as games and reference materials sell for between $50 and $300, depending on the depth and complexity of the title.

Compact disc Interactive (CDI) in the consumer arena and Digital Video Interactive (DVI) in the business arena are hardware-dependent standards for encoding multimedia data, especially video, on CD-ROMs. CDI is supported by a consortium headed by Philips that includes Sony, Motorola Inc., and other major vendors and software companies. DVI was invented by RCA/Sarnoff Labs and is being further developed by Intel Corporation. It is supported by IBM Corporation and other major vendors.

Digital Recording

Digital recording is a technology for representing continuous, analog signals (such as sound or video) by measuring the strength or amplitude of the signal every few thousandths or millionths of a second. It also requires the recording of these measurements as digital numbers on tape, disk, or some other medium. With appropriate techniques, a digital recording can be used to recreate a nearly identical version of the original analog signal in a playback device. Audio CDs use digital recording. Most existing videotape recorders use analog recording.

Digital recording has the advantage of being much more precise than traditional analog recording. The disadvantage of digital recording is that the equipment required is more complex and expensive and the resulting data files are larger (requiring more space on tape or disk).

The most important advantage of digital recording for multimedia is that it permits the manipulation, editing, and integration of previously separate message forms such as text, graphics, sound, and video within a relatively low-cost PC or workstation environment.

Graphics

In the context of multimedia, graphics refers to visual information that can be stored and manipulated in a computer using geometric descriptions such as points, lines, areas, and volumes or visual parameters such as color or shadowing.

Since the introduction of the Macintosh with its inherent graphics capabilities, all PC and software vendors have increased the graphic display and manipulation capabilities of their products.

Photographs, printed images, digitized video stills, and hand-drawn diagrams can now be scanned into a PC, with some modest loss of resolution. They can be manipulated by a wide variety of graphic software packages reused in different contexts for different purposes.

Many user-created graphics are used to support live presentations. Most involve two-dimensional text and charts with some color. Three-dimensional stills (actually 2-D images with added perspective) are more complex but are well within the capability of existing low-cost PC graphics software packages. Dynamic or interactive 3-D images generally require the additional computing power of a technical workstation.

Image

Image takes on many forms, from office applications for document imaging systems that convert paper-based documents to digital images, to more "creative" applications involving still images of photographs, video clips, art prints, handwritten notes, and sketches. Imaging is taking on new dimensions with the ability to generate real-life images with a computer. The integration of an image (the pictorial representation of a physical object) is a catalyst in the growing awareness of multimedia capabilities in the computer industry.

We are seeing significant technological advances in the main areas of imaging that include capture, storage and retrieval, and manipulation. Image capture involves the digitization of an image through a variety of peripheral devices including cameras, video equipment, and scanners so that it can be stored and later manipulated. Recently, more intelligence has been added to the scanning function through optical character and/or page recognition software to enable subsequent manipulation of selected information within the image itself. In the technical area, raster-to-vector conversion software can convert bit-mapped images to vector objects that can be recognized by CAD software.

Image storage can be done in one of three primary ways: photographic techniques to create microfilm or microfiche; optical discs for permanent or archival storage and retrieval, or erasable optical media for temporary storage and access; or CD-ROM for storage of large amounts of multimedia information.

The retrieval of images involves the ability to index and access the images. Database companies including Ingres, Informix, Oracle, and Sybase have expanded their capabilities to treat information objects such as an image like any other database field that can be easily accessed.

Image manipulation requires a considerable amount of storage and processing power (a standard letter-size page in color can represent as much as 20 million bits). Many imaging applications today require powerful super computers to perform complex simulations and analysis. As desktop computers become more powerful, we will see more and more image manipulation performed at the end-user level. An example of this is PhotoRealistic Renderman from Pixar. This product brings 3-D photo realistic display to computer graphics. Users are able to create pictures that have all the qualities of real life, including shadings, reflection, and motion blur on desktop computers.

Many companies are developing products for real-time digital imagery. This has application in the general image processing market, medical imaging, graphics arts, animation, and CAD/CAM industries. Companies such as Applied Memory Technology are capable of transferring data at a rate of up to 10 MB/sec, which is generally sufficient for real time, and 30 frames per second digital imagery.

The human eye and vision system are exceptionally powerful in recognizing what a person sees (three-dimensional images, full-color, full-motion), processing it, and storing the visual image for subsequent retrieval. Increased imaging capability at the desktop will only continue to enhance our ability to use and learn from visual information.

Operating Systems

The operating system is a layer of control software that sits between the computer hardware and the end-user application. It controls the interaction between the computer and the application software by providing instructions for accessing, storing, and printing information from the application. It also provides a user interface for how information and applications "look and feel."

The operating system is a significant factor in multimedia computing. Early PC operating systems are insufficient for multimedia computing. MS-DOS, the operating system that powers more PCs than any other, was written in the early 1980s and was created to deal with text and data only. MS-DOS is a single-tasking operating system that can present only one application at a time. To run multimedia applications, an operating system must be able to deal with a wide number of information types (text and data, but also audio, video, scanned images, and animation). In addition, it must provide a graphical or image user interface to navigate easily and intuitively throughout the multimedia system.

A number of operating systems currently compete for the multimedia desktop. They include the following:

- MS-DOS/Windows 3.1 with Multimedia Extensions from Microsoft Corporation—The current operating system for migrating MS-DOS into multimedia computing; runs on IBM and compatible PCs; Multimedia Extensions enable developers to develop mixed object applications to run in this environment; simulates multitasking by allowing view/access to desktop from within an application; graphical user interface through Windows
- Windows NT from Microsoft—Powers IBM and compatible PCs (under development); will be a multimedia capable/multitasking operating system to replace MS-DOS/Windows
- OS/2 from IBM—Powers IBM and compatible PCs; offers true multitasking; integrates mixed data elements; graphical user interface is called Presentation Manager
- UNIX and its variants—Powers technical workstations from vendors including Digital Equipment Corporation, Hewlett-Packard Company, IBM, NeXT Inc., Silicon Graphics Inc., and Sun Microsystems Inc.; a powerful multitasking operating system that handles mixed data elements
- System 7 from Apple—Proprietary operating system that powers the Apple Macintosh computer; provides a multitasking environment; presents information and files through an iconic graphical user interface; and along with QuickTime, handles a wide variety of data elements for multimedia and interactive computing
- Amiga from Commodore Business Machines Corporation—Proprietary operating system that powers Amiga computers; handles mixed object computing and provides a graphical user interface

Peripheral Devices

A peripheral device is a piece of hardware attached to a computer, usually a PC, that is generally used to record, store, or play back analog information and/or to translate between specific analog and digital formats.

Examples of multimedia peripherals include CD-ROM drives, laserdisk players, video recorders, audio recorders, speakers, microphones, scanners, printers, modems, fax boards, and graphics tablets.

PC and Workstation Platforms

In the context of multimedia computing, platform refers to a configuration of PC or workstation hardware, operating system, and peripherals that make the system capable of authoring, displaying, and/or using multimedia applications.

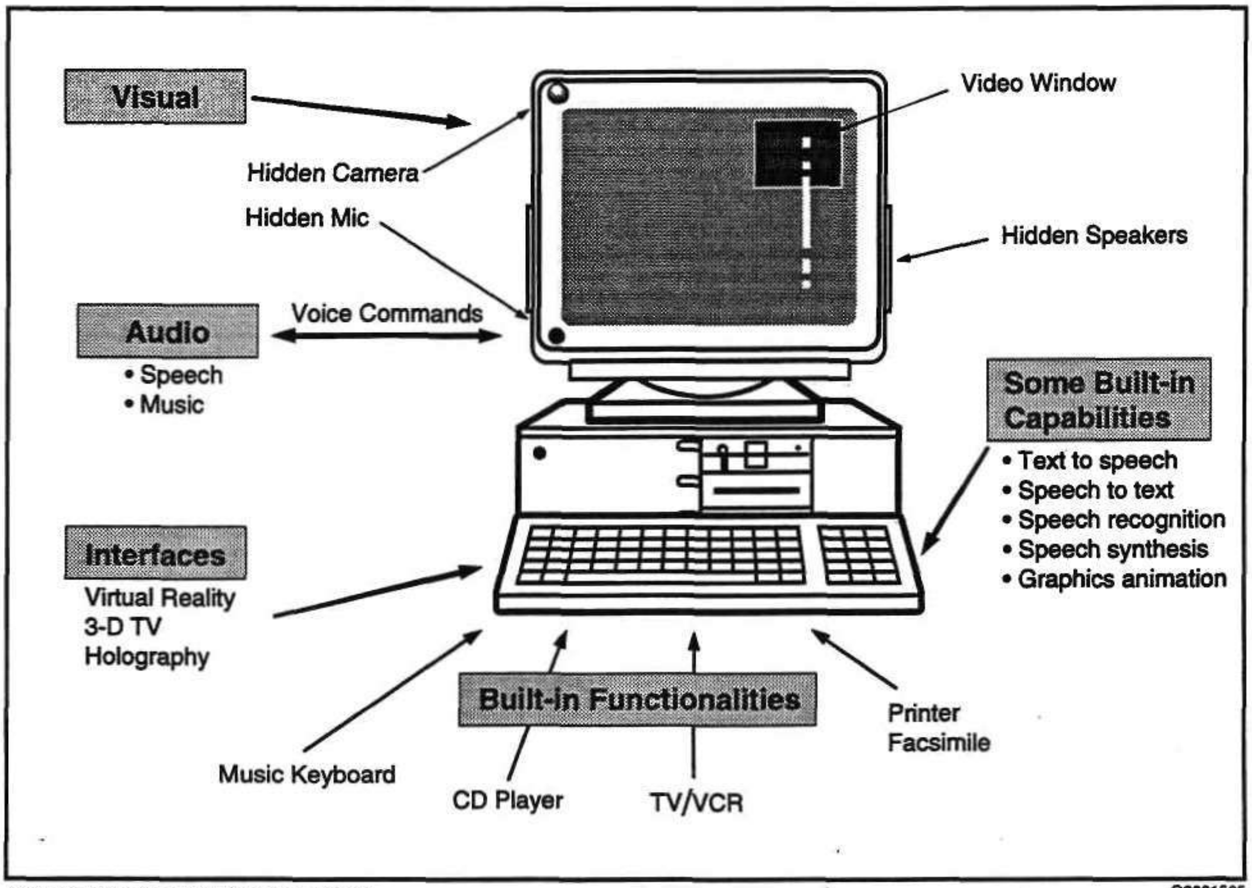
Battles rage over which platform is best for running multimedia applications. The most popular multimedia platforms include the following: Apple's Macintosh, Commodore's Amiga, IBM and compatible PCs or PS/2s, the NeXT computer, and UNIX workstations. Most of these platforms—even the technical workstations—are not multimedia-ready when they leave the factory, however. In order to perform authoring or run multimedia applications, the machines may require additional memory and storage as well as additional hardware including audio and video boards, speakers, and a CD-ROM drive. Upgrade kits containing the necessary peripherals are available to assist early adopters adapt current PCs (see Figure 2-3).

A critical issue for multimedia developers is the diversity of platforms and the number and cost of the cards and peripherals required to support multimedia, especially full-motion video. Major vendors are working on future PCs and workstations that will incorporate more multimedia support in the operating system software and standard hardware. The multimedia workstation of the future will integrate all required components and software in one pre-configured package (see Figure 2-4).

Figure 2-3
Multimedia PC Upgrade Kit from NEC Corporation

Source: NEC Corporation

Figure 2-4
The Multimedia Workstation of the Future



Source: Dataquest (September 1992) G2001565

Semiconductors

Semiconductors include very broad classes of electronic devices. Two types of semiconductors particularly relevant for multimedia are the microprocessors (CPUs) from which the various computer platforms are built and the digital signal processing technology that supports digital-analog conversion, compression, graphics manipulation, and other important multimedia functions.

Platforms can be grouped according to their CPU manufacturer. IBM PCs, PS/2s, and compatibles use one of Intel's series of processors (80286, 386, and 486). Apple Macintoshes and Commodore Amigas use one of the Motorola 68000 series chips (68000, 68020, 68030, 68040). For now, the higher numbers refer to newer, faster, and more capable CPU chips. UNIX workstations can be built on either series, but most workstation manufacturers are incorporating reduced-instruction-set computing (RISC) chips such as the SPARC chips developed by Sun Microsystems, or other RISC processors developed by Chips & Technologies.

Digital signal processing technology is more diverse. Intel Corporation and C-Cubed Microsystems are examples of companies that manufacture DVI chips offering open approaches to video compression for use of standard IBM PCs and compatibles. Other third-party vendors offer a variety of digital signal processing technologies incorporated into video capture boards and audio boards for PCs or workstations. Expected advances in digital signal processing will lead to faster and more efficient compression of digital video and audio information within more cost-effective multimedia platforms.

Telecommunications

Telecommunications refers to the electronic transport of all types of data between machines that are generally not in the same physical location. Phone calls to customers, faxing letters between branch offices of a company, video conferencing, and satellite data transmission are all examples of telecommunication.

The addition of large, time-dependent multimedia messages to the more traditional voice and data forms sent via networks makes increased demands on telecommunications networks and switching equipment. Integrated Services Digital Network (ISDN) is a medium bandwidth standard that replaces traditional voice-grade telephone lines with digital equipment capable of simultaneously supporting interactive mixed-media messages. Implementation of this standard has been slower than anticipated, but it still promises to make conferencing and database access more feasible and cost-effective.

Fiber-optic cabling among telephone company offices and to a limited number of homes and businesses has raised the possibility of much higher bandwidth services over the public telecommunications networks. Consumers and businesses would not be limited to receiving low-resolution compressed video images of a single caller (as with ISDN). Multiple interactive 3-D images from different people and databases could be displayed on screens at much higher resolution than currently available from existing television and shared by all the participants in a video conference call.

Given the present rate of replacement of copper wiring with fiber-optic cable, the vision of high-bandwidth fiber to every home is decades away. Public policy decisions in the United States and other countries may accelerate this process.

High-definition television (HDTV) also falls into the telecommunications arena. HDTV refers to a multitude of conflicting proposals for enhancements to television beyond the current National Television Standards Committee (NTSC) standards. High-definition television is most frequently associated with television pictures having the sharpness of a movie on a flat screen that could be near the size of a theater screen. HDTV does not require a fiber-optic network, but it would be much easier to support HDTV with one.

A number of HDTV projects are already under way. A Japanese television network, NHK, is already broadcasting one hour of high-definition television a day. Special effects using HDTV equipment are already being experimented with by producers around the world.

Much controversy exists as to the emphasis on HDTV. Many believe that fiber optics, not HDTV, is the technology that the United States should be putting its efforts into. They believe that time and resources should be concentrated on fiber optics, super computers, and workstations that represent America's strong suit, rather than the HDTV industry that is being defined by the needs of the consumer-oriented broadcast industry.

Cellular phones, another telecommunications technology, have provided mobility for consumers but have highlighted the competition for available broadcast bandwidth. Since a mobile user cannot be "wired" and since most TVs stay in the same place, several researchers have suggested that the use of broadcast channels and phone lines should be reversed. Television would be wired, through fiber-optic cable, along with a multitude of new digital services for the home or stationary office. Telephones would take over the broadcast spectrum so that potentially every person would have a phone and phone number that travels with him or her.

User Interfaces

The philosopher Polyani used the analogy of a blind man with a cane to demonstrate the power and the risks associated with using any tool. Every tool in human history has had a user interface. The blind man taps the ground with his cane, and the feel of the cane and the sounds it makes create mental images of the ground that warn him and guide him as he walks. The man does not think of his cane as an interface; after a while he is not aware of it. But the cane is still there, influencing how he senses his path, and even determining what he will or will not notice. The interface has often been so much a part of the tool that it has been indistinguishable from it. Interfaces take on disproportionate psychological significance because users tend to merge the identities of the interface, the underlying system or tool that the interface controls, and the view of the world that is enhanced or emphasized by the interface.

We are all partially blinded (and partially helped to see) by the computer and media interfaces we now use and will use. This explains the near-religious importance that some developers and users attach to the differences between the Microsoft DOS prompt, the Macintosh desktop, the Windows 3.1 interface, and the competing graphic interfaces that run over UNIX.

In the context of multimedia, a user interface is the set of visible and invisible design assumptions that define what a user sees and hears and is permitted to perceive while using a multimedia application. It includes how choices are translated into software and hardware commands.

New multimedia applications are broadening the range of inputs and outputs that we can use to interact with applications. Handwriting tablets and touch screens are already practical for some vertical applications. Remote controls adapted from TVs are being used to navigate through reports in executive information systems. And doctors can dictate within a controlled vocabulary and see their spoken words typed into emergency room reports.

Virtual reality (VR) is the newest evolution of the user interface. It uses goggles and gloves equipped with touch sensors to create a sense of being inside an artificial world. VR explicitly tries to make the cane disappear. Paradoxically, the fully artificial flexibility of VR will allow it to be used for more realistic simulations of travel through other countries as well as for impossible journeys through models of the circulatory system or the human brain.

Video

Video refers to several classes of methods for electronically recording, storing, manipulating, and displaying moving images and sound. Most uses of the term video in the United States refer to an analog signal that matches or is a close derivative of the National Television Standards Committee broadcast standard.

Digital video is a representation of an analog video signal in digital form (see "Digital Recording" earlier in this chapter). Converting video to digital form allows the signal to be more easily integrated into the digital environment of a PC. It also makes it easier to support a wide range of digital effects such as windowing multiple sources on one screen.

Because the digital representation of even a few minutes of full-motion video would fill hundreds of megabytes of computer memory, several techniques have evolved to shrink the size of a digital video recording. Theoretically, shrinking a video signal without any loss of resolution is possible because large areas of most video images are redundant. A large blue object need not be stored as thousands of tiny blue dots with the same color and brightness. A shorthand description of the shade of blue and the area to be covered will do. Computer algorithms can apply these kinds of shrinking techniques to reduce a digital video signal by a factor of 10 to 50 times very rapidly. Some loss of sharpness, detail, or clarity of motion generally results, but the effect is acceptable for most purposes.

More extensive compression (on the order of 150:1) is necessary to fit 72 minutes of full-screen, full-motion video on a CD-ROM. For example, the DVI standard for compression currently requires about one second of minicomputer processing to compress each frame of video. Since video is displayed at 30 frames per second, this compression must take place before the video is copied to a CD-ROM. This process is nonreal-time or asymmetric compression because it occurs over a longer period of time and on different equipment than is used to play back (decompress) the video signal.

Real-time or symmetric compression will be possible with future PC products. The results will be a trade-off between the quality of the image and the amount of storage space required for the compressed signal. Significant improvements in the price/performance ratio of compression chips are expected within the next year.

Videodisk

Videodisks historically have been 12-inch laser disks that contained a read-only representation of an hour of full-motion video or stills plus sound. Videodisks were introduced more than a decade ago and their expected growth was limited by competition from videocassettes that were cheaper and could be erased and rerecorded on the home VCR.

Videodisks have the advantage over cassettes of preserving a higher-quality video image without degradation from repeated use, and of supporting random access. Random access permitted the development of interactive videodisk programs that married the interactive control features of the PC to the dramatic power of full-motion video for the first time. Some would consider this development, achieved in the early 1980s, to be the birth of multimedia.

Recent sales of both linear (noninteractive) videodisks for home entertainment and interactive videodisks for training have increased. If an erasable form of the videodisk becomes cost-effective, it could provide some competition for the home VCR market and more effectively compete with emerging compact disc video formats. However, the size and cost of larger formats would remain a barrier to many buyers.

Market Dynamics

Multimedia computing probably represents the largest market opportunity of any electronic technology—ever. This is because it crosses consumer, commercial, and technical user boundaries and is the intersection point for so many technologies. This section takes a look at where multimedia is most prevalently found today and conjectures on market opportunities that will open up during the rest of the decade. In addition, it reviews factors that will drive the market and examines some of the barriers that stand in the way. And finally, it presents our forecasts for growth of the various segments of the multimedia market.

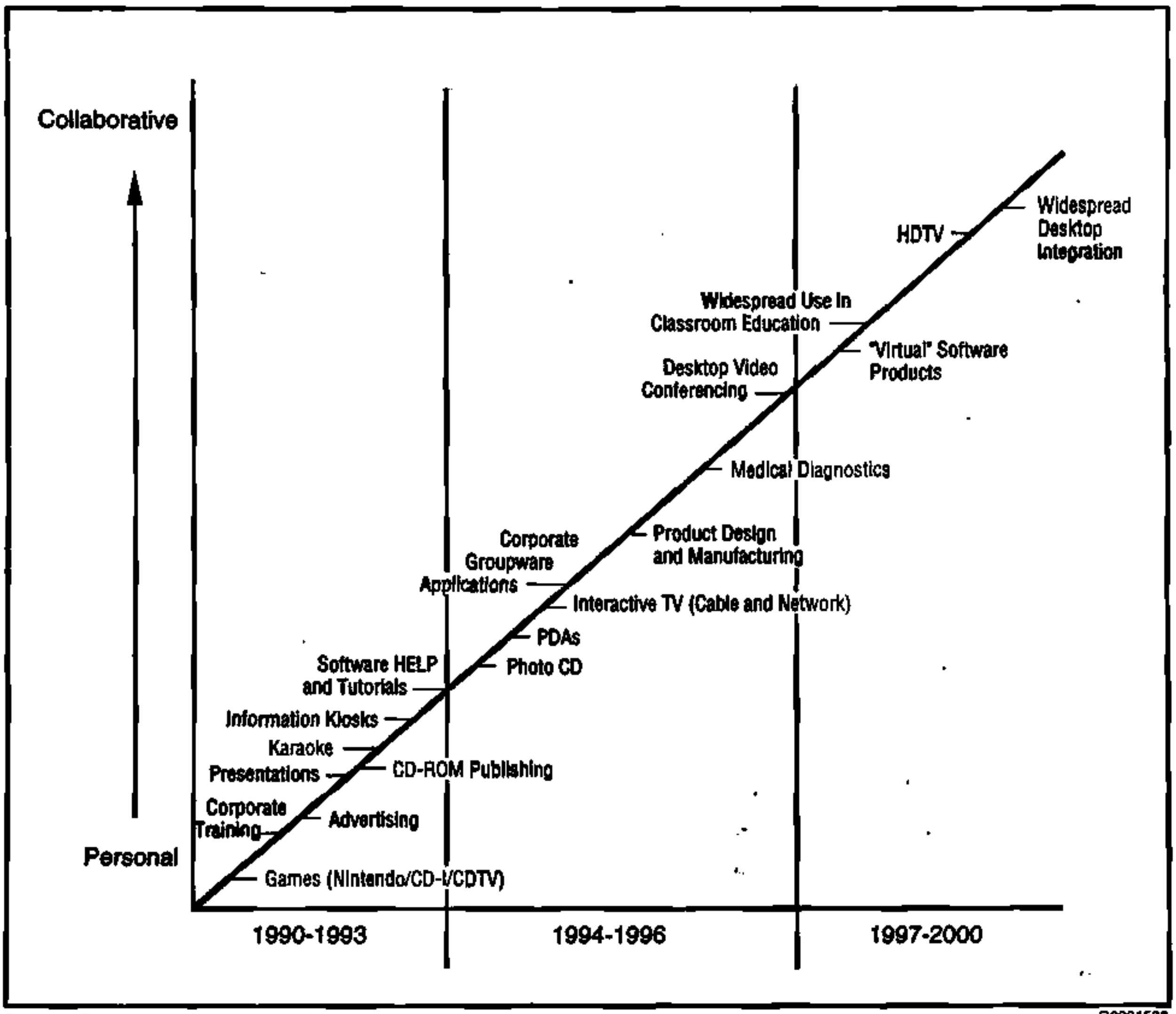
Market Opportunities—Today

As shown in Figure 2-5, today's multimedia products and services are clustered in five areas, including: training and education, advertising and presentations, information publishing, information services, and consumer/entertainment.

Training and Education

Many factors make multimedia an excellent vehicle for delivering training and course work: its multisensory environment makes learning more stimulating and fun; its ability to duplicate near to real-life environments can simulate hazardous or expensive conditions in a safe/inexpensive way; its interactive capabilities give students immediate feedback on their progress; it can reduce or

Figure 2-5
Multimedia Applications Implementation



Source: Dataquest (September 1992)

G2001588

eliminate the need for one-on-one classroom instruction by a teacher or trainer; and, because computers never sleep, learning labs can be made accessible around-the-clock to better accommodate learners' work or school schedules. Studies confirm that people remember visual information more than verbal information, and if they are emotionally involved with the learning process, they learn even more. Multimedia education is both visually stimulating and emotionally involving.

Most multimedia training has been developed by in-house corporate training departments using PC or Macintosh software authoring tools such as Authorware from MacroMedia Inc. or Multimedia Toolbook from Asymetrix Corporation. American Airlines' training department, for example, has developed more than 600 hours of computer-based training for its ground personnel using Authorware. The modules focus on ground crew education such as security, ticketing, and baggage handling services and, using video, sound, and animation, very realistically replicate the equipment and conditions that ground crew must be familiar with in their jobs. These programs are available for use in interactive, self-paced modules through American's learning lab. Trainees may use the lab any time, 24 hours per day. The multimedia training program has been so successful and popular that American is developing more training for flight attendants, and even some flight training for its pilots. Computer-simulated flight training (to familiarize pilots with controls and protocols prior to actually going "live" in expensive simulators and real aircraft) can save the airline hundreds of thousands of dollars.

Educational institutions are also coming up with innovative ways to use this technology in teaching. The University of Washington's Center for Instructional Development and Research, for example, is working on several multimedia projects. One is the Multimedia Language Learning System for its foreign language studies program. This will upgrade its language lab from audiotapes to multimedia systems that include text-based interactions, listening, reading, click-and-drag interactions, animations, audio-lab functionality, and interactive foreign language video. Another university project was created for the Department of Speech and Hearing Science. This program is an interactive videodisk that contains examples of stuttering speech defects. The school also has launched an experimental "electronic classroom" where multimedia presentations are combined with classroom instruction.

Brigham Young University (BYU) has also implemented a multimedia foreign language training program that teaches languages not only to students but also to prospective Mormon missionaries (BYU is a Mormon university). This program allows students to electronically visit the country whose language they are studying, play videoclips of "natives" speaking, and visit the local sites on guided interactive tours. Another multimedia project under way at BYU is a program to teach French sculpture and architecture. Hundreds of art slides are being digitized for incorporation into this tool, which will enable students to take self-guided, interactive art tours.

Advertising and Presentations

Multimedia has also gained tremendous momentum for building advertising features and professional presentations. The main users in this area are advertising agencies and corporate users. The real value-add of PC multimedia authoring software is that creating professional corporate videos or presentations is no longer the domain of expensive agencies. Now, a user with the right equipment and an artistic sense has the tools to create interesting, lively, colorful, and entertaining productions. Corporate users are drawn to "do-it-yourself" multimedia to save money, time, and to have more autonomy over the end result.

Members of Compaq Computer Corporation's Multimedia Integration Team recently became involved with multimedia computing to develop a trade show application showcasing Compaq technology. The presentation was developed to run on Compaq's LET 386s/20 notebook computers in order to demonstrate that today's small portables have enough power to run multimedia. The notebooks were connected to 27-inch monitors, video adapters, and videodisk players. The touch screen demo spotlighted Compaq computers and applications productivity. The demos were so successful that the engineers who created them were swamped with requests from within Compaq to build more applications and presentations. Now internal training projects are under way to teach Compaq's corporate A/V production personnel how to use PC authoring tools to build multimedia programs for the corporation's use.

Information kiosks are another up-and-coming use of multimedia in advertising. These are walk-up display stations, usually equipped with a touch screen and a simple graphical interface, that provide information and sometimes perform reservation or order services. The 1992 Summer Olympics in Barcelona, Spain, for example, featured kiosks to assist games visitors with tourist services including the following: locator maps of the city and of the Olympic Village; Olympic events schedules and locations; Barcelona sights and sightseeing tours; hotels and restaurants guides; and public transportation schedules. Kiosks are also becoming a regular sight at trade shows. Digital's recent DECWorld Conference featured kiosks that provided events schedules and helped guests make hotel and restaurant reservations. Some kiosks are moving into the realm of interactive television and provide "show daily" video newspapers that visitors can navigate through with touch screen commands. Supermarkets and chain stores are also becoming interested in this technology as a way to spotlight the week's sales items, dispense coupons, and stimulate consumer purchases.

Information Publishing

Multimedia has probably been most widely distributed through the vehicle of CD-ROM publishing. One CD-ROM disk can contain 600 million characters as opposed to the mere 1.4 million available on a floppy diskette. In addition, where floppy diskettes are only capable of storing text and data, CD-ROM disks can store not only text and data, but also still and video images, sound, and animation files. Because of its fairly voluminous storage capacity, ability to store multiple data types, and the steadily declining costs of mastering and replicating disks, information publishers have gravitated toward this medium as a superb vehicle for delivering information.

In the past few years, information publishers have begun to publish large text and graphic databases on CD-ROM. Examples include financial data bases, periodical article databases, and large, bulky reference works that require frequent revisions to stay current (for example, CorpTech guide to corporate information). In addition, a number of large corporations are offering the CD-ROM option for publishing information such as annual reports, user's manuals, policy manuals, and catalogs. The advantage of putting this information on CD-ROM is for quick access by users and low-cost updates. These publishers continue to wrestle with critical design and marketing challenges, however, including providing for user navigation, incorporating graphics and images, choosing standards, and distributing to a growing but still limited number of owners of CD-ROM drives among their intended user population.

Consumer/Entertainment

The mass consumer market is considered by most of the players in the market to be multimedia's nirvana. Where business users represent millions of potential customers, consumer users number in the billions.

Many factors are driving technology and multimedia into the home. For one thing, consumers are becoming more computer literate through using PCs at work and school, so it is a natural extension to bring computing products into the home for the purposes of work, education, and entertainment. In addition, troubled by declining standards in public education, many parents are compelled to buy PCs for their kids to use as teaching/learning tools. Many people are also working at home, or running small businesses out of the home, and require computers to help them work. Finally, with rising costs of living and lower earnings due to recessionary times, more people are staying home and using TVs, CD players, Nintendo and other game players, and PCs equipped with CD drives to deliver entertainment.

CD-ROMs containing games and info-tainment titles are the primary vehicle for delivering multimedia to consumers today. The MPC Marketing Council reports that 54 developers are currently creating titles that conform to MPC specifications, with 75 titles currently shipping and 125 titles expected by the end of the year. CD-TV and CD-I titles, numbering less than 100, also bring multimedia into the home. Compact disk titles can be classified into two categories:

- Entertainment—Titles such as *Battle Chess, Mixed Up Mother Goose, Sherlock Holmes, Where in the World is Carmen Sandiego?, A Silly Noisy House,* and *Sandy's Circus Adventure*
- Learning/reference—Titles such as *Microsoft Bookshelf, Multimedia Beethoven, Compton's Multimedia Encyclopedia, National Geographic's Mammals, Birds of America, Time's Compact Almanac, Warner New Media's Orchestra,* and *A Visit to Sesame Street: Numbers*

The cable television industry has focused on multimedia's interactivity as a vehicle for delivering a new type of entertainment to consumers. Interactive TV uses two-way communication to send cable programming to consumers and to receive responses back from the viewers. Early implementations use two-way cable for ordering cable services (pay-per-view and premium channels). But soon a host of two-way services—both personal and entertainment—will be available, including home shopping, ordering airline tickets, banking via cable, voting and polling, and playing game shows along with TV contestants.

Karaoke is a multimedia entertainment phenomenon. This electronic form of lounge singing originated in Japan. Patrons come up on stage, hear prerecorded music through earphones, read the song lyrics by "following the bouncing ball" on a TV monitor, and sing out their rendition of the song to the listening audience. Much more than electronic exhibitionism, this has become an "art form" in which many "entertainers" take great pride. It has spread to clubs and restaurants throughout the world. Some enthusiasts even have Karaoke studios set up in their homes so that they can practice their art. Virtual-reality karaoke systems are being developed to give entertainers the thrill of performing before an audience without even leaving home. The benefit here is that the performer can choose the location, the audience size, and can preset the audience's reaction to his performance—a great training environment for those with stage fright!

Market Opportunities—Tomorrow

Future market opportunities for multimedia (see Figure 2-5) are dependent both on refinements in related technologies (networking, for example) and in the widespread availability of low-cost, high-value multimedia delivery platforms. The following paragraphs describe some areas where we expect to see multimedia applications growth during the next five years.

Business

Multimedia is destined to change the face of business computing. By the end of the decade, the majority of business users will have high-performance, multimedia-capable workstations on their desktops running applications that easily access a wide variety of information types and data sources. Instead of a "killer" multimedia application—something new and totally different—that will change the face of computing in the business market, we believe that multimedia capabilities will be slowly integrated into the existing functionality of the productivity applications currently in use (word processing, spreadsheets, databases, presentations, and graphics) to enhance their communication capabilities even further.

We also expect that publishing on CD-ROM will accelerate throughout the decade, replacing many conventional in-plant printing operations with CD mastering and replicating departments.

The use of multimedia for advertising and presentations will also flourish in the business world. Much as "letter quality" letters went the way of the daisy wheel printer, use of black-and-white transparencies for presentations will dwindle as people realize the competitive advantage of using multimedia presentations.

Engineering

Software products that enhance the engineering design and review process will integrate multimedia technologies by the mid-1990s. We are already beginning to see the emergence of desktop conferencing tools that allow two engineers at different locations to have the same drawing up on their workstation screens simultaneously, and changes made by one individual are visible to the other immediately (Intergraph Corporation's CAD Conferencing, Insoft Inc.'s Communique!, and Sun Microsystem's ShowMe are example of such products). Current products use the telephone for the voice portion of system, but as workstations are fitted with microphones and audio communications capabilities, speaking to your partner directly from the workstation will be commonplace. Also, the integration of cameras and video capabilities into workstations will pave the way for picturephone communications (the person you are talking with appears in a real-time video window on the workstation screen). This capability will also allow people to handle problems where a physical object must be seen to be accurately diagnosed.

The integration of voice and video with CAD and raster file sharing will facilitate product design and review cycles enormously by allowing engineers at remote locations to collaborate on product design in real time.

Entertainment

Entertainment applications will continue to be multimedia's premier market driver. Throughout the mid 1990s, we expect to see entertainment uses of multimedia grow as follows:

- Computer-based applications such as games and "edu-tainment" titles will flourish.
- Cable television will also drive interactive programming into the home.
- Photo-CD promises to be a way for people to organize and view their photograph collections using CD-ROM technology.
- The availability of PC-based graphics, video, animation, and audio editing tools will allow novice end users to make their own video productions.

Financial Services

Tight financial times are forcing the banking industry to focus keenly on customer services as a means of attracting new customers and keeping existing customers happy. Multimedia kiosks installed in bank branches will provide customers with a wide range of interactive services far beyond those currently offered through automated teller machines (ATMs), including:

- Checking current interest rates for programs such as mortgage loans, savings accounts, money market funds, certificates of deposit, treasury bills, and so on
- Checking and savings account status inquiry
- Electronic funds transfer for paying bills
- Information on the checking and savings programs available from the bank
- Loan, refinancing, or credit application services

Insurance

The insurance industry has been an early adopter of document imaging to maximize productivity, claims processing, and customer service in this paper-intensive industry. The ability to accept multiple file types in addition to scanned images is bound to be the next enhancement to insurance document imaging systems. Some systems are already capable of accepting freeze-frame video images, useful for getting pictures of accident scenes or articles to be insured into the system. The ability to annotate folders of information with voice notes and to bring in full-motion video clips would assist claims processors, adjusters, and underwriters alike to get the full picture when assessing an insurance application or claim.

Medicine and Health Care

It is clear that multimedia technologies will be used more and more in the health care industry during this decade, both for training and diagnostic purposes.

One multimedia teaching tool is ADAM (Animated Dissection of Anatomy for Medicine), an interactive anatomical reference guide that enables medical students to examine the parts of the human body from a variety of viewpoints and peel off up to 40 layers of tissue to explore the muscles, nerves, blood vessels, bones, and organs that compose the body (available in both PC and Macintosh version on CD-ROM). The program is also hyperlinked to a large medical database for uncovering more detailed information on body topics. This tool simulates dissection of the human body so that students have a strong foundation in physiology prior to the dissection of a real cadaver.

Virtual reality will no doubt play an increasingly important role in medical diagnostics. Here, it will be possible to use microcameras to penetrate the human system and film/videotape problem areas (tumors, occluded arteries, heart values, malfunctioning organs, joints, and so on). The surgeon can then "enter the patient's body" using virtual software and visual tools (goggles) to explore the problem area from all sides and decide on the best course of treatment. Such diagnostics prepare the physician for exactly what he or she will encounter when surgery actually begins and assure a much more successful surgical outcome.

Another health care application for multimedia is in hospitals. Many hospitals have already begun to use multimedia kiosks to provide patient services, including the following:

- Hospital orientations
- Hospital maps and directories
- Patient locators
- Patient services
- Insurance claims filing
- Presurgical information videos

Legal

The legal system has rapidly adopted computer technologies such as OCR, full-text retrieval, and document imaging to help get its arms around the voluminous amounts of information that must be compiled and reviewed to form a case. Multimedia is starting to play a role here also. Autodesk, for example, recently introduced software products that use animation as a communication tool for explaining complex situations to jurors. Called "forensic animation," this software enables attorneys to build cases using animated clips that present complex series of events much more clearly than standard charts and diagrams can. Forensic animation has applications in a variety of courtroom cases including criminal, personal injury, contraband, medical malpractice, product liability, air crashes, and intellectual property.

Real Estate

Real estate brokers are interested in multimedia because it can save them time and money in listing and selling property. The average realtor makes an estimated 10 to 20 trips with each potential buyer to look at residential or commercial properties before actually making a sale. Each trip averages between 30 and 60 minutes. The buyers are interested in 10 percent of the listings visited—90 percent of the trips were a waste of time.

Multimedia can be used to create video tours of all properties on sale so that prospective buyers can browse through each house and only visit the ones that really appeal. In the case of people moving out of the area, the systems can be connected to online multiple listing databases for pulling up information and video clips of houses in other parts of the country.

Multimedia systems can also be used in real estate to advise clients on financing and loan rates, review payment schedules based on various interest rate scheduled, and help customers determine whether or not they qualify for the loan in the first place.

Retail Sales

Information kiosks and point of sale terminals are already beginning to penetrate shopping malls, grocery stores, and chain stores around the United States. These interactive stands provide customers with product information and assist in ordering good and services. Some envisioned retail uses of multimedia kiosks include the following:

- Catalog browsing and ordering services
- Advertise products on sale and dispense store coupons
- Store and mall product directory services
- Collect customer feedback through surveys and shoppers' polls

Travel and Tourism

Imagine arriving at that hotel in Singapore from the comfort of the travel agent's office rather than at 2:00 in the morning after a

15-hour flight, only to discover that the place is a *dive!* Interactive multimedia travel directories help travelers do just that. Clients can visit travel locations, review the sights, tour hotel and restaurant facilities, and automatically book airline, ground transportation, and hotel reservations.

The tourism industry is also expected to benefit from multimedia kiosks where travelers can learn about the delights of distant destinations and request more information.

Growth Factors/Barriers to Success

It is commonly believed that the multimedia market is one of those technologies waiting for a bombshell application to really make it explode. But besides dropping that "A-bomb," there are a number of other factors that will affect the speed with which the multimedia mushrooms. These include user acceptance, enhanced platforms, improved networks, distribution channels, and standards, to name a few. The implications of these growth factors/barriers to success are discussed in this section.

User Acceptance

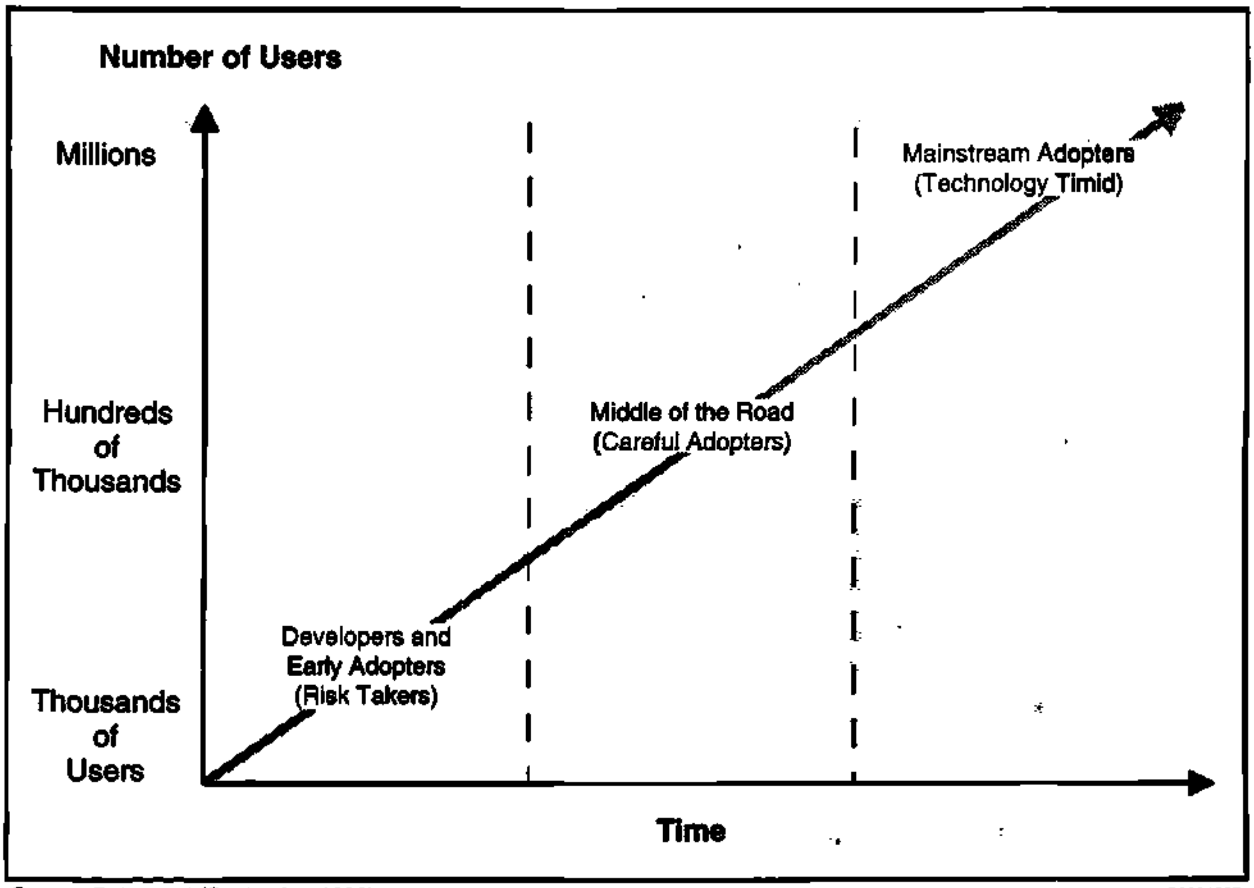
One of the biggest issues with selling any new paradigm is getting people to understand what it is, what it does, and what it means to them. Until potential users of a new technology understand how it applies to them (to entertain, inform, or solve a problem), it will languish unused. We have observed this phenomenon throughout the development of the computer industry. Many of today's established computing methods (PC computing, graphical user interfaces, desktop publishing, client/server computing replacing mainframes, and document imaging, to name a few) needed a good deal of evangelical selling before they engaged people's imaginations and started to move into the mainstream. This model holds true with multimedia, as well, and places a burden on vendors to "spread the good word."

Another user factor at work in the multimedia market is the "early-adopter" phenomenon. We observe that users' acceptance of new technologies comes in waves—beginning with the fearless pioneers who, usually driven by cost-saving and competitive advantage motives, develop their own applications and often work in partnership with vendors to resolve system/software bugs; followed by the more conservative implementers who get involved when reliable applications can be demonstrated and working solutions are available; and followed at last by technology-timid users who finally come to the realization that they better get with it or be left in the competitive dust. This cycle usually coincides with declining technology costs, another factor that draws in the more timid. Today's multimedia market is at the beginning of the first cycle (see Figure 2-6).

Platform Issues

Multimedia is a very compute-intensive, multifaceted application in a world of desktop devices unequipped to run it. Dataquest estimates that only 1 million of the approximately 124 million desktop

Figure 2-6
User Acceptance of New Technologies



Source: Dataquest (September 1992) G2001667

PCs installed worldwide are equipped with the necessary processing power, memory, high-resolution, color monitors, CD-ROM drives, sound systems, and video and audio adapter cards required to run multimedia applications efficiently. Technical workstations are much better suited from a raw processing power point of view to run multimedia (except that most lack CD-ROM drives), but they represent less than 1 percent of total desktop devices installed (the installed base of technical workstations numbered approximately 1.5 million). This picture will definitely change on both the PC and workstation fronts during the decade as users upgrade desktop workstations through equipment replacement cycles and as multimedia PCs and upgrade kits become available at affordable prices. But today, the availability of multimedia desktop platforms is definitely an issue.

End-User Applications

As mentioned previously, most end-user applications that use multimedia were developed by in-house users. The search for commercially available applications yields very few titles, however.

This scarcity of titles frustrates vendors sales efforts. The business community will not buy into implementing multimedia until it can see real-life applications.

Using the PC and Macintosh authoring tools now on the market, developers are beginning to work on new multimedia applications and incorporate multimedia capabilities into existing ones. We predict that the next 18 months will see an explosion of multimedia titles, which will help the market to blossom.

Network Limitations

A multimedia document containing a mixture of voice, data, text, graphics, and video files can contain hundreds of thousands of bytes of data. Even using hardware and software compression schemes to squeeze multimedia files into smaller packets, it is not practical to transmit these documents using today's network technologies. This problem is further magnified when hundreds of users within a corporation start trying to send around multimedia documents on the company's local and wide area networks.

A number of network traffic and network management issues must be resolved before it will be practical to transmit multimedia data packets around and across networks.

- Bandwidth limitations of LANs—Today's LANs are way too slow to transmit multimedia documents. The effective bandwidth of Ethernet and Token Ring LANs is around 4 Mbps. At this rate, it would consume the entire network resource just to transmit one video image.
- Server-based store and forward—The transmission of video and color graphics can best be accomplished using high-speed servers that are dedicated to this task and can switch network traffic at high speeds. This technology is just beginning to emerge.
- Integration of network protocols—The current network protocols for managing voice, data, and video traffic have evolved independently and are totally incompatible. Efficient transmission of multimedia documents requires an integrated protocol.
- Integration of local, broadband, and wide area networks—Today's network technologies operate at very different speeds. The average 25-MHz PC is capable of sending data at between 10 to 25 Mbps. These data move from the PC to the LAN, which has an average transmission speed of 3 to 10 Mbps. When these data move to a wide area network, transmission speed decreases to between 64 Kbps and 1.6 Mbps. Digital voice, video, and data can be moved much faster and more efficiently using some of the newer wide area protocols including Asynchronous Transfer Mode (ATM), Broadband Integrated Services Digital Network (B-ISDN), and Switched Multimegabit Data Services (SMDS), but it is uncertain when these will become widely implemented.

- Multimedia network contention issues—Unlike standard data networks, where network administrators can predict and allocate network resources based on their company's peak work load periods (for example, accounting operators finalize payment batches and send them to the mainframe for posting every evening around 4:00 p.m.), multimedia documents will more often than not be routed on an ad hoc basis. This makes it difficult, if not impossible, to plan network resource allocations to better handle multimedia traffic.

Distribution Channels

Building a distribution infrastructure for multimedia hardware and software is also an issue in this young market. Depending on the multimedia product being sold and its target consumer, any and all of the following distribution channels may be in effect for getting a product to market. Building reliable and sustainable relationships with partners in so many diverse channels is a marketing challenge, especially for the small multimedia companies:

- Direct
- Dealer channels
- OEMs
- Resellers and VARs
- Mail order
- Government
- Education and nonprofit
- Retail consumer channels

Packaging

One wouldn't think that packaging would be much of an issue with computer tools, but in selling multimedia it definitely is. This is because many multimedia products are going through retail consumer channels, so products have to have eye appeal and glitzy presentation to stand out from competitors on the shelf. Where the simplicity and good taste of a plain white box with a discrete logo in the upper left corner might work in corporate America—because corporate America buys after conducting rigorous requirements analysis and does not even notice the packaging—being discrete will not cut it in the consumer market where an emotional response and the impulse purchase is responsible for moving a lot of product. Would-be multimedia heavyweights are already studying the packaging strategies that separate successful consumer goods from those that sit unpurchased on grocery or department store shelves.

Standards

In the computer industry, a standard is defined as a set of rules, principles, guidelines, and/or specifications for developing computer hardware, software, and communications. Standards can be asserted by a single manufacturer (usually a manufacturer attains dominance through market share momentum) or negotiated by users, manufacturers, and standards bodies. The purpose of setting standards is to limit the overwhelming potential for diversity among systems and thereby establish a necessary critical mass of compatible customers who will buy a new technology.

Establishing standards is essential in multimedia because so many diverse hardware, software, and telecommunications elements must interconnect to form a complete multimedia system. However, establishing a *single* multimedia standard is impossible. Currently, relevant standards are evolving for all of the technologies used to develop, deliver, consume, store, and output multimedia.

One of the biggest standards battle fronts is for domination of the multimedia desktop. The Multimedia PC Marketing Council is a consortium of vendors that seeks to define the base line IBM PC platform for delivering multimedia and gain member consensus to develop to this specification. Apple has a proprietary standard for the Macintosh, as does Commodore for the Amiga PC. The workstation vendors such as HP, NeXT, and Sun argue that their products are premier multimedia platforms, but all are based on proprietary architectures.

Another important standards organization is the Interactive Media Association (IMA), which is composed of most major computer hardware and software developers, end users, and agencies. The IMA is working to define cross-vendor standards. If the efforts of IMA are successful, it will be possible to create a multimedia message on one vendor's platform, incorporate images and data from a second vendor's database, mail the resultant message across a third vendor's network, and play it back on a fourth vendor's desktop PC.

Operating system standards are another issue. Developing a common multimedia operating environment drives the work going on at Kaleida Labs Inc., the Apple-IBM joint venture announced on the summer of 1991. Specifically, Kaleida's mission is to develop common multimedia file formats and operating systems for both computer and consumer electronics products. In the computer area, Kaleida's operating system will first support Apple and IBM platforms. This would attract third-party developers because it guarantees that software developed under Kaleida specifications would run on a wide range of computer systems with cross-platform compatibility. An interactive media scripting language called KaleidaScript is currently under development and will form the core of Kaleida's technology. KaleidaScript will run in Macintosh System 7 and OS/2 operating environments, with support of other operating environments under consideration. Kaleida has also targeted the consumer products arena. The company is developing an operating system called Script-X that is designed to be an open operating system to power products such as Apple's Newton PDA.

Software development standards is another area of concern. No existing multimedia platform can input and play multimedia programs or applications created for another platform without extensive translation and often a loss of features. A few software vendors such as MacroMedia are building crossover products that support development on a Mac and delivery on IBM PCs.

Table 2-1 lists the proposed standards that are currently vying for supremacy in multimedia systems and development. These are discussed in various sections of this report where a given set of standards applies to a particular technology area.

The Japanese Influence

The Japanese could represent a significant force in multimedia. They are clearly taking a holistic view of the market opportunities, mixing and matching technologies from the computer, consumer, and telecommunications industries. Sony recently announced a multimedia computer featuring video windows that show movies downloaded from an 8mm camcorder. Fuji Photo Film has developed memory cards to store captured electronic still images that can be accessed by a PC. Companies such as Ricoh Corporation have developed a new system for IBM PCs and compatibles that enables a user to run commercially available software programs by spoken commands. PC-Voice Recognizer is a speaker-dependent, voice-recognition board outfitted with a standard microphone jack and a voice-input keyboard emulator.

In the area of emerging technologies, the Japanese view multimedia-capable computers as nothing more than "intelligent" HDTV sets that will be capable of editing home movies, concerts, and sports events. The Realtime Operating system Nucleus (TRON) Project represents developments in the next-generation home systems using embedded computers. The TRON House, an experimental living environment in Tokyo, links 300 processors and sensors that control home security, air conditioning, heating, windows, sprinklers, and entertainment.

Multimedia networking is also gaining momentum in Japan. Though ISDN and similar communications technologies are beginning to catch on in the United States, Japanese companies see multimedia networks and computers as highways for interactive communications services. NTT Data Communications provides multimedia value-added network (VAN) services in major Japanese cities. NEC focuses on two target markets: Mobile Media (wireless) and Multi-Media (wired).

Given the Japanese general know-how in consumer electronics and their near-term emphasis on the home, U.S. companies would be better served by aggressively collaborating in identifying multimedia opportunities in the home/consumer marketplace. This is already beginning to happen and Apple Computer is leading the way. Examples of joint U.S.-Japan consumer products include Apple's Newton, the result of joint product development between Apple and Sharp Electronics, as well as a recently announced deal between Apple and Toshiba Corporation to develop a hand-held device that will play multimedia education, entertainment, and business software. Code-named "Sweet Pea," this device will support compact discs containing video, audio, graphics, and text. Microsoft is also getting active in Japan. The company is preparing to set up

Table 2-1
Evolving Multimedia Standards

Application for Standard	Acronym	Acronym Stands For	What It Does	Proponents
General	RIFF	Resources Interchange File Format	Collection of file formats for specifying text, bitmaps, vector graphics, audio, video, and animations for Windows applications	Microsoft
Text	ASCII	American Standard Code for Information Interchange	Universal text file format	Industrywide acceptance
	ODA	Office Document Architecture	Compound document specification for documents containing text and graphics	Digital and IBM, among others
	RTF	Rich Text Format	Text and graphics format for compound documents	Industrywide acceptance
Graphics	BMP	Bitmap	Scanned flat file image format	Industrywide acceptance
	DIB	Device Independent Bitmap	File format that contains specifications for bitmap images, color, and color palette	Microsoft, among others
	TIFF	Tagged Image File Format	File specifications for paint and draw graphics images	Industrywide acceptance
	WMF	Windows Metafile Format	Vector graphics file format used as an interchange by MS Windows	Microsoft
Audio	MIDI	Musical Instrument Digital Interface	Code-oriented control language for specifying the notes and timing of a computerized musical score	Apple and Microsoft, among others
	WAVE	Waveform Audio File Format	File format for representing digital sound	Apple and Microsoft, among others
Animation	MMM	Multimedia Movie Format	Animation file format defined in Microsoft's Multimedia Extensions	Microsoft

(Continued)

Table 2-1 (Continued)
Evolving Multimedia Standards

Application for Standard	Acronym	Acronym Stands For	What It Does	Proponents
Full-motion Video	AVI	Audio Video Interleaved	Video software compression/ decompression	Microsoft
	DVI	Digital Video Interactive	Video and still image compression algorithms and specifications	Intel, IBM, Olivetti, Picture Tel among others
	DV MCI	Digital Video Media Control Interface	Specification for media control for video	Microsoft, Intel, Tandy, IBM, and others
	H.261	H.261	Video teleconferencing compression standard	CCITT standard
	MPEG-1	Motion Picture Experts Group-Version 1	Specification for storing VHS-quality compressed video on CD-ROM and transmitting it over 1.2 Mbps networks	C-Cubed, Philips, JVC in Japan
	MPEG-2	Motion Picture Experts Group-Version 2 (final spec expected by end of 1992)	Specification for storing broadcast-quality compressed video	Emerging specification
	QuickTime	QuickTime	Multimedia extensions to Apple's System 7 operating system; allows users to synthesize and synchronize animation, video, and sound, and incorporate results into Macintosh applications	Apple
Still Images	JPEG	Joint Photographic Experts Group	Draft standard for still image compression	Receiving near universal vendor support
CD-ROM Storage	CD-I	Compact disc Interactive	Compact disc format for encoding multimedia data, especially video, and for supplying interactive programming on CD-ROM	Philips, Sony, Motorola, and others
	CD-ROM	Compact Disc Read-Only Memory	Optical format for mass duplication of CD-ROM titles	Sony and Philips; industry-wide acceptance

(Continued)

Table 2-1 (Continued)
Evolving Multimedia Standards

Application for Standard	Acronym	Acronym Stands For	What It Does	Proponents
	CD-ROM XA	Compact Disc Read-Only Memory Extended Architecture	Compressed digital audio file format and interleaved sound storage method	Sony, Microsoft, and others
	CDTV	Commodore Dynamic Total Vision	Commodore Amiga workstation with integrated CD-ROM	Commodore
Communication Protocols	ATM	Asynchronous Transfer Mode	Method of high-speed transmission of data and voice at speeds up to 150 Mbps	AT&T, Bellcore, telephone companies, and major computer companies
	CCITT Px64	Px64	Provides specifications for scalable teleconferencing at rates of 64 Kbps and higher	Most video conferencing vendors
	FDDI	Fiber Distribution Data Interface (expected to be available in 1993)	Fiber optic-based network that uses dynamically allocated bandwidth and can support audio and video	Digital, IBM, and most major computer companies
	ISDN	Integrated Services Digital Network	Network protocol by which a single telephone wire can handle multiple voice and data lines	Most major computer companies and PBX manufacturers; international standard
	B-ISDN	Broadband Integrated Services Digital Network	Emerging international standard for high-speed ISDN supporting speeds of 150 Mbps	Most major computer companies and PBX manufacturers; emerging international standard
	SMDS	Switched Multimegabit Data Service	Data network service with high bandwidth and low transmit delay carried over the public phone networks; bandwidth up to 45 Mbps	Most major communications carriers and major computer companies

Source: Dataquest (September 1992)

a Japanese research center in Tokyo by year-end, which will be used to develop not only software, but also hardware for multimedia computers that may include voice-data input systems.

Research Centers

Research centers are institutions that examine fundamental questions in computer science, communication theory, electronics, learning psychology, and other fields that are relevant to the design, development, or implementation of multimedia tools and applications. They also conduct experiments and develop prototype products and tools.

Most research centers are located on or near the campus of a major university. They receive support from a variety of corporate sponsors, public agencies, and recently, foreign agencies and corporations. Most of the current multimedia tools and techniques were pioneered in research centers during the last two decades.

For developers of multimedia tools and applications there are several ways to benefit from the work at these research centers. At a minimum, potential developers should subscribe to publications from these centers and respond to any invitations to center-sponsored briefings or conferences in fields related to their potential business. Companies should also investigate formal and informal collaboration with one or more of these centers.

Even companies that are deeply committed to existing relatively mature communication technologies can benefit from knowledge and access to advanced tools that are years from being commercially viable. Research centers may also supply examples of tools that, although not viable as products themselves, are critical to the design of other more viable products.

Examples of research in multimedia include the Human Interface Technology Laboratory at the University of Washington. This lab was established in September 1989 to advance the virtual world research. Virtual worlds replace conventional computer interfaces and allow users to interact in a computer-generated, three-dimensional environment. Virtual worlds have applications in education, creative arts and entertainment, design and architecture, health and medicine, and manufacturing, among others.

At the Massachusetts Institute of Technology (MIT), the Intelligent Engineering Systems Laboratory is researching ways to integrate artificial intelligence, graphics, and communications technologies into the next-generation workstation design. The lab envisions multimedia databases that will allow users to access visual, textual, graphical, and audio information.

The Center for Productivity Enhancement at the University of Lowell in Massachusetts focuses on tools for the creation and modification of natural and artificially created images. A division of the lab concentrates on hardware and software for industrial multimedia needs, including high-speed imaging coprocessors and high-resolution graphics adapters.

Stanford University's Center for Telecommunications explores ways to solve local, wide area, and broadband network issues critical to the efficient delivery of multimedia programs and applications.

Market Size and Forecast

Just how big is the multimedia computing market and where are the greatest opportunities for growth? These are probably the most frequently asked questions about multimedia computing. This section will help answer these questions by segmenting the multimedia computing market, taking a closer look at current market size, and presenting a summary of Dataquest's forecasts for growth of the market.

Market Segmentation

Depending on one's perspective and biases, the multimedia market can be segmented any number of ways. This is one of the reasons that it is so hard to draw a box around it. All of the following ways to dissect the players and products in this market would provide useful cuts of how far the multimedia market has evolved and where it is headed.

- By technology—Semiconductors, computer platforms, add-on board subsystems, operating environments, software, CD-ROM and optical storage, telecommunications, peripherals, emerging technologies
- By user communities—Home, business, technical, entertainment, and education
- By application—Advertising, cable TV, cataloging and archiving, CD-ROM publishing, design and simulation, education and training, entertainment and games, graphic arts, information services, maintenance and safety, manufacturing management, navigation, kiosks and point of sale terminals, testing and quality control
- By industry—Agriculture, construction, insurance, government, finance, telecommunications, manufacturing, utilities, trade, health care, information services
- By platform/operating environment—Apple Macintosh and System 7 with QuickTime; Commodore Amiga and Amiga OS; IBM and compatible PCs with DOS and Windows 3.1, Windows NT, or OS/2; technical workstations (Digital, HP, IBM, NeXT, Silicon Graphics, Sun) running UNIX versions; and emerging PCs/operating systems such as PowerOpen/Script X from Taligent and Kaleida
- By size of system—Desktop, networked, and enterprise
- By how multimedia is used—Passive versus interactive
- By the role the multimedia product plays in the overall multimedia solution—Role in creating, delivering, using, or storing/outputting multimedia applications

Dataquest's primary objective in this report is to segment and define the multimedia computing market. As shown in Figure 2-7, Dataquest has segmented multimedia computing by a cross-cut of two of the above segmentation schemes. We look at the technologies that comprise multimedia computing and the roles that these technologies play in providing a multimedia solution (such as input/develop, deliver, consume/use, and output/store multimedia applications or products).

If it were possible to derive multimedia-related revenue for all vendor products in all categories on this chart, that figure would equal the total value of the multimedia computing market today. The problem lies in determining what proportion of installed equipment (digitizing equipment such as scanners and graphics tablets, capture devices such as video and audio recorders, or creative software such as animation graphics or video editing software) has a primary use for developing multimedia. We believe that it is not possible to do this without significant primary research into how people are using these peripherals. Therefore, Dataquest's multimedia forecasts factor in the more quantifiable technologies shown in highlighted boxes on Figure 2-7, as follows:

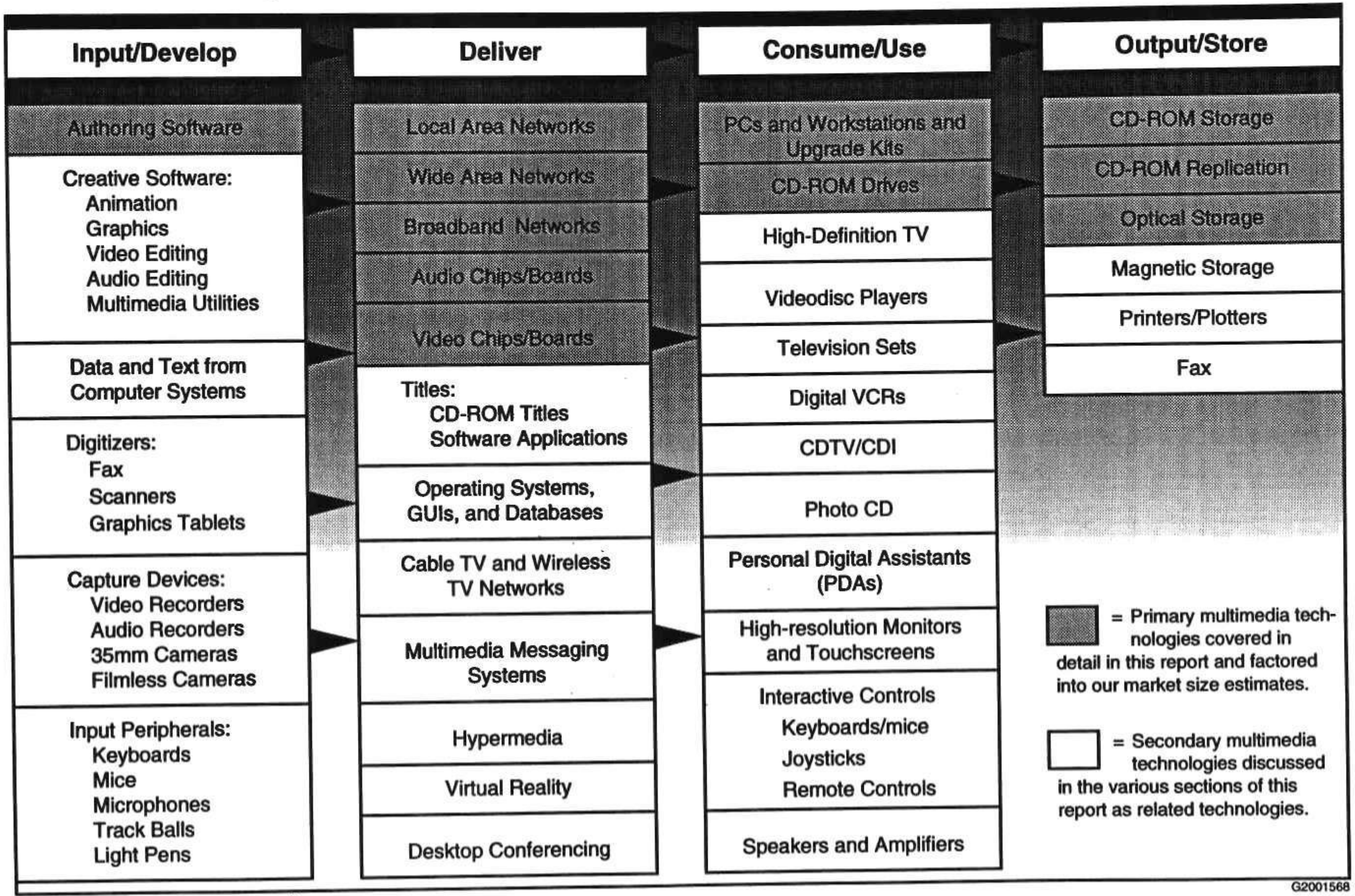
- Authoring software tools—Software used to create multimedia-enabled presentations, applications, education materials, and CD-ROM titles
- Networks—Local area networks used to deliver multimedia applications and programs
- Board subsystems—Audio and video board subsystems necessary for compression/decompression and playback of sound and full-motion video on computers, home entertainment systems, and game systems
- PCs and workstations—Preconfigured, multimedia-ready PCs and workstations
- Upgrade kits—Hardware upgrade kits comprising add-on audio and graphics boards, speakers, headsets, software, and CD-ROM drives used to multimedia-enable existing PCs
- CD-ROM drives—CD ROM drive hardware used to play back titles and applications stored on CD-ROM

We estimate that these technologies alone may represent as much as 75 percent of the total value of the multimedia computing market.

Forecast Assumptions

Dataquest's multimedia market forecasts are based on sets of assumptions about the factors that will drive and inhibit the growth of multimedia computing. Assumptions vary according to technology segment. Overall assumptions are outlined in the following paragraphs.

Figure 2-7
Multimedia Market Segmentation



Source: Dataquest (September 1992)

PCs and Workstations

- The PC and workstation multimedia forecast is the summation of MPC standard personal computers, plus Macintoshes, PowerPCs (new systems expected from Taligent in 1993-1994 time frame), multimedia-enabled technical workstations, and other systems. Other systems include Commodore's Amiga as well as other proprietary vendors' PCs. Multimedia-enabled computers must include a CD-ROM drive, audio and video support, and speakers.
- Multimedia-enabled PC and workstation shipments will grow at the same rate as CD-ROM drive shipments during the decade.
- Initially, sales of upgrade kits will outpace sales of multimedia-ready PCs. However, as more fully configured, multimedia-ready PCs are shipped directly from manufacturers, multimedia PC upgrade kit shipments will peak by 1994, see flat growth in 1995, and begin to decline in 1996.
- Shipments of fully configured multimedia PC systems will outpace upgrade kit shipments beginning in 1995.
- Multimedia PC hardware vendors will be pressed to differentiate their offerings from those of their competitors during the decade as multimedia-ready PCs and workstations become commodity items.

CD-ROM

- CD-ROM is and will remain the de facto standard for mass replication and distribution of multimedia titles and applications.
- The average price paid by an end user for an add-on CD-ROM drive will decrease from $621 in 1991, to $255 in 1993, and then to $120 by 1996.
- No other type of optical drive will approach CD-ROM's price-performance ratio in the forecast period.
- CD-ROM prices will be driven down by several factors: competition, economy of scale leveraged as the CD vendors move manufacturing off-shore, and volume shipments anticipated by major suppliers. The price declines will act as a strong market accelerator.
- The CD-ROM drive products are divided into low-end, midrange, and high-end segments. Three quarters of the total CD-ROM drives shipped in 1992 are estimated to be multimedia-capable and were purchased for running multimedia applications. The remaining one quarter shipped will be used for low-end text-only applications (for example, software distribution). However, Dataquest believes that by 1994, all the CD-ROM drives will have the performance necessary to run multimedia applications.

- CD-ROM networking will grow rapidly due to increased need for information access coupled with corporate incentives to save money on hardware purchases. Major software vendors will offer CD-networking software to provide another alternative to purchasing CD-drives or multimedia upgrade kits for individual users.

- Sony and Philips are developing standards for CD-Recordable with considerable industry support and participation. Dataquest anticipates that more than six vendors will introduce CD-Recordable products in the next 18 months. With this many vendors competing for a limited market share, the price of CD-Recordable will drop from $6,000 to $3,000 in the next 18 months. The affordable CD-Recordable drive will be widely used by multimedia title developers and for certain low-volume projects benefiting multimedia markets.

- CD-ROM XA will eventually replace CD-ROM for most applications because it will provide enhanced sound capabilities at a price comparable to CD-ROM. Most importantly, many new titles will include CD-ROM-XA audio capability, and this drive will be required to play them adequately.

- Included in Dataquest's overall CD-ROM forecasts are drives embedded in CD-I and CD-TV players, but not drives for video games such as NEC's PC Engine. Sales of CD-ROM drives in consumer products such as CD-I will not reach high levels until after 1995.

- Except for special multimedia PC models with built-in drives, most CD-ROM drives will be sold as a separate option.

Multimedia Authoring Tools

- Historically, authoring tools have been used predominantly by professional software developers, graphics arts and advertising professionals, educators (particularly higher education), and in-house training professionals. They are programming languages with graphical front ends that are used to integrate graphics, text, audio, and video elements into a single presentation or program. In order to penetrate the mass market, low-end toolkits are emerging at a rapid pace. These are easier to use, are geared toward creating presentations and short, self-guided lessons, and contain less features and capabilities than professional tools.

- While approximately 30 to 40 vendors are shipping true multimedia authoring software tools, the market is dominated by 2 major players, Asymetrix and MacroMedia. Their combined revenue totaled $45 million in 1991, which should grow to about $81 million combined in 1992.

- Authoring software vendor revenue in 1991 was approximately $81 million. We expect this amount to double to nearly $161 million by the end of 1992.

- Bundling software authoring tools with multimedia upgrade kits is a strategy used by Asymetrix and MacroMedia to "seed" the market. While the vendors are practically giving away the software (average royalty fee is estimated to be $20 to $40 per copy), this represents a way for toolkit vendors to penetrate the market very deeply with minimal sales effort.
- As a result of bundling, shipments of multimedia authoring software will skyrocket this year, from roughly 27,000 copies sold in 1991 to more than 700,000 copies in 1992.

Applications and Titles

- We estimate that there are approximately 200 multimedia titles commercially available in 1992. The vast majority are entertainment and information titles; only a handful can be considered business productivity applications.
- This picture will change during the next 12 to 18 months as developers begin to release productivity titles currently under development.
- The release of these applications will stimulate further demand for multimedia compatible PCs and a second-round development cycle for multimedia software.

Operating Systems

- The MS-DOS/Windows environment will be the predominant near-term place holder as a desktop multimedia operating environment.
- The most viable long-term operating systems for running multimedia applications will be multiuser, multitasking operating environments that provide a graphical or image user interface. OS/2, Windows NT, and PowerOpen are candidates. Except in its traditional niches, we do not expect to see UNIX widely accepted for either desktop or networked multimedia computing.

Semiconductors and Add-On Boards

- Sound boards will reach nearly 2 million units shipped in 1992, driven primarily by home info-tainment use.
- Acceptance of digital video and image handling will be slower to evolve because source material is still in development and compression standards are just stabilizing.
- Count on the chip industry to begin offering programmable audio, music, compression, and digital video chip sets from multiple sources. The cost of hardware should not be an issue.
- Sound (sound and music capture) will be embedded on nearly every PC/workstation by the end of the decade.

Telecommunications

- The primary definable multimedia networking market is for LANs and LAN internetworking hardware and software, including fiber-optic data distribution interface (FDDI) LANs. Central office switching, Centrex, PBX add-ons, T1 and T3 equipment and services, and the portion of data services attributable to multimedia cannot realistically be quantified. There will be growth in network services and equipment as a result of increased bandwidth demand and changing traffic characteristics coming from multimedia applications, but that demand will surface as a general increase in backbone networking.
- Shipments of multimedia-ready PCs and workstations will be associated with commensurate shipments of LAN components, while shipments of upgrade kits, nine times out of ten, will not, since the PCs and workstations being upgraded will already be serviced by LANs. In the forecasts for LANs related to multimedia, this has already been taken into account.
- Counted on the multimedia LAN configurations are network interface cards, network operating systems, intelligent hub ports, and routers. Cabling, installation, and repeaters or bridges were not counted.
- The growth in LANs supporting multimedia PCs and workstations is derived from two countervailing trends: (1) the increased percentage of PCs and workstations connected to LANs, and (2) falling component prices and an increase over time of the number of nodes on a LAN.
- Most of the networking revenue in the early period of the forecast will come from Ethernet and token-ring LANs. By the end of the forecast period, FDDI LANs will become increasingly important, however. Other exotic wide bandwidth equipment, such as SONET and asynchronous transfer mode (ATM) switches, and B-ISDN network services will come on stream during the forecast period. They will be market enablers, but their impact on the market will not be multimedia specific. As a result, they have not been added to the quantitative market forecast. Similarly, frame relay services and equipment, and other value-added wide area networking services have not been included.

Methodology

Dataquest's multimedia market size estimates are based on research conducted by the team of analysts that compiled this report. Each market segment was individually researched using methodologies that included the following:

- Vendor interviews—Face-to-face and telephone interviews with leading vendors in each field to gather product data including shipments, installed base, specifications, and sales channels; and company information including financials, employee headcount, and multimedia strategy

- OEM and third-party interviews—Face-to-face and telephone interviews with leading OEM partners and independent developers to verify and cross-check vendor-supplied data
- Secondary research—Reviewed annual reports, financial reports, computer data bases, company backgrounders, and other secondary sources to verify and cross-check vendor data
- Product demonstrations—Attended dozens of product demonstrations and leading industry trade shows to view and use the technologies discussed in this report
- Standards bodies—Interviewed representatives from leading multimedia standards bodies to "take their pulse" on where the multimedia industry stands today and where they expect to see it move in the future
- Analyst expertise—Dataquest analysts worked together as a team to validate and cross-check each other's statistics so that all reported data segments reconcile

Market Forecasts

Dataquest's overall forecasts for the value of the multimedia computing market are shown in Table 2-2. This includes the value of PCs and workstations, PC upgrade kits, nonkit audio and video boards (such as boards sold to individual users and for use in consumer electronics and games equipment), authoring software, local area networks, and CD-ROM drives sold in 1992 to support multimedia computing.

Figure 2-8 breaks out multimedia computing revenue forecasts by technology segments. We estimate that the current value of the multimedia computing market is nearly $2 billion. Nearly half of this revenue is for sales of complete multimedia-enabled systems. Based on the assumptions described above, during the next five years, we expect total multimedia computing revenue to grow to more than $9 billion dollars.

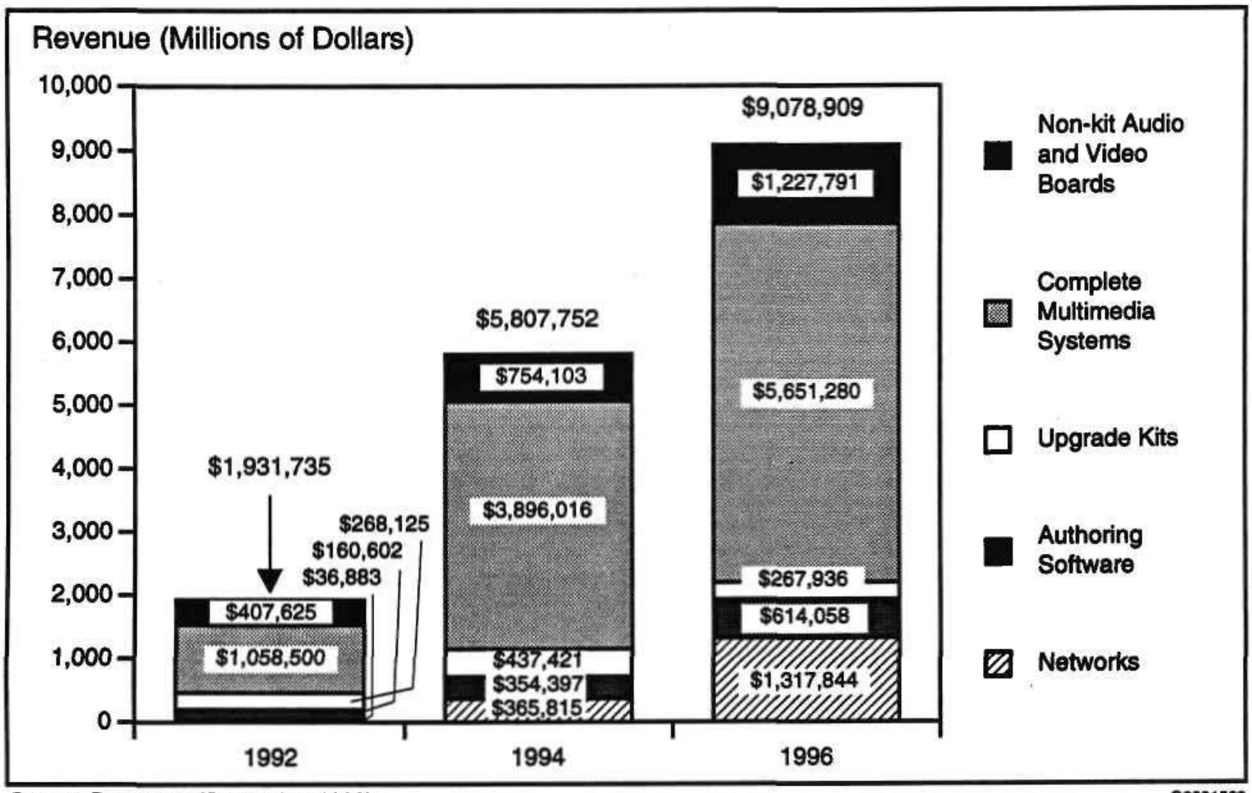
Figure 2-9 breaks out the percentage of revenue earned by the various technology segments. In 1992 and throughout the remainder of the forecast period, we expect revenue derived from sales of fully configured PCs and workstations to comprise the largest proportion of overall multimedia revenue. This will grow from 55 percent of total revenue in 1992 to 62 percent in 1996. Upgrade kits are responsible for 14 percent of revenue today, but this will decline to only 3 percent by 1996 as CD-ROM drives, video and audio boards, and other upgrade kit features become standard on all PCs. Local area network revenue will grow from 2 percent of the total market today to approximately 15 percent by 1996 as users implement multimedia networking services within their companies. Authoring software units sales will continue to grow, but will represent an increasingly smaller portion of total revenue over time compared with hardware revenue. And finally, revenue for audio and video boards sold independently of PCs and upgrade kits will

Table 2-2
Worldwide Multimedia Computing Market Forecasts by Technology Segment

	1991	1992	1993	1994	1995	1996	1992-96 CAGR (%)
SHIPMENTS (UNITS)							
Complete Systems:							
Authoring Software	36.4	728.9	1,726.1	1,831.8	2,222.1	2,709.7	38.9
Multimedia PCs/Workstations	50.0	325.0	1,690.5	1,909.6	2,711.2	3,818.4	43.1
Networks	3.2	11.6	49.0	89.9	156.5	250.4	115.7
Total	89.6	1,065.4	3,465.6	3,831.2	5,089.8	6,778.5	58.0
System Upgrades:							
Upgrade Kits	150.0	675.0	1,109.5	1,290.4	1,288.8	961.6	9.8
Peripherals:							
CD-ROM Drives	677.5	825.0	1,720.0	2,735.0	3,014.0	3,573.6	44.3
Sound Boards	600.0	1,800.0	3,200.0	4,900.0	5,900.0	6,800.0	39.4
Video Boards	140.3	450.0	820.0	1,320.0	2,060.0	2,990.0	95.8
Total	1,417.8	3,075.0	5,740.0	8,955.0	10,974.0	13,363.6	66.8
FACTORY REVENUE ($K)							
Complete Systems:							
Authoring Software	80.920	160,602	304,180	354,397	457,999	614,058	39.8
Multimedia PCs/Workstations	250,000	1,058,500	3,885,840	3,896,016	4,753,240	5,651,280	52.0
Networks	10,103	36,833	174,538	365,815	757,554	1,317,844	144.6
Total	341,023	1,255,935	3,644,258	4,420,820	5,987,553	7,583,182	56.8
System Upgrades:							
Upgrade Kits	100,250	268,125	412,640	437,421	376,200	267,936	-0.0
Peripherals:							
CD-ROM Drives	237,125	259,875	481,600	689,220	663,080	714,720	28.8
Sound Boards	61,200	171,000	304,000	450,800	513,900	561,400	34.6
Video Boards	245,000	315,000	460,000	555,000	735,000	960,000	32.1
Total	543,325	745,875	1,245,600	1,695,020	1,911,980	2,236,120	31.6

Source: Dataquest (September 1992)

Figure 2-8
Worldwide Multimedia Computing Market—Revenue Forecast by Technology Segment



Source: Dataquest (September 1992)

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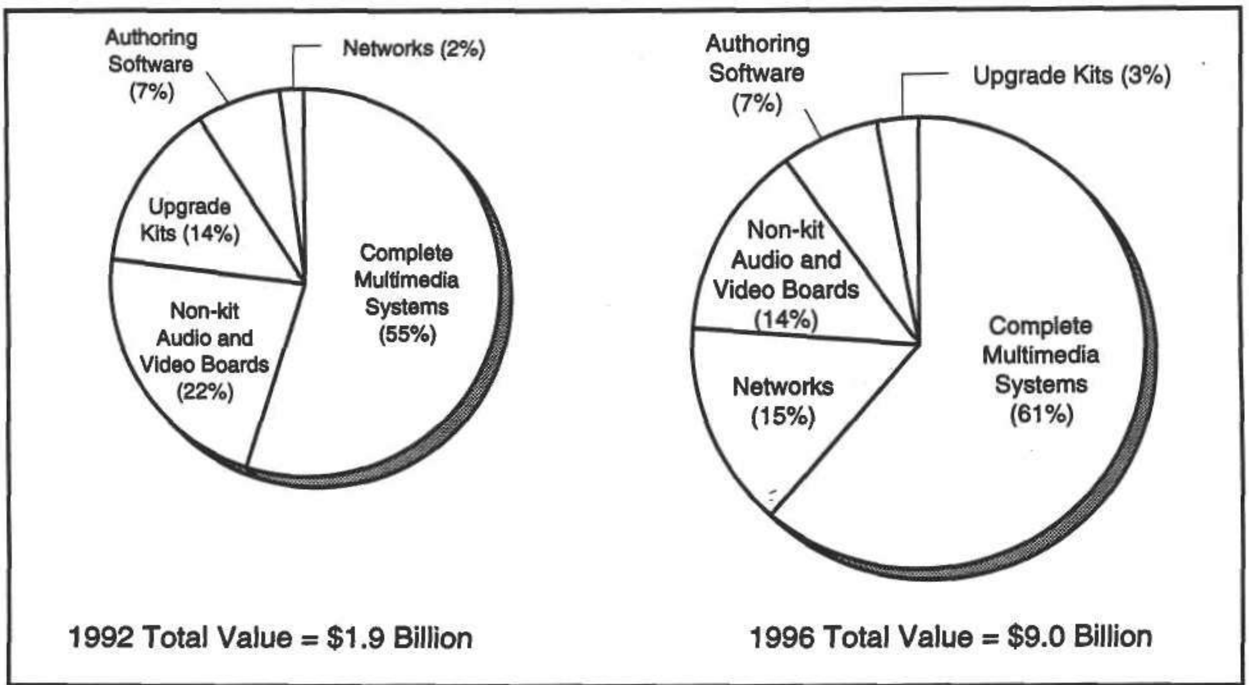
remain strong as these devices continue to be sold into both computing and consumer electronics segments.

The growth in unit shipments for the various multimedia computing segments is shown in Figure 2-10. Authoring software tools will enjoy the highest unit volume of any of the computer technology segments, rising from only 36,000 units shipped in 1991 to more than 2.7 million units by 1996. The spike in unit volume between 1991 and 1993 is attributed to volumes pushed through the upgrade kit market. The rise of complete multimedia systems shipments will be only slightly slower, growing from 50,000 units in 1991 to around 2.5 million in 1996. Local area network shipments will show a steady unit growth commensurate with the rise of multimedia-capable systems, from 3,152 multimedia LANs shipped in 1991 to approximately 251,000 by 1996. The rise and decline in sales of

Figure 2-9
Multimedia Computing Revenue Growth



Source: Dataquest (September 1992)

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upgrade kits that was discussed previously is visually apparent in this chart. They will grow to a high point of 1.6 million units in 1994, then begin to decline.

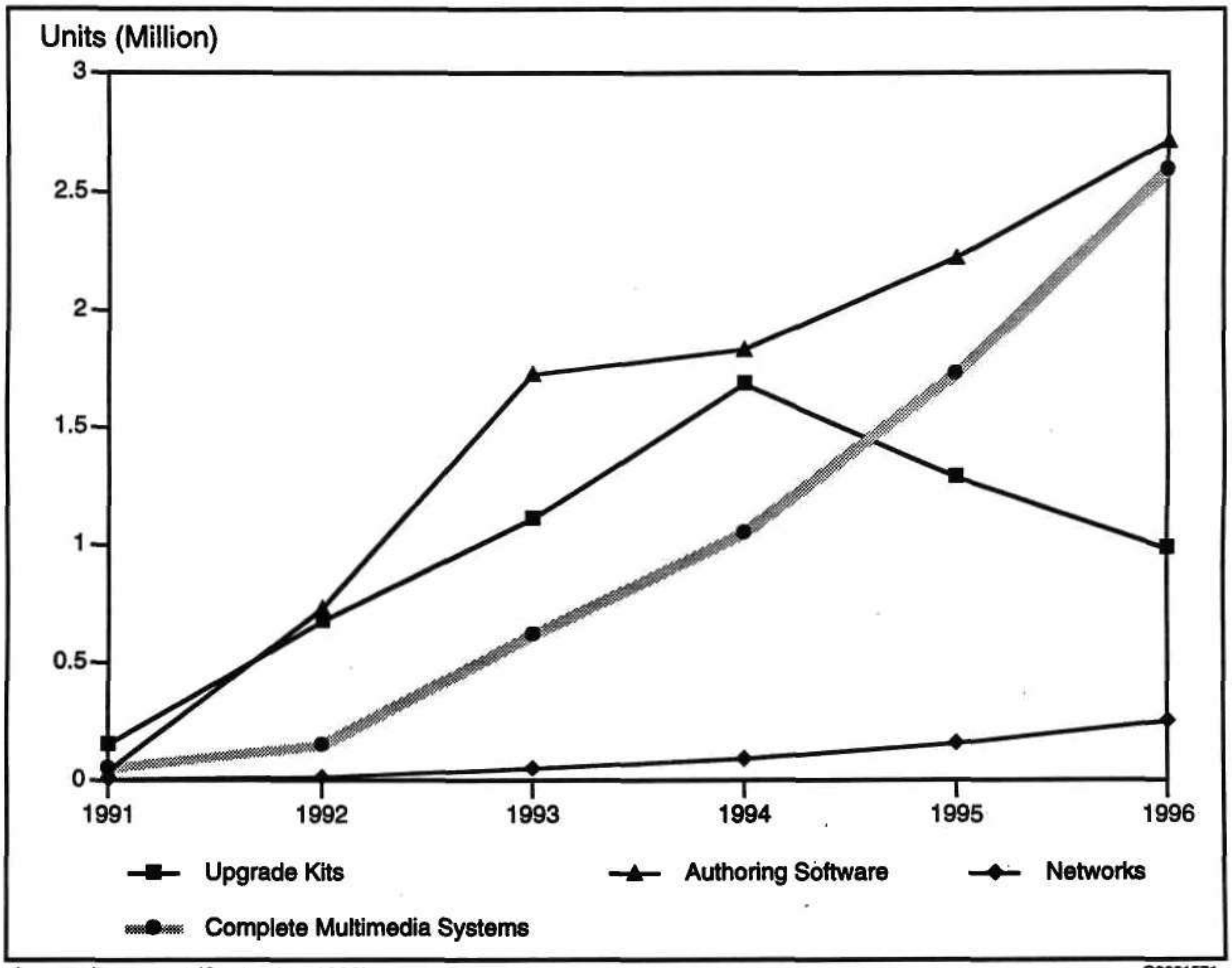
Shipment forecasts for audio and video boards are shown in Figure 2-11. We assume that audio and video boards will be embedded in PCs during the reporting period. Sales of audio boards will be nearly triple those of video boards due to greater market requirements for high-quality sound in consumer and computing devices, whereas most video boards will be used primarily in computer systems. Audio board unit shipments will grow from 600 million in 1991 to 6.8 billion in 1996. Video board shipments will grow from 140 million to 2.9 billion during the same period.

Please refer to the individual chapters of this report for more in-depth segmentation, market statistics, and market analyses of the various multimedia computing technology segments.

Dataquest Perspective

Multimedia technology will increasingly impact the way that people use and disseminate information during the course of the 1990s. By the end of the decade, multimedia capabilities including audio, full-motion video, animation, hypermedia, and image interfaces such as virtual reality will be firmly embedded in the computer systems in everyday use. In the home, too, consumers will be exposed to

Figure 2-10
Multimedia Computing Unit Shipments by Technology Segment

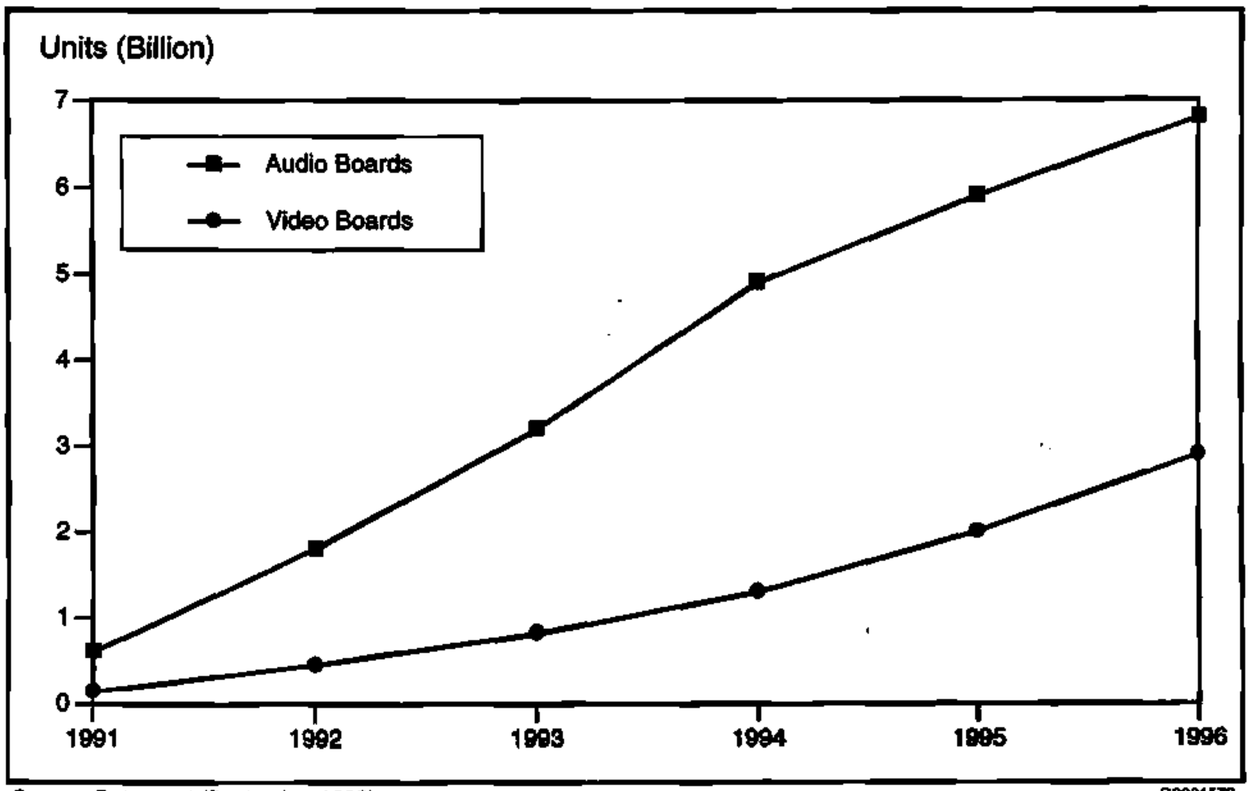


Source: Dataquest (September 1992) G2001571

multimedia communications daily through television, interactive systems, and telephone video communications.

The remainder of this two-volume report provides an in-depth exploration of key technologies that will influence and drive the development of multimedia, with primary emphasis on the multimedia computing market.

Figure 2-11
Worldwide Video and Audio Board Unit Shipment Forecasts



Source: Dataquest (September 1992)

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Chapter 3
Semiconductor Technologies and Opportunities in Multimedia

Multimedia Opportunities

A substantial market opportunity for semiconductors is drawing near, and that opportunity is called multimedia. Properly defined, the multimedia market is a collection of markets associated with coincidental, semiconductor-rich evolutions of computer, communications, and consumer systems.

Opportunity exists in the following areas:

- Computer multimedia hardware market—In PC and workstation add-on subsystems for sound and video/images
- Communications hardware—From video communication to new equipment for handling bandwidth demands of multimedia communication
- Consumer multimedia—In home information and entertainment ("info-tainment") terminals and their interactive interface to outside services

Dataquest estimates that multimedia applications will generate $423 million in incremental revenue to the semiconductor industry in 1992. This figure will climb to $1.7 billion by 1996. Near-term volume opportunities await in the computer sound and optical disk areas, while intermediate-term opportunities are in computer digital video, video communication, and consumer terminals. Long-term markets are in LAN, WAN, and internetworking equipment.

In this chapter we examine many of these areas and illuminate the architectural trends and market opportunities for semiconductors.

Market Analysis

Definitions and Market Segmentation

From a semiconductor market standpoint, Dataquest has classified multimedia hardware opportunities into three basic categories: computer, communication, and consumer systems and subsystems. Definitions are as follows:

- Computer platforms and upgrades
  - PCs, workstations, windows terminals, kiosks

- Digital video/graphics boards and functions
- Sound/MIDI processing boards and functions
- Storage systems (optical, RDD, VCR, among others)
- Scanners/filmless cameras

- Communication
  - LAN, WAN, ISDN: systems, boards, and functions
  - Video teleconferencing systems, boards
  - Video telephones
  - Broadcast/cable/satellite studio and distribution equipment
- Consumer
  - Information and entertainment terminals
  - Interactive and on-demand systems
  - Satellite/cable receivers
  - Digital and HDTV receivers, VCRs, camcorders
  - Specialized consumer: karaoke, filmless photography

Technology Overview

Semiconductor technology is truly an enabler of multimedia computing and communication. Continued improvements in semiconductor technology in terms of miniaturization and power consumption are allowing difficult multimedia problems to be solved economically.

Semiconductor Basics

The basic challenge multimedia brings to these systems is the need for processing and transmitting a huge amount of data in a short amount of time. New developments in semiconductor design, process, and packaging technology are allowing those challenges to be met.

New electronic computer-aided design (ECAD) software tools are empowering chip designers to implement extremely complex, manufacturable designs in just days. With synthesis, a way to generate a chip design from high-level specification, key functions vital to multimedia can be created almost overnight.

Application-specific integrated circuits (ASICs) are important vehicles used to implement multimedia functions today. ASIC process technologies such as 0.65-micron CMOS are capable of creating 250,000-gate designs that can easily integrate most multimedia functions onto one chip. ASICs can come as gate arrays, cell-based ICs, field-programmable gate arrays (FPGAs), or as combinations. Gate arrays allow the customer to specify the gate connections on an array of unconnected gates. Cell-based ICs allow customization with blocks of gates in predefined functions. FPGAs can be customized by the OEM without involvement of the chip company.

ASICs can be designed by the OEM for proprietary use or by a chip company. In the latter case, ASICs developed for the mass market are called application-specific standard products (ASSPs).

Multimedia Enablers

Multimedia computing and communicating entails processing, compressing, transmitting, and storing sound, video, and still images, in addition to traditional text and graphics data. Because these new data types create large files when converted to computer format, they are unstorable and untransmittable unless compressed. These data types are converted to computer or digital format so that they can be processed under application software control, such as for authoring a presentation.

Digitizing and compression form the heart of new semiconductor activities in multimedia. New chips are being introduced based on industry standards for sound, video, and compression. These chips help make handling of multimedia data types an affordable prospect for mass market appeal.

Digital signal processing (DSP) technology is crucial for many of the more mathematically intensive aspects of dealing with sound or compressing video. DSP technology can be a microprocessorlike chip or it can be embedded into other functions or ASICs. Hardware compression, like that used for CD audio or video data, relies heavily on DSP functionality at its core.

Digitization of sound and video involves the use of data conversion technology to send data to and from the analog (or real world) state and the language of computers, the digital state. Because data are embodied onto one chip, it is a mixed-signal IC. Breakthroughs in integrating more analog and digital features are considered to be a defining achievement in further reducing the cost of multimedia systems.

As a final point, the myriad of standards found in multimedia technologies and the role semiconductors play should be remembered. Standards exist for signals such as NSTC (U.S./Japanese TV standard), CD audio, and video teleconferencing, as well as various compression methods. Productive ECAD systems and high-density ASIC processes are making implementation of these standards common and economical.

Technology Markets and Drivers

Key multimedia applications for semiconductors were identified previously. The impact will be significant volume semiconductor opportunities developing over the next decade. As a foundation for analysis and market projections, it is important to revisit some observations.

Technology Trends and Opportunities

The following subsections identify semiconductor opportunities and explore the technological and architectural trends within the multimedia hardware identified previously.

Computer Platforms and Upgrades

Upgrades in kit form or individual subsystems such as boards or disk drives will prove to be the most viable manifestation of the computer multimedia market in the near term. We can expect PC and workstation manufacturers to begin turning to embedding multimedia subsystems as a means of differentiation and margin attainment over the next two to three years.

Sound: Can Be Heard Leading the Pack

Almost all PCs and workstations are capable of generating sound from a small embedded speaker. Most often this sound capability is 8-bit monaural and can only be accessed via application program calls such as those generated by most video games. The majority of systems cannot accept user sound inputs such as voice or music, but this is changing. The use of sound is expected to evolve, becoming more sophisticated as it expands beyond its video game roots into applications such as voice annotation, CD quality music, and interactive training (see Figure 3-1).

Sound Developments: Standards and DSP Rollout. The huge success of Creative Lab's Sound Blaster add-in board products has captured the interest of the computer industry. Creative Labs and its competitors capitalized on the large installed base of home PCs and sound-laden entertainment titles. The success has helped stimulate establishment of sound standards. Standardized operating system environments (for example, QuickTime, DOS Multimedia Extensions, and Windows 3.1 MCI) and application program interfaces (APIs) in particular are stimulating the development of sound-embedded software programs and titles. Object linking and embedding (OLE) within advanced, multitasking operating systems will further stimulate sound in mainstream business desktop applications.

Several important recent announcements within the world of computer sound are as follows:

- Apple Computer is understood to be working with AT&T Microelectronics for incorporation of its DSP technology on certain high-end offerings to be introduced soon.
- IBM is reported to be incorporating Texas Instruments' DSP-based mWave technology into its platforms for 1993. The DSP subsystem will also manage modem and fax processing.
- Microsoft is rumored to be working on a next-generation sound capability known as "Foghorn."

Figure 3-1
The Evolution of Computer Sound

Today

Sound board: add-on
Microphone: add-on
Speaker: mono/add-on
Standard GUI
MIDI: Add-on, synthesized
Limited speech recognition

Tomorrow

Embedded sound subsystem
Embedded microphone
Embedded stereo speakers
Sound user interface
MIDI: command processor, sampled
Continuous word speech recognition
Text-to-speech
Voice mail

Source: Dataquest (September 1992) G2001579

- Over the last year the IBM-compatible platform market has witnessed Creative Labs' Sound Blaster become a de facto standard claiming more than 1,000 compatible software titles and shipment of more than 1 million boards. Media Vision and others have joined Creative Labs in offering compatible products for the Windows 3.1 environment. Yamaha's OPL 3 FM synthesis technology also became a de facto standard. Media Vision has a relationship with Cirrus logic to design and market a multimedia audio chip set.
- Analog Devices, Compaq Computer, and Microsoft have joined forces on a project known as "Business Audio." The purpose of this project is to develop hardware and software that enriches business applications under Windows 3.1 with sound "annotations" or files. Based on Analog Devices' SoundPort chip, this sound subsystem is capable of 16-bit, 44.1-KHz (CD-quality) sound I/O. Lernout and Hauspie is working with Analog Devices to provide speech recognition and speech-to-text software for its DSP processors.
- Apple's line, the Commodore Amiga, and NeXT's Cube are the best early examples of sophisticated sound usage by platforms. NeXT employs a Motorola 56001 DSP MPU in all its computers for processing speech and music.

- In Japan, Fujitsu's FM Towns multimedia PC with CD-quality sound is shipping very well into the education market. More than 200,000 units are claimed to have shipped through mid-1992.
- Built into Tandy's new Sensation PC is Yamaha's Magic chip set for sound processing.

Sound Technology and the Future. The basic trend is toward 16-bit stereo (or more channels), with CD-quality sampling at 44.1 KHz, and a MIDI—despite a lack of 16-bit stereo applications. Another trend is toward the use of more sophisticated synthesis and sampled sound to replace or complement FM synthesis in reproducing sound. This addresses the complaint that computer sound has an "arcade game" quality. Sampled sound uses actual ROM-captured sound elements of instruments, among others, to produce higher-fidelity music and sounds.

The key assumption behind these trends is that a higher performance standard will emerge beyond the MPC specification. A key enabler will be development of titles that take advantage of the higher CD-quality sound.

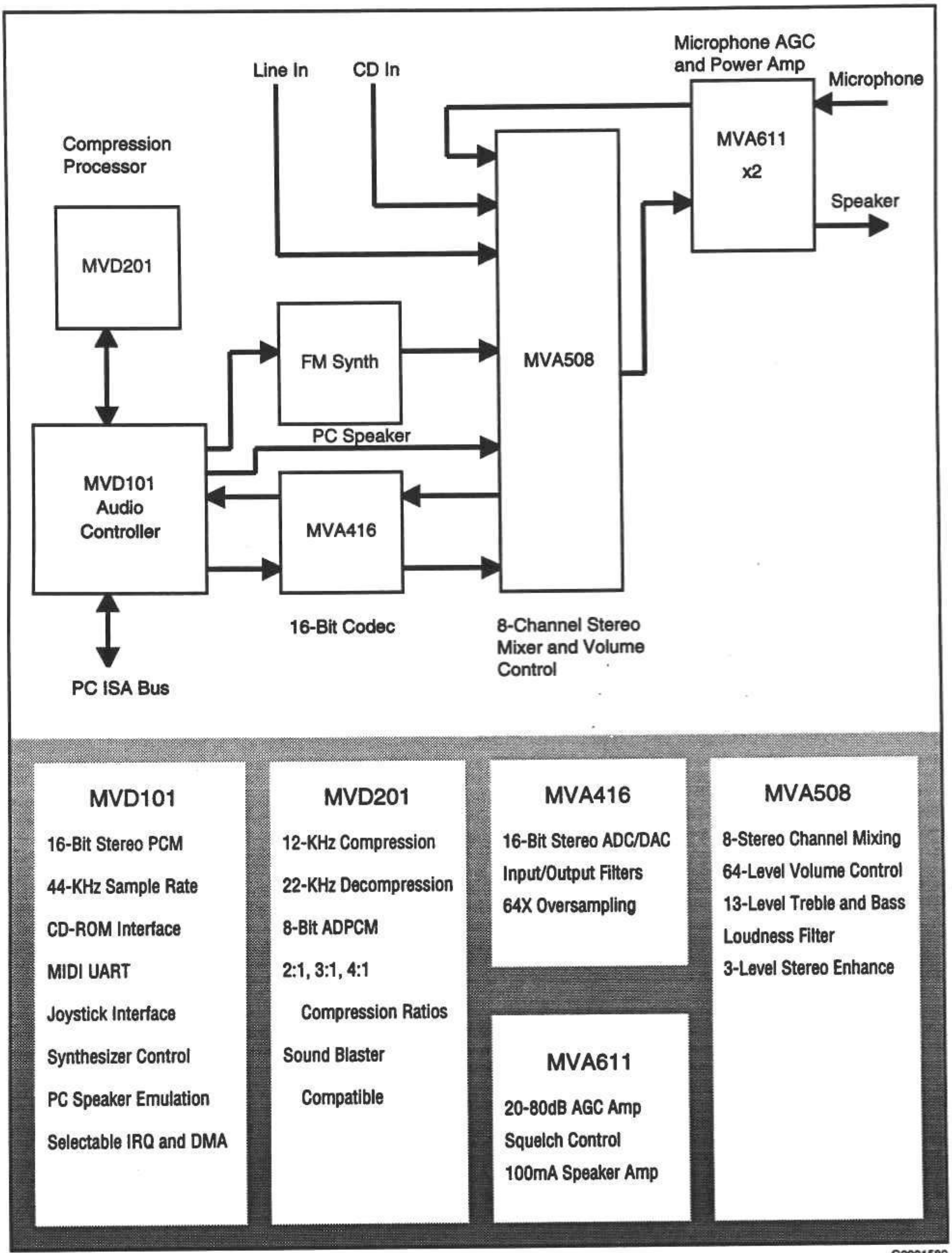
Sound processing functions will be implemented in both standard ICs or ASSP chip sets with DSP cores, or as programmable DSPs, or as cell-based ASICs. The ASIC solution is the most popular currently as proprietary technologies battle for market dominance. However, it is giving way to ASSP approaches (see Figure 3-2). ASSP chip sets for digital sound processing and synthesis range in price from $20 to $60 (sampled sound is more). Companies with computer sound chip sets include: Cirrus Logic/Media Vision, Analog Devices, Yamaha, Matsushita, Sierra Semiconductor, AOM, E-mu system, Roland, Zoran, Philips, Integrated Circuit Systems, Information Storage Devices, and Ensoniq. Yamaha OPL 3 chips currently are the most widely used.

Sound is also migrating to programmable DSP-based motherboard subsystems that can time-share between sound/music capture and output, fax, modem, voice mail, speech recognition, and speech-to-text. Time-sharing this hardware investment is making it possible to add all these features at once. Likely hardware vehicles for executing that functionality are DSP MPU ICs varying from 16- to 32-bit and integer and floating point in capability. The amount of time-sharing tasks and compression processing will determine the performance level.

Numerous digital, mixed-signal, and analog semiconductor opportunities are available on sound add-in boards and sound subsystems of mother boards, as follows:

- DSP MPUs or custom versions with DSP cores (16- to 32-bit)
- Cell-based ASICs (CMOS, 40K gates)

Figure 3-2
Sound Subsytem 16-Bit Block Diagram



Source: Media Vision

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- 8, 12, 16 A/D and D/A converters (up to 44.1-KHz sample rate)
- ADPCM codec (up to 4:1 compression)
- FM synthesizers (for MIDI), sampled sound (0.5-4MB of ROM, EPROM, flash)
- Sound source mixer, audio filters, amplifiers (up to 5W)
- FIFO (64 bytes), buffer (up to 1MB slow SRAM)
- MIDI interface (UART), MIDI command processor
- Host bus transceivers/buffers
- Optional: SCSI interface

Independent Algorithms: Have Standard, Will Travel. Companies such as AT&T with its DSP32 VCOS software environment, Texas Instruments 320xxx series ICs with its mWave software, and Analog Devices with its Signal Computing approach are providing hardware alternatives bundled with second-party-developed software algorithm libraries. These "living" and "updatable" libraries can be invoked by user application via one of the standard APIs and can include the following algorithms (from AT&T Microelectronics):

- MPEG audio
- DTMF decode/generate
- G.722 audio coding
- V.32 9600-baud fax modem
- V.29 9600-baud fax modem
- MPC music synthesizer
- Speech recognizer
- HQ call process detection
- Handwriting recognition
- Video and image handling
- SBC speech coder telephone interface
- Sample rate conversion
- CD-ROM/XA audio coding
- V.22bis 2400-baud modem
- MPC MIDI interface
- LD CELP speech coder
- Text-to-speech synthesis
- Caller ID
- Speakerphone AEC

Video and Image Handling

Along with animation, video and image processing is the most challenging multimedia feature from the standpoint of cost-effectiveness and hardware technology. Image processing involves the capture, processing, and display of a rasterized still image. Video is the same, except that it involves the time element, with multiple frames per second.

Our surveys indicate that digital video capability will be one of the slower aspects of multimedia to catch on because it remains relatively expensive and difficult to use. Both issues are expected to be addressed as ULSI componentry tackles cost issues and some sizable early applications stimulate software developer interest in video-rich applications. Early adopters of digital video capabilities include the following, which can readily use still images, animation, or video to increase effectiveness:

- Publishing, journalism, and advertising
- Corporate and vocational adult training
- Education (for example, second languages)
- Corporate communication (internal, external)

We expect workstation vendors to be the early patrons of embedded digital video as video teleconferencing capability is coupled with it. This is because the early adopters of workstation technology are engineers, designers, and financial users that would be willing to pay for the productivity improvements of visualization and "no-travel" meetings. Figure 3-3 shows the many aspects of video/image handling and storage for desktop platforms.

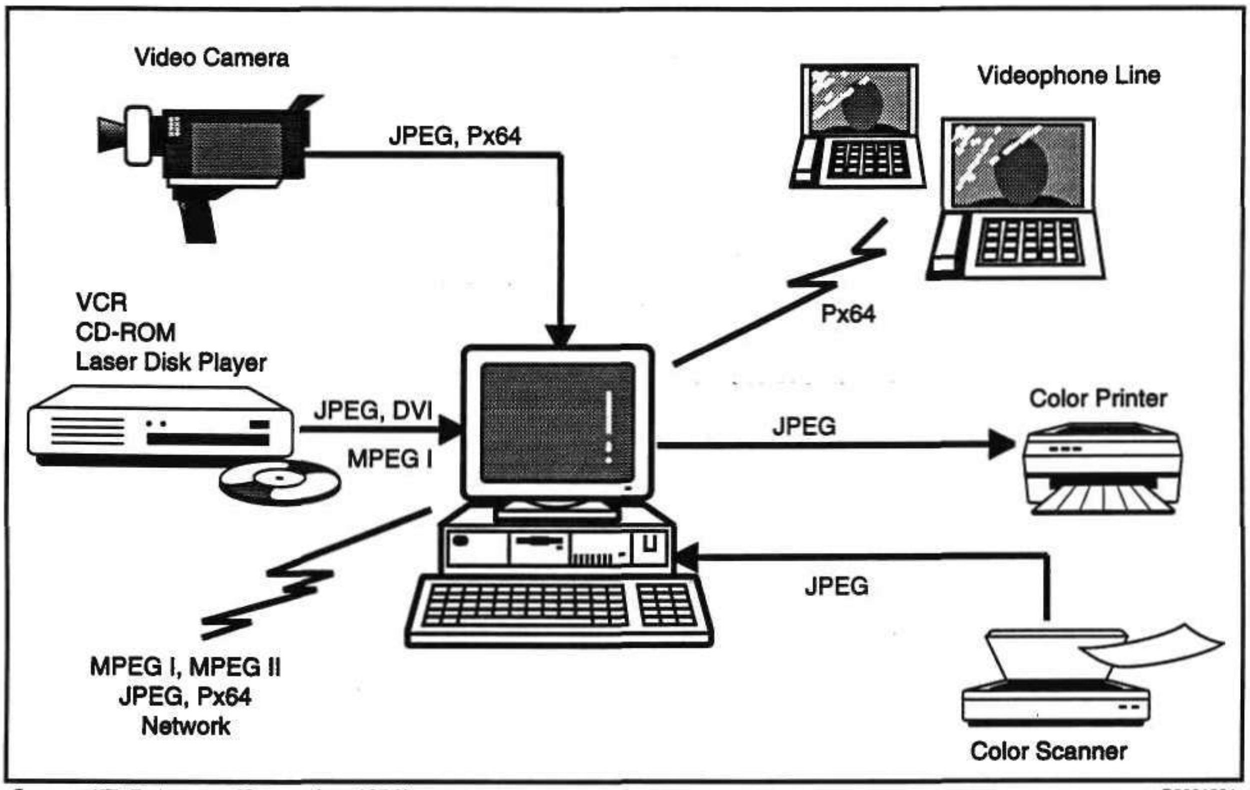
The Opportunities. Figure 3-4 is a block diagram of a multifunctional add-in board featuring image digitization, capture, digital processing, compression/decompression, display, and storage. In reality, only a subset of those functions is found on most boards. On the low end are boards that merely capture a frame or display TV pictures in a window with no additional processing. At the high end are boards that can compress and manage data on the hard disk or other attached storage device.

As image processing becomes more mainstream, we expect digital video functions to merge with graphics functions such as controllers and RAMDACs. Ultimately integrated multimedia controllers or coprocessors will emerge that manage most of the accelerated hardware sound, communication I/O, and video processing.

Semiconductor opportunities within digital video exist for a variety of functions in ASIC and standard ASSP forms. Most are subject to integration with each other as well as with the sound and graphics functions. Functions of note include the following:

- A/D to D/A (video rates, 8- to 16-bit)
- NTSC/PAL/SECAM encode/decode ICs

Figure 3-3
Generic Computer Digital Video

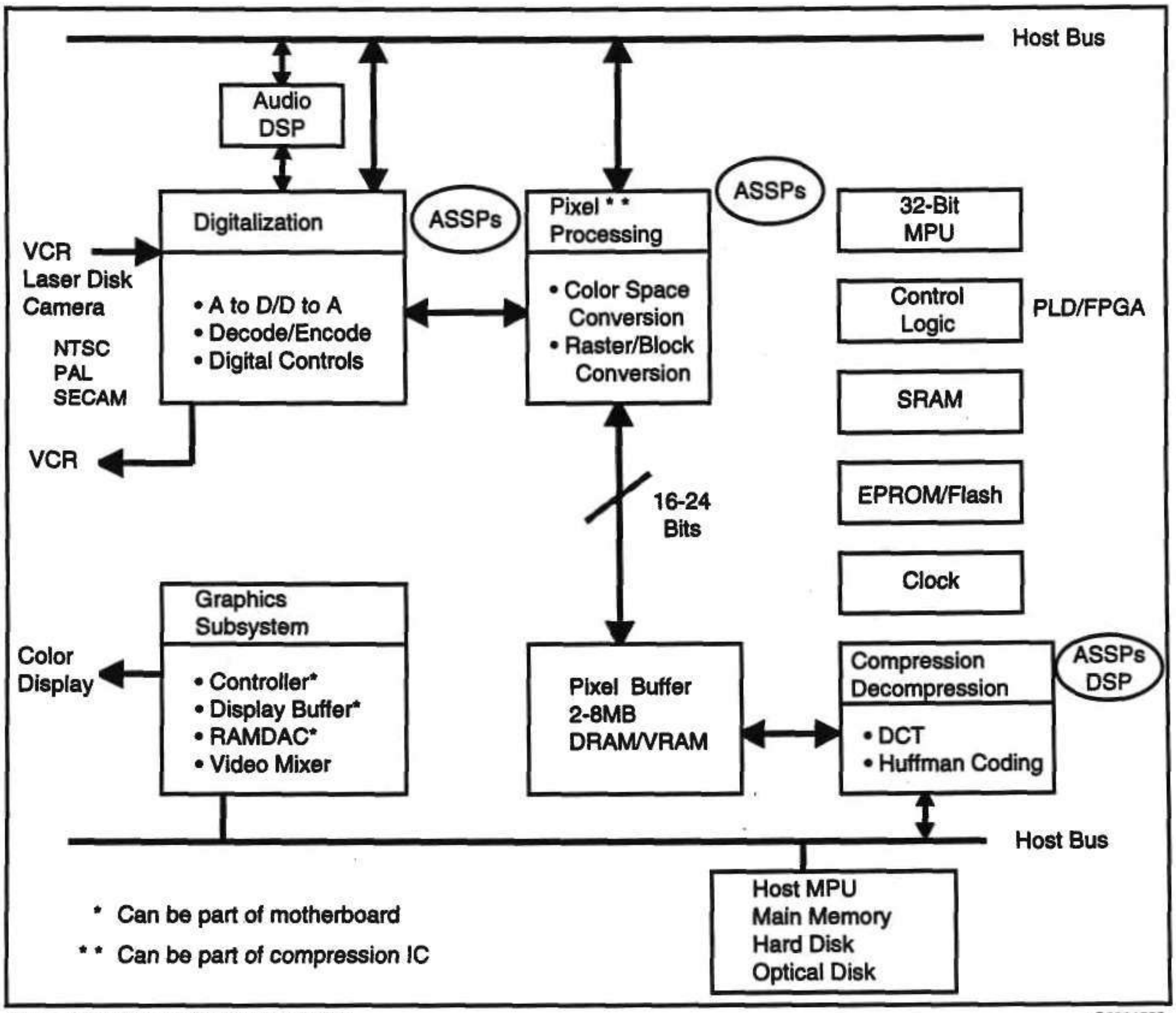


Source: IIT, Dataquest (September 1992) G2001581

- Tuner section ICs (for tuner cards)
- Compression ICs (JPEG, MPEG, DVI, QuickTime, AVI)
- Color space conversion ICs (YUV-RGB)
- Window-sizing ICs (for example, NTSC to QCIF)
- Pixel stream mixer ICs (for example, combined VGA, video, and teleconferencing)
- Programmable controller/DSP (executing combinations of above)
- Frame/line buffers (DRAM/VRAM/SRAM—45ns, 2-8MB)
- PLD/FPGA (3,000 to 5,000 gates, custom features, time-to-market)
- Clock/clock distribution (gen lock), interface functions
- Optional: 16- to 32-bit processor to off-load main CPU, SCSI controller, RAMDACs, and graphics controllers integrated with above features

Compression and Bandwidth Challenges. Compression is seen as a major factor enabling computer digital video and imaging. This is because one color photograph can require 20MB to store and an NTSC (TV)

Figure 3-4
Computer Digital Video Block Diagram



Source: Dataquest (September 1992) G2001582

film clip of 5 seconds can require 150MB, in uncompressed states. Likewise an uncompressed digitized NTSC video signal can require 12 MHz of 8-bit bus or network bandwidth. Compression can come in four forms: lossey and lossless, and still-image-based and motion-oriented. Generally video/image compression is lossey where a percentage of the original information is lost through the compression/decompression cycle.

Compression takes advantage of the fact that much of the information in a picture does not change dramatically over a small area and therefore is redundant and filtered out. For motion video, there is the additional observation that most of the image does not change from frame to frame, and this is redundant as well. Compression algorithms take advantage of these two factors.

Several standards have been proposed to address the need for compression, some open and some proprietary. Likewise some allow real-time encoding economically, and some do not. Table 3-1 compares some open standards. The Joint Photographics Experts Group (JPEG) standard is targeted at still image or picture compression. The Motion Picture Experts Group (MPEG) standard is targeted at motion video. Central to both technologies is the use of discrete cosine transform (DCT) matrix algebra and a Huffman coding algorithm (see Figure 3-5). Both standards are managed and evolved by a committee of the International Standards Organization (ISO). A third open standard known as Px64 or H.261 is targeted at video conferencing/phone technology and is managed by the CCITT.

Competing Compression Technologies. The principal difference between the different compression standards involve coding efficiency (compression ratio), amount of loss (susceptibility to artifacts), and data transmission bandwidth and storage (see Figure 3-6).

Several companies offer or are working on proprietary standards and variants to MPEG. Real-time, high-quality (VHS or better), and low-cost encoding is one of the principal designing challenges to stimulate authoring and content development. The following section describes companies working on video/image compression functionality.

Companies working on MPEG/JPEG are as follows:

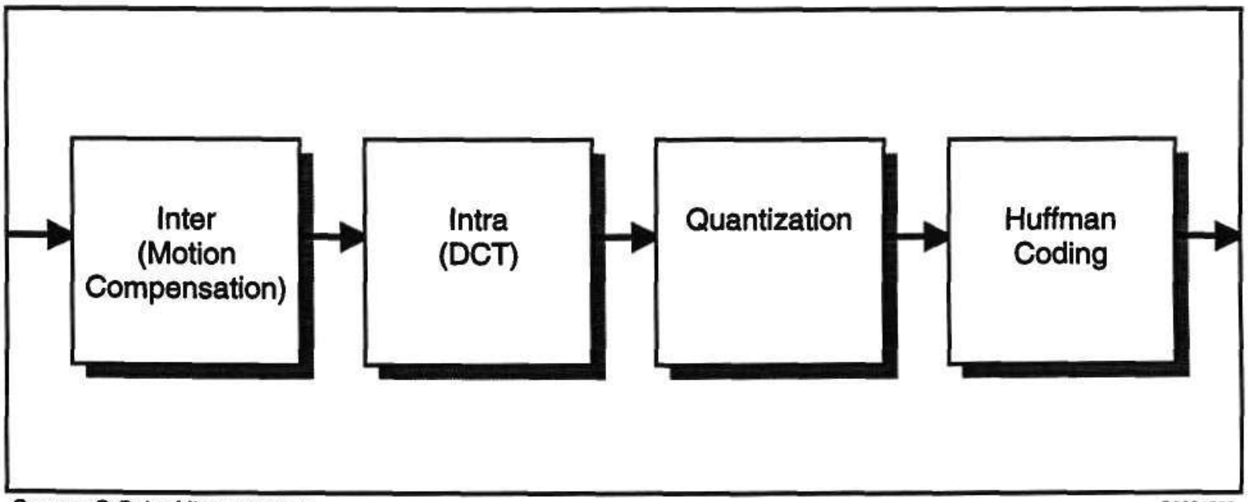
- C-Cube Microsystems—The leader in open standard, single-chip implementations; low-cost MPEG decompression IC for CD-I (see profile)
- AT&T Microelectronics—Flexible programmable chip set-capable, featuring real-time MPEG encoding
- LSI Logic—Early entrant with JPEG and H.261 chip set

Table 3-1
Open Compression Standards

	Standard			
Feature	JPEG	MPEG I	MPEG II	Px64
Color Still Image	X	X	X	X
Motion Video	X*	X	X	X
Real-Time Video Capture/Playback	X	X		
Broadcast Motion			X	
Compression Ratio**	to 80:1	to 200:1	to 100:1	to 2000:1
Bandwidth**		to 1.5 Mbps	to 10 Mbps	64 Kbps-2 Mbps

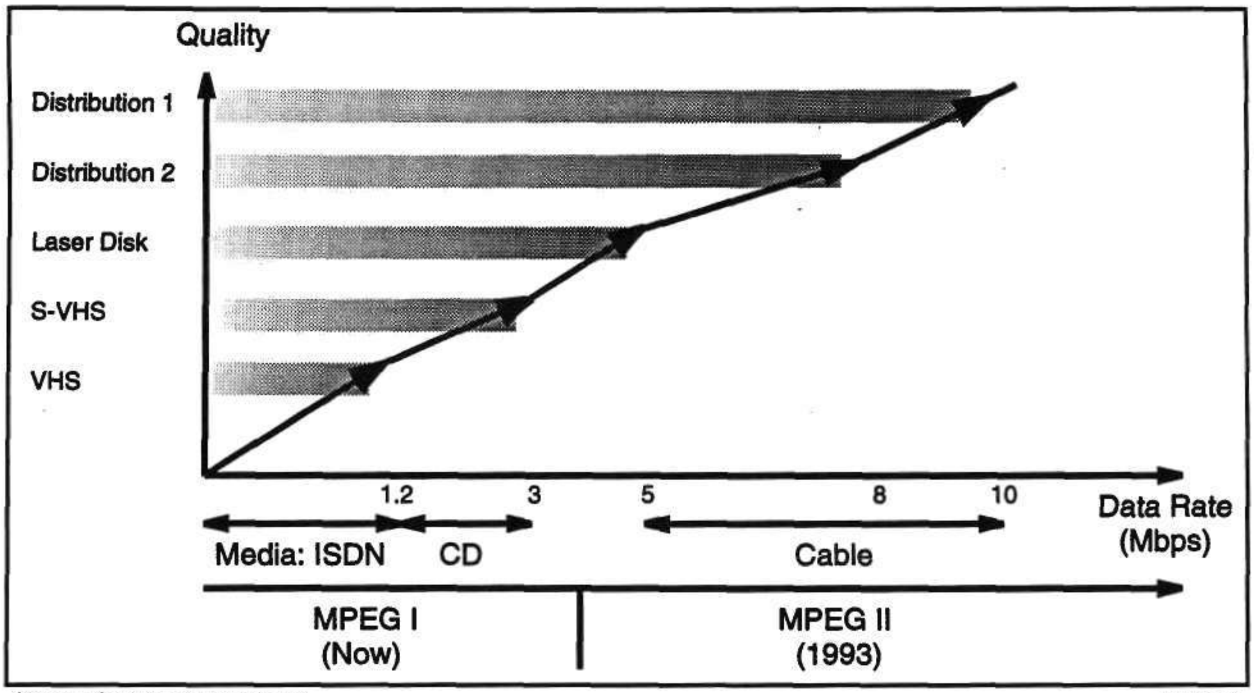
*Requires higher bandwidth
**Varies with resolution, frame rate, and image complexity
Source: Dataquest (September 1992)

Figure 3-5
MPEG Compression Process



Source: C-Cube Microsystems G2001583

Figure 3-6
Motion Video Compression Standard Trade Offs



Source: C-Cube Microsystems G2001584

- SGS-Thomson—Also early entrant with building block functions such as motion estimators; plans to introduce an MPEG decoder and combined MPEG/H.261 encoder/decoder chips this year

- Integrated Information Technology (IIT)—Has programmable Vision Processor technology; working with Compression Labs on several video phone/conferencing projects
- Zoran—Has JPEG chip set; working with Fuji on filmless camera compression into memory card
- Others (rumored or lab)—Motorola, Texas Instruments (DSP based), Cypress Semiconductor

Digital Video Interactive (DVI) from Intel as originally introduced supports two modes of operation: real-time video (RTV) with resolutions currently up to 128 x 120 pixels can achieve 20:1 compression at 30 frames per second; production-level video (PLV) with resolutions currently up to 512 x 480 pixels can achieve 100:1 compression at 30 frames per second. DVI/PLV allows for discrete frame flagging for video-editing purposes. PLV encoding or mastering of source material is done by Intel or a service bureau on a mainframe computer at a charge of $200 per minute, with up to one month of lead time.

The technology is implemented on Intel's i750B compression chip set. Intel is positioning the technology as programmable with the ability to execute the open MPEG and JPEG standards and their evolutions as well. Version 3.0 of DVI, which is supposed to be akin to MPEG-2 in performance, is reported to be on the way. To date IBM is a DVI major patron; it has built it into its Ultimedia platform, the joint IBM/Intel ActionMedia II board set, and kiosks developed by IBM for Blockbuster Entertainment to demo videos interactively. PictureTel of video conferencing fame also uses DVI as its core technology.

QuickTime, Apple's multimedia environment, offers software-based JPEG/MPEG-like compression for video (QuickTime Movies), still images, animation, and graphics. Hardware acceleration of this is considered a good semiconductor opportunity.

Microsoft's audio-video interleaved (AVI) technology, set to be further unveiled in September, is expected to support compression like QuickTime does. It is expected to support three quality modes for decompression for high-, medium-, and low-resolution and frame rate. The higher-performance modes will require significant host CPU cycles to execute and therefore are considered candidates for acceleration.

OS/2 2.0 will support multimedia and compression this fall.

The numerous variants to MPEG offered as de facto standards include the following:

- MPEG JVC extension—Less lossey; 50:1 compression ratio; 6-Mbps bit stream
- MPEG III—Targeted at HDTV with 60-Mbps bit stream

- Compression Labs—Compressed Digital Video (CDV) up to 6.6-Mbps bit stream; more than 60:1 compression ratio; planned usage on ATRC HDTV proposal and Hughes's DBS TV system
- Fractals—Object-based; uses a control language rather than DCT; patents held by Iterated Systems; $25,000 system based on i960 and 8 ASICs; 500:1 compression; takes 1 second to decompress

Now What for Compression? None of the existing compression standards in silicon is perfect from a performance standpoint. There continues to be a bandwidth versus performance trade-off. Image quality drops off with artifacts and other problems creep in near 50:1 compression with DCT-based approaches. On the other hand, developers and users want an open standard so that files are interchangeable. The latter issue may be solved as the industry's major operating systems move to software compression, creating an attractive opportunity for developers to work on video-oriented tools, applications, and titles. Dataquest believes that hardware acceleration of these will emerge quickly as chip opportunities. The movement to a local graphics/video bus as proposed by VESA and Intel also could alleviate the quality/bandwidth problem by allowing higher bandwidth at lesser compression ratios.

Digitization and Processing Functions. Compression might get most of the press, but to date not most of the profits. Functions for conversion of TV signals (video and audio) into a format for digital manipulation is the most stable aspect of digital video so far. Digital manipulation includes frame capturing, compressing, editing, and creating special effects. There is a battle to decide whether TV-oriented semiconductor companies or computer graphics semiconductor companies can execute on the right product definitions. Some players include the following:

- Philips Semiconductors/Signetics—In particular has a dominant position in digital video functions such as A/D converters, TV signal decoders (for creating square pixels), color space conversion, frame sizing, clock generation, and digital encoders
- Cirrus Logic/Pixel—Has a newly launched integrated digital video processor to complement graphics and data conversion products
- Brooktree—Has introduced NTSC/PAL encoder chip with plans to expand RAMDAC line to integrate digital processing functions
- SGS-Thomson—Has offerings in RAMDACs, compression, and digital TV processing
- Chips & Technologies—Has PC video chip designed into some high-volume boards
- Sony—Has offerings in digital TV circuits and a corporate focus on multimedia
- Matsushita—A video giant with the same potential as Sony

- Graphics and printer rasterizer controller companies such as: Tseng Labs, Chips & Technologies, Adaptec, and Destiny are potential competitors

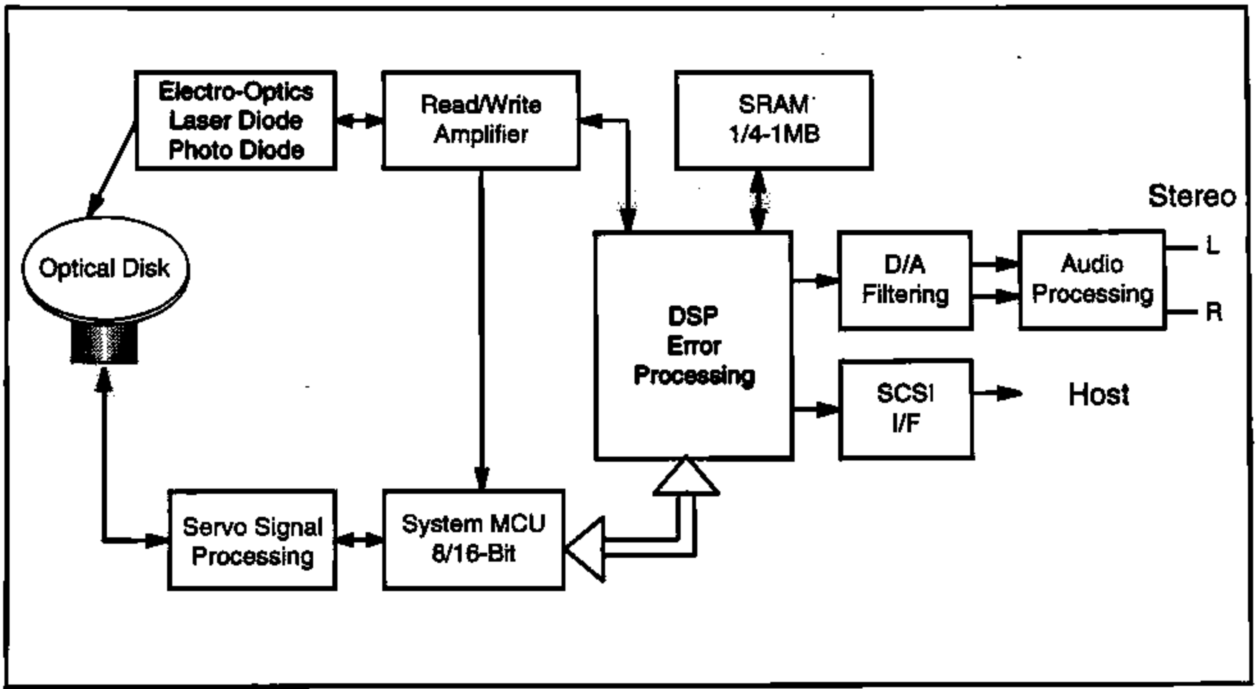
Multimedia Storage Opportunities

Optical Is Visible. Multimedia is a principal catalyst stimulating the exploding market for optical storage. Optical storage is popular in multimedia because of the large multidata-type files of images and audio, among others, and because it offers near-gigabyte capacity on a publishable media. In addition to CD-ROM, CD-ROM/XA (extended architecture for interleaved ADPCM audio) and CD-I (compact disc interactive) are emerging this year as optical storage alternatives.

Figure 3-7 shows a block diagram of a CD-ROM/XA drive. Opportunities exist for 16- to 32-bit DSP MPUs, error detection/error correction coding (ECC) functions, laser/photodiodes, SCSI controller (for host too), SRAMs, amplifiers, interface, and for an 8- to 16-bit MCU for motor control/housekeeping.

Sony and Panasonic/Matsushita are the world leaders in specialized CD-ROM controller chips. Sanyo Semiconductor, meanwhile, has introduced what it claims is the world's first chip set to handle encoding, decoding, and real-time ED/ECC concurrently for four

Figure 3-7
CD-ROM/XA Block Diagram



Source: Dataquest (September 1992)
G2001585

CD formats: CD-ROM, CD-DA, CD-I, and CD-DRAW (for MO drives).

VCRs and Other Equipment. Computer multimedia will also be a demand stimulant for gigabyte-class magnetic rigid disk drives. There will be demand for a new generation of high-performance magneto-optical technology, as well as control, data management, filtering, and interface electronics (these are not covered in this report).

Other multimedia-induced storage opportunities for semiconductors include VCRs (both VHS and 8mm/S) and laser disk players. Also expect digitally controlled VCRs to be stimulated by the need for addressable frame/edit control. NEC's Video Sequencer and Paltex International's EDDI editing systems allow for pull-down menu control between VCRs. DiaQuest's DQ-Animaq is an example of a system that takes computer-resident images, video, and animation sequences and writes them frame by frame to videotape. We believe that the market for these systems tracks the shipments of mid- to high-level authoring software packages.

In general, we expect VCRs to transition to digital controls, amenable to the interactivity of creating and using multimedia material. General Instruments and Toshiba recently announced an alliance to develop digital VCR technology. We expect other VCR suppliers such as Matsushita and JVC also to enter the market.

Scanners

There are more than 50 companies marketing scanners or optical character recognition (OCR) equipment to the world market. Scanners capture printed (or film) images and send them to a host computer for processing as an image or as recognizable characters. The three basic types of scanning hardware varying in performance, speed, and portability, are as follows:

- Flatbed—$1,000 to $2,500 price range
- Sheetfed—$6,000 to $20,000 price range
- Hand-held/camera—$250 to $900 price range

Scanners can run from 300 dots per inch (dpi) to more than 1,000 dpi utilizing for the most part linear CCD arrays. For good color or gray-scale capture, 600 dpi usually is employed. The bulk of the scanners handle 256 gray-scale levels or color levels out of a 24-bit palette of options (limited by computer display capability). Marketers of scanners include the following:

- AGFA
- Apple Computer
- Artix Technologies
- Bell & Howell
- Caere

- Chinon
- Diamond Flower Electric
- Epson
- Everex
- Fuji Photo
- Fujitsu
- Hewlett-Packard
- Imapro
- Kodak
- Logitech
- Marstek
- Minolta
- Mitsumi
- Nikon
- Nisca
- Panasonic
- Pentax
- Polaroid
- Ricoh
- Sharp
- The Complete PC
- Wang Labs
- Xerox

Dataquest estimates the world market for scanners in 1991 to be 450,000 units yielding $425 million in revenue. As driven by multimedia authoring and OCR scanning, this market could grow to 950,000 units by 1996 and to revenue of $570 million. A composite of various market estimates place color capability at 50 percent and hand-held at 20 percent of the market by 1996.

Kiosks: Multimedia Meets the Public

Multimedia kiosks, or small stands with computer terminals embedded in them, are springing up all over. Used in point-of-sale or point-of-information settings, they provide visitors and shoppers with interactive help. At airports and hotels they provide information about the city, restaurants, and sights, complete with interactive, compressed video and stereo sound. Use by retail establishments is boundless, including the following ideas:

- Product demos (cosmetics and fashions, among others)
- How-to demos (home improvement stores, car part stores)

- Movie rental (library clips can be viewed)
- Tape/CD demo (prepurchase samples at record stores)

The technology employed includes a base PC or workstation and display augmented with CD-ROM (or CD-I), compressed, CD-quality sound with speakers or headphones, and compressed digital video as necessary. Voice input is on the horizon for these systems as well. Companies at the forefront of this technology include IBM and AT&T/NCR. The estimated 1992 worldwide market is in the 10,000- to 20,000-unit range, with prices ranging from $2,000 to $10,000 per unit. As content is developed and large retail chains deploy kiosks, annual volumes could reach the low millions by the 1996 time frame.

Multimedia Communications Opportunities

The need to communicate multimedia information is creating an attractive opportunity for communications equipment companies and their chip partner/suppliers. In this section we will examine multimedia communications markets in the context of three interrelated categories: networking (both public and private); video communication; and a category called home communication, which includes the delivery of broadband and interactive services.

Multimedia Networking

Multimedia communication is certainly the demand driver ISDN was looking for to break the cost-volume logjam, as ISDN lines continue to run 1.5 times the price of a plain old telephone service (POTS) line. The principal impact of multimedia network communication is that it will require greater bandwidth than what is commonly available today.

As shown in Table 3-2, compressed video communication is the most demanding of multimedia data types and has very different requirements than those found in the typical ethernet or token-ring LAN.

Perhaps the most important need of interactive multimedia transmission (that is, a video conferencing session) is bandwidth on demand. These interactive sessions require full duplex connection such as regular telephone service offers. LANs were not optimized for this ability.

Table 3-2
Characteristics of Video Traffic

	Data Traffic	Video Traffic
Type	Bursty	Stream-oriented
Data Rates	Variable (0-peak)	Steady (64 Kbps)
Reliability	Crucial	Tolerates loss
Delivery Timing	"Loose," retransmissions	Crucial, real time

Source: Starlight Networks, Dataquest (September 1992)

Enter ATM. Figures 3-8 through 3-10 present a likely scenario as to how LANs/MANs/WANs could evolve over the coming decade to support multimedia networking. Today's approach uses hub/concentrator-anchored LANs connected by internetworking equipment such as bridges, routers, and gateways. This is evolving into layouts using FDDI as the backbone with processor-intensive internet equipment. This move will aid delivery of improved bandwidth to the individual users, but it still has many faults.

In an effort to prepare for the bandwidth onslaught, telecom service providers around the world are designing new systems to allow global, seamless, networking that encompasses the demands of multimedia and its diverse data types. As an upgrade to X.25 packet switching systems, a new technology called frame relay is under consideration. Frame relay is capable of 56 Kbps with upgradability to T1 (1.54 Mbps). Another broadband capability for switched public networks is the switched multimegabit data service (SMDS) originally proposed by BellCore in the United States and being tested by the regional Bells and several European countries. SMDS uses the IEEE 802.6 access protocol and runs at T1 and T3 (44.7 Mbps) rates, with 155 Mbps planned.

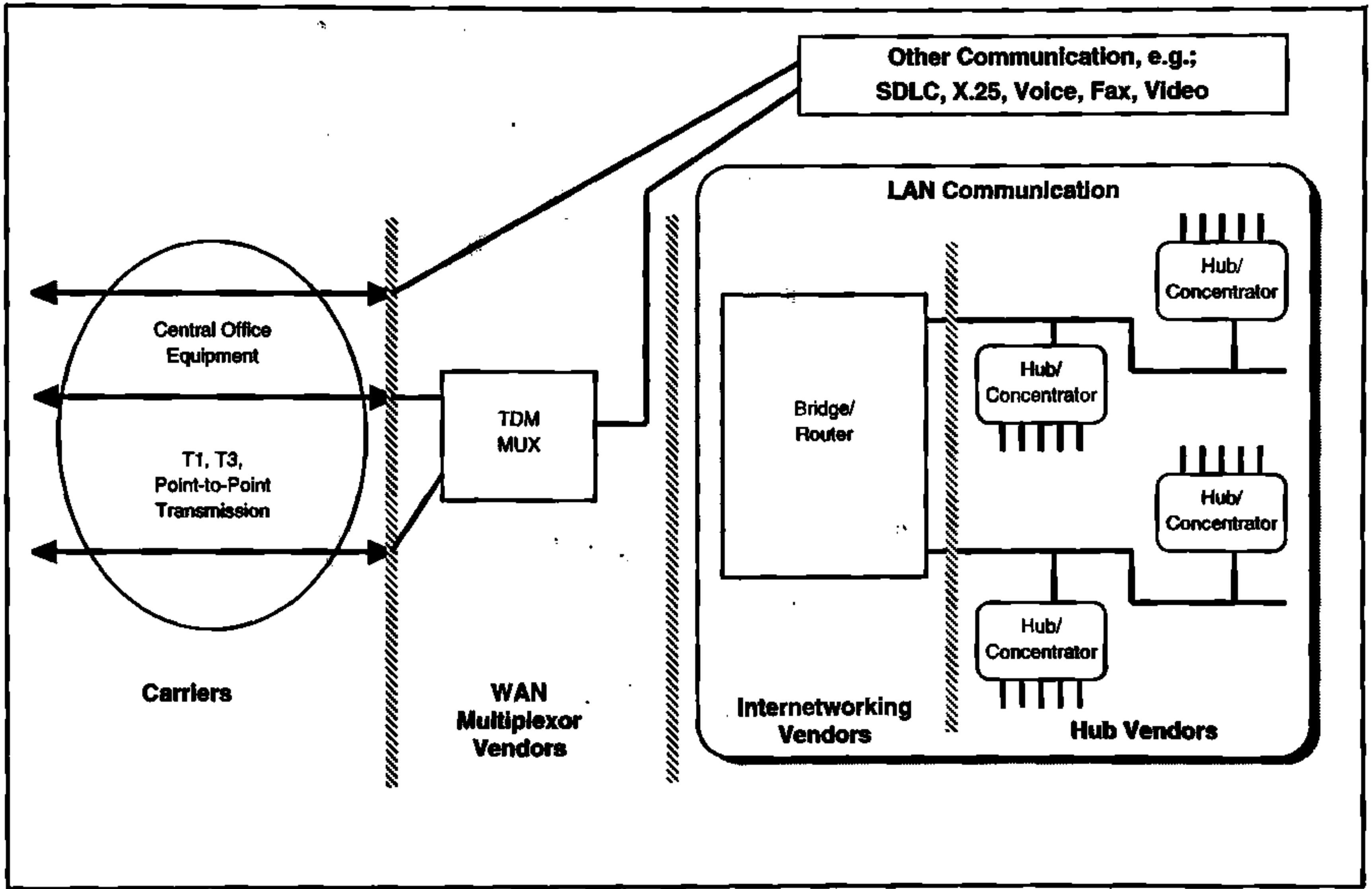
SMDS is viewed by many in the industry as the leading intermediate solution, as opposed to frame relay. However, asynchronous transfer mode (ATM) is another technology that many consider to be the ultimate solution to the problems outlined previously. Initially, ATM will be capable of delivering up to 155 Mbps in on-demand bandwidth (known as isochronous communication). To be eventually capable of 622 Mbps (OC-12) transmissions as well, ATM uses fixed cells of 53 bytes (5 for header, the rest for data). ATM provides no error checking and thus processing is simplified. ATM circuits receive the data asynchronously and overlay (or recover) the data onto the train of cells passing at the transmission rate (for example, 155 Mbps). Idle cells are inserted to adapt the user data rate to the transmission rate. To accommodate varying communications services, an additional protocol layer known as the ATM adaption layer (AAL) can be employed.

ATM would operate on fiber-optic media utilizing the synchronous digital hierarchy (SDH) technology as specified by the CCITT. SDH is also known as SONET. SDH forms the transmission medium of what is known as B-ISDN and is capable of 1.244-Gbps and 2.488-Gbps rates as well.

Figure 3-11 shows how an ATM connection would be implemented in silicon using the functions described.

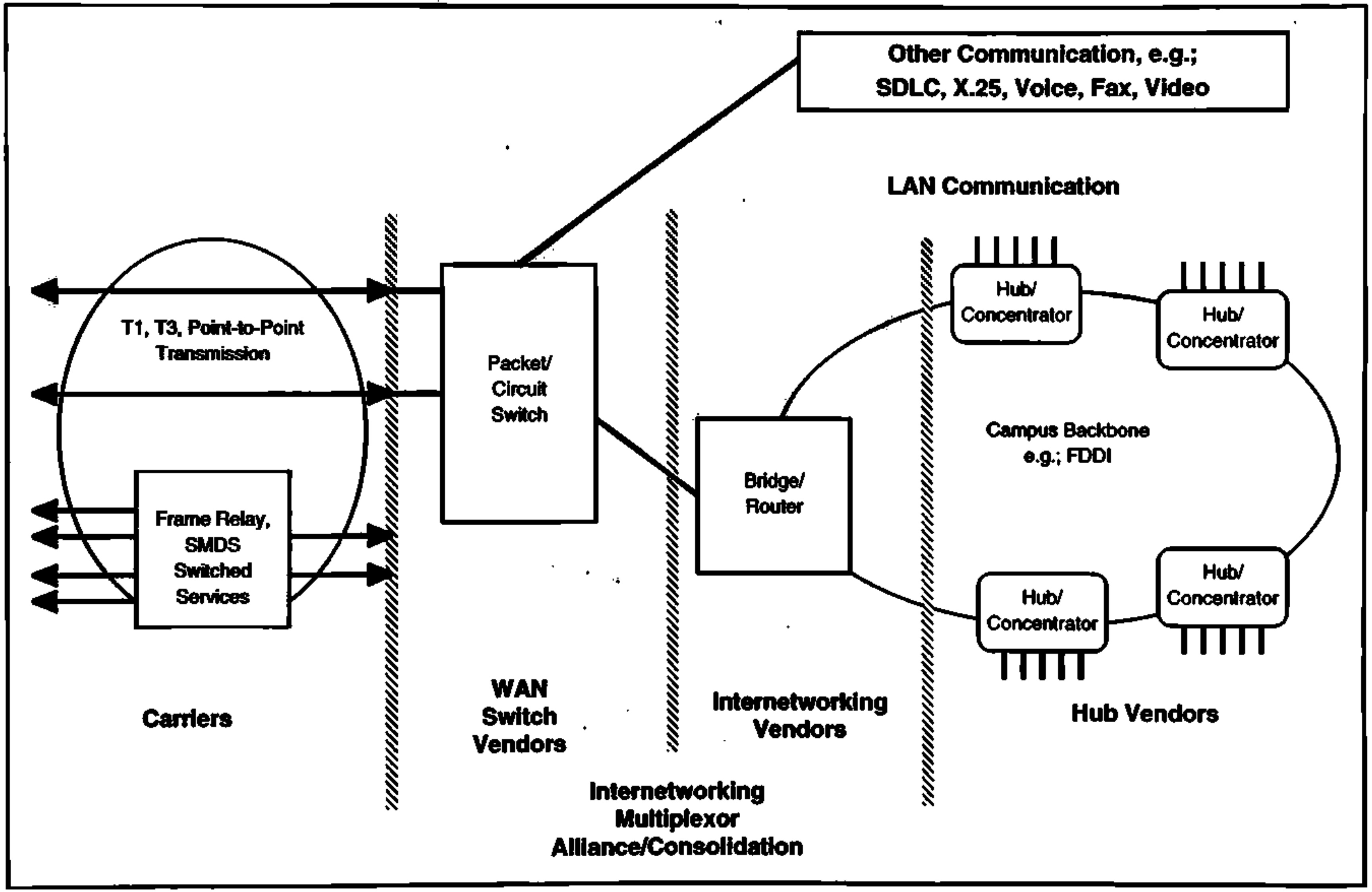
A host of companies are working on ATM/SONET switches, multiplexers, and internetworking equipment. An industry group known as the ATM Forum was formed to promote product development

Figure 3-8
Integrated Enterprise Networks Today



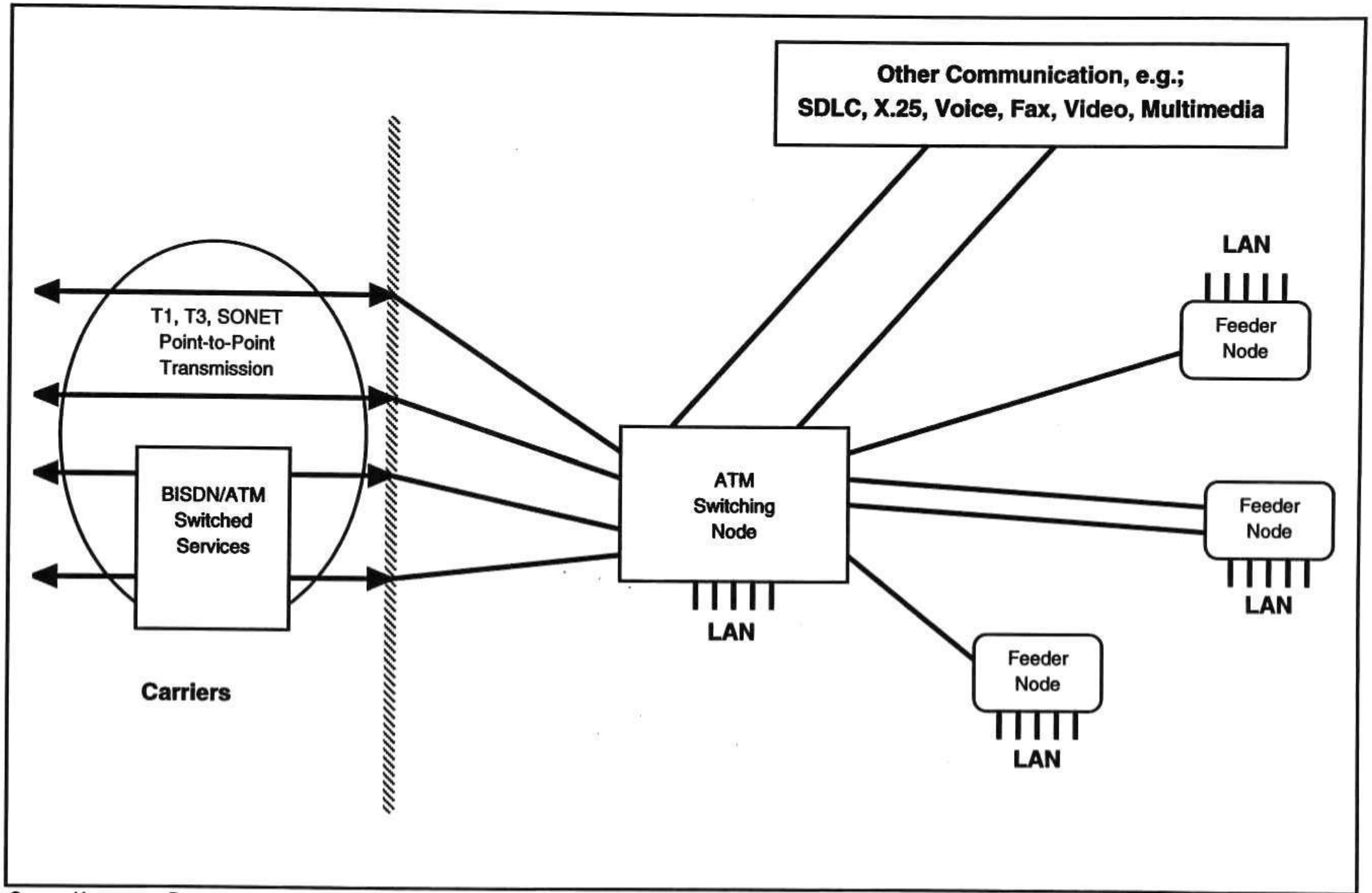
Source: Ungermann-Bass

Figure 3-9
Near-Term Network Evolution



Source: Ungermann-Bass

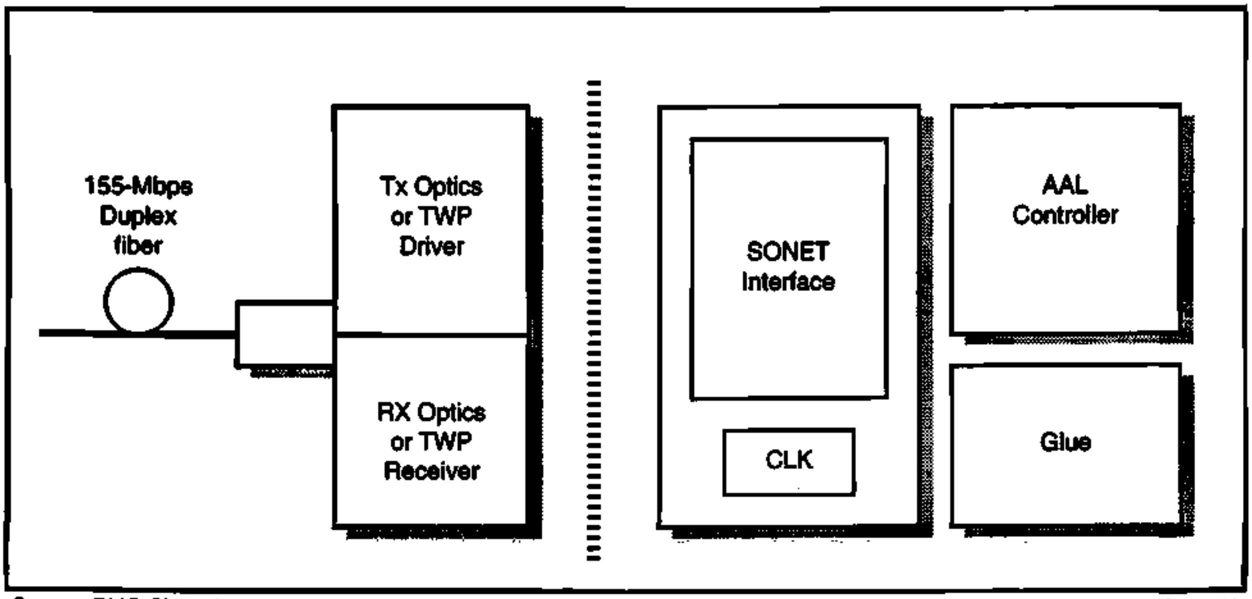
Figure 3-10
ATM-Based Network: Seamless Multimedia Networking on a Global Scale



Source: Ungermann-Bass

G2001588

Figure 3-11
ATM/SONET Interface



Source: PMC-Sierra Inc.

G2001589

and has more than 100 members. Equipment developers include the following:

- Adaptive (NET)
- Xerox PARC
- NEC
- Fujitsu
- Siemens
- Northern Telecom
- AT&T
- Thomson CSF

Chip suppliers of ATM/SONET circuits include: AT&T, Sierra-PMC, Base2 Systems, Transwitch, Hitachi (SONET), Bipolar Integrated Technologies, Vitesse, National Semiconductor, Applied Micro Circuits Corp., Philips, and Triquint (SONET). ATM functions included cell assembly/disassembly and media interface in both ASIC and ASSP forms. There are ongoing opportunities to supply N-ISDN functions such as S/T and U interfaces, rate adapters, and transceivers supporting high bit-rate digital subscriber line (HDSL) and its follow-ons.

Multimedia Servers. Storage and communication of multimedia data types will impact the downsizing phenomenon from mainframes and superminis to networked servers based on scalable RISC architectures. In addition to filing, computing, e-mail, faxing, WAN communication, and print server functions, we can expect still image, video, and sound (as separate from voice mail) handling added to a server's capability. From a hardware point of view, this could dramatically impact severe storage requirements, perhaps even quadrupling the amount needed at an average installation.

Video Communication

Video communication pertains principally to video teleconferencing, desktop teleconferencing, and video phones. Initially the province of a group of start-up companies, the hardware and supporting telco services are becoming a sizable global market. The market is being enabled by the strong shipment growth of 56-Kbps N-ISDN lines with accompanying service charges as low as 7 cents for 3 minutes in Japan and 19 cents per hour in the United States. One source of growth is a desire to reduce corporate travel budgets and time spent traveling to meetings, especially intracompany meetings.

The market is moving in two directions, as follows:

- Improved high-end systems for formal/customer conferences based on proprietary compression techniques and high transmission rates
- Cost-effective desktop and video phone systems migrating to CCITT international standards and N-ISDN transmission rates

With the firming of a host of CCITT standards concerning signaling, audio and video compression, and multipoint protocol, among others, and the availability of VLSI silicon to implement them, lower-cost equipment is on its way. To date, the bulk of video conferencing equipment has been incompatible from vendor to vendor (that is, no interoperability). This will probably continue for higher-performance equipment with proprietary technologies that feature video bit streams of 384 Kbps or greater. For desktop and video phone applications however, the new CCITT standards (see Table 3-3) should help stimulate low-cost hardware development and thus broadscale use. Once again, engineering and design markets will be the early adopters of modestly priced systems in an effort to avoid the costs of travel in money and time.

Different Performance Classes. As in all matters involving multimedia and compression, teleconferencing involves a trade-off between compressed bit rate bandwidth and quality. In this case, quality refers to the frame size and frame rate. It is generally believed that the closer video teleconferencing comes to TV broadcast frame sizes and rates, the better the perceived quality. The CCITT standards define two quality levels with frame rates up to 30 frames per second (fps): CIF (352 by 288 pixels) and QCIF (176 by 144 pixels). QCIF is generally suited for desktop video and video phone usage and CIF is for low-end conference room-type systems. High-performance systems such as Compression Labs' Rembrandt II offers 368 x 480-pixel resolution (NTSC mode) and a maximum of 30 fps. The bit bandwidth on these high-performance systems can run from 384 Kbps to 2.048 Mbps. High-performance systems currently run $25,000 and up.

Table 3-3
Open Video Conference Standards

Standard Name	Description	Status
H.261	Video coding	Adopted 1990
H.221	Framing information	Adopted 1990
H.230	Control and indication signals	Adopted 1990
H.242	Call setup and disconnect	Adopted 1990
H.320	Overall requirements for N-ISDN systems	Adopted 1990
G.711	64 Kbps PCM audio	Adopted 1984
G.722	48/56/64 Kbps ADPCM audio	Adopted 1986
G.728	16 Kbps audio	Adopted 4/92
H.223	Encryption	In development
H.232/H.243	Multipoint conferencing	In development
H.261 Option	Still-frame graphics	No formal activity

Source: CCITT

Compression Labs' Cameo Personal Video system for Apple computers exemplifies QCIF-like desktop systems. Costing $2,000, the system comprises a small vertical coder box that attaches to the Nubus backplane and a CCD camera module that attaches to the top of the computer. It employs CLI's proprietary PV2 video compression technology, 64-Kbps u-law audio PCM coding, and has 2B + D ISDN interface.

As for video phones, the AT&T 2500 offers 128 x 112 resolution. It operates at 15 fps and retails for $1,500. Its target market is early adopters and young parents. British Telecom (with GEC Marconi), NTT, and nearly all the Japanese handset manufacturers have either entered or are about to enter this market. Dataquest believes that the picture quality will need to reach the QCIF level before consumers start buying in earnest. The market should behave like the fax market: enough people will have them in five to seven years that they can begin shipping in the millions.

Key players in the video conferencing market include: Compression Labs, PictureTel, GPT, Video Telecom, and NEC. Other companies principally playing in the midrange to low end are: Fujitsu, IBM (Japan and United Kingdom with BT), Mitsubishi Electric, Oki, British Telecom, NTT, Siemens/Rolm, Concept Communications, and EyeTel. Other high-end players include: Broadband Technology, Northern Telecom, ABL Engineering, Grass Valley Group, and Rockwell.

Compression. The principal open standard regarding video compression for real-time video conferencing is H.261 (also known as Px64), a CCITT standard. It operates very similarly to MPEG (uses DCTs), except that it is optimized for real-time encoding and decoding. The principal difference is that H.261 does its interframe comparison with only past and current frames and not future (unknown in real-time) frames, making for smaller compression ratios.

H.261 is designed to be efficient, with resolutions to CIF and rates to 30 fps while generating a 56-Kbps compressed output stream for transmission. Several proprietary compression algorithms are used today, including Compression Labs' CTX, CTX plus, and PV2, and PictureTel's SG3. Intel is helping PictureTel implement SG3 in economic silicon through its DVI technology. Table 3-4 is a representative list of semiconductor offerings in video codec technology. Codec alliances are very strategic and necessary for differentiation.

The programmable approaches appear to be gaining favor as silicon vendors enable the OEMs to encode their proprietary algorithms or migrate to H.261. The programmable approaches utilize a DSP architecture with RISC-like features. The AT&T and IIT chip sets are good examples of this. In some cases, only software updates by users are required to make the bandwidth-quality trade-off. The recently announced Motorola/British Telecom 3 chip set ($100, scheduled for 1994 shipments) implements MPEG, JPEG, and H.261 compression plus all audio and other CCITT standards, to form a video conferencing engine.

The direction of video conferencing technology, with the exception of programmable building blocks, remains firmly in the control of the OEMs. That is to say, the tricks needed to make a system perform require very specialized systems knowledge. As volumes and design expertise develop, perhaps this may change as chip vendors unveil integrated "engines" for mass applications.

Table 3-4
Video Codec/Compression Semiconductor Offerings and Alliances

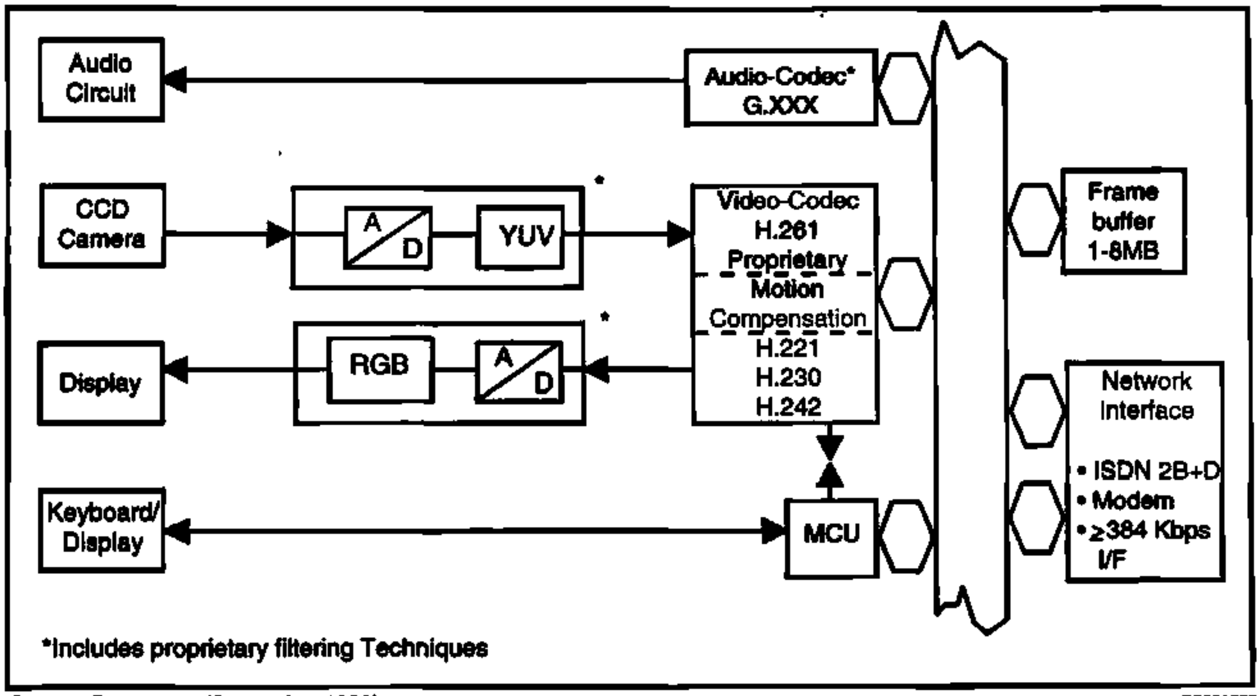
Semiconductor Company	Type	OEM Patron
Graphic Comm. Tech. (GCT)	CCITT	IBM Japan
Motorola	Programmable	British Telecom/IBM
Intel	Programmable	PictureTel
IIT	Programmable	Compression Labs
LSI Logic	CCITT	
GEC	Hardwired	Japanese OEM, Bellcore
NEC	Programmable	Captive
NTT	Programmable	Captive
Texas Instruments	Programmable	Video Telecom
AT&T	Programmable	Captive
SGS-Thomson	Hardwired	

CCITT = H.261, etc.
Source: PictureTel, Dataquest (September 1992)

Figure 3-12 presents a block diagram of a generic video communications system. Video telephones have a semiconductor content of about $150. The desktop versions ($2,000 to $5,000 price range) run 10 to 12 percent of value, and high-end version run $25,000 and up with about 7 to 8 percent content. Other silicon function opportunities in video conferencing include the following:

- 8- to 16-bit A/D and D/A (perhaps integrated with filtering-processing functions) for audio and video
- Audio codec (u-law, a-law PCM, ADPCM, Dolby adaptive delta modulation) 16 Kbps, 56 Kbps to 200 Kbps
- Signaling and protocols functions (proprietary: ASIC; CCITT: programmable)
- Preprocessing filtering (spatial and temporal) for unneeded detail and postprocessing artifact removal (adding back information to smooth the image)
- Audio-video synchronization (perhaps the biggest secret maintained by OEMs)
- ISDN functions such as S/T interfaces and link control
- Integrated, DSP-core versions of described functions

Figure 3-12
Generic Video Conferencing/Phone System



Source: Dataquest (September 1992)

G2001690

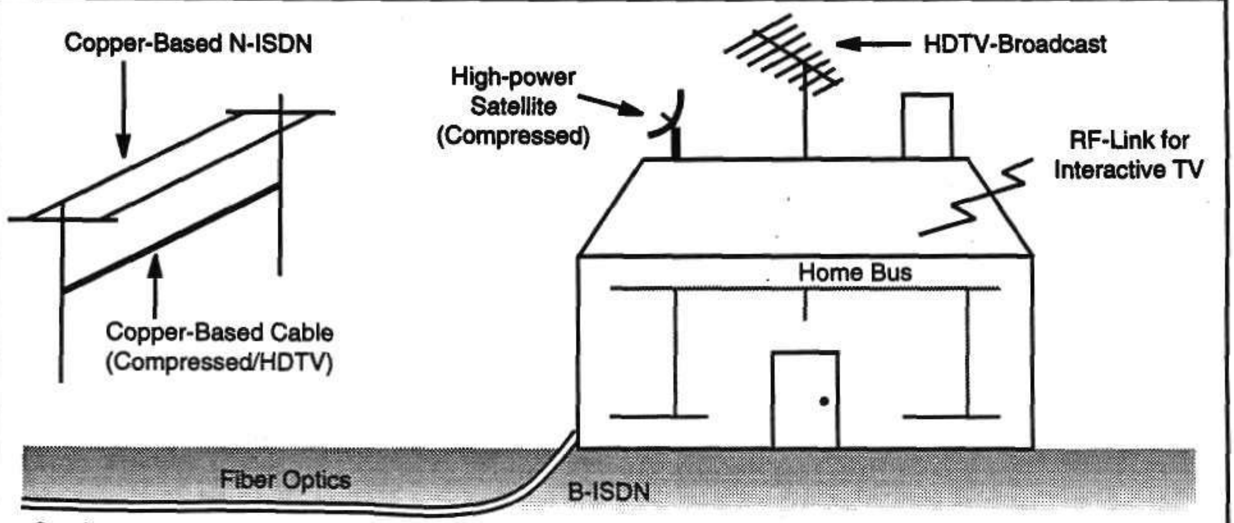
Multimedia Home Communication and Broadcast

Over the coming decade electronic communication to and from the home will upgrade to a new plateau of options and interactivity. Expected changes, and thus opportunities, are described in the following section (see Figure 3-13).

ISDN to the Home. After spending much of the past five years settling standards and seeking economic justification, ISDN lines are beginning to ship in earnest in Japan and Europe; the U.S. market and others developed significantly through the late 1990s (we refer to narrowband ISDN, or N-ISDN, designed to offer the home or business digitally based, 56/64-Kbps communications links, also known as 2B + D).

Perhaps the major recent development impacting ISDN is the decision by the Federal Communications Commission in the United States to allow regional Bells to deliver a "video dial tone" as well as the video equipment linking the phone to the TV. This decision

Figure 3-13
Evolution of Electronic Home Communication



Services:
- Home shopping/banking/classrooms
- Video-on-demand/pay-per-view
- 100-channel-plus satellite/cable
- Video telephones
- Interactive TV (game shows, sports)
- Music-on-demand/pay-per-title
- HDTV: broadcast/cable

Source: Dataquest (September 1992)

G2001591

was taken in order to provide consumers with an alternative to cable and to encourage N-ISDN and ultimately B-ISDN rollout in the United States. This breaks a long-standing right in the U.S. market of cable companies exclusively providing nonfree space (wired utility) video services.

Satellite and Cable. Positioned as alternatives to terrestrial broadcast TV in most of the major markets, satellite and cable companies are being compelled to upgrade the nature of their services. Both approaches to video delivery to the home face a threat from the emerging alternative of PTT-based N-ISDN/B-ISDN video services. Videotape rental stores also are serving the consumer's desire to watch movies when they want, for a modest pay-per-view price.

Direct Broadcast Satellite (DBS). Already a sizable business in Europe and Japan, the DBS market remains minuscule in North America because it competes with cable. New developments in satellite transponder, compression, and receiver technology will stimulate further global growth of DBS shipments. New opportunities exist to supply private satellite video networks as well as for educational and corporate broadcasts.

Two emerging opportunities in North America are SkyPix and DirecTV. SkyPix (Kent, Washington) is a pay-per-view system that requires an $850 receiver/decoder and dish. It employs a proprietary compression system developed by affiliate Northwest Starscan. The hardware is to be built in the United States by a subsidiary of Siemens. Initially at 60 channels, the pay-per-view charge will run $1 to $4. It features a menu-driven interface on the home TV screen including two-way ordering/messaging via hook to the home telephone line. Planned introduction is this fall, and the company hopes to sell 1 million units in the first year. The effort remains in jeopardy: SkyPix investors are reported to be nervous about the several rollout delays.

Another DBS effort known as DirecTV is being led by GM Hughes with Thomson Consumer Electronics. Hughes is cleared to launch the first HS-601 satellite with high-powered transponders in December 1993. Hughes is signing up program sources (studios and sports leagues, among others), and expects to have 10 million North American subscribers by the year 2000. The system will use an MPEG compression scheme to deliver the promised 150 channels. The MPEG encoding algorithms were developed by Thomson and the Sarnoff Research Center, and Compression Labs will build the encoding system for studio/uplink use. Thomson, using the RCA label, will build the receiver/decoders ($700 consumer price) in Indianapolis, Indiana. This effort is related to a similar one in the HDTV arena where Thomson and Compression Labs are part of the Advanced Television Research Consortium (ATRC), where MPEG encoding is proposed as well.

With new high-power satellite-based transponders now available, 6-foot satellite dishes become 18-inch "plates" that can be attached to outside walls. MPEG-like compression technology also allows bandwidth to be effectively increased two to three times (that is, two to three times the number of channels). This has created an opportunity for new uplink encoders for video and audio as well as TV top satellite boxes that decode and demultiplex and can be addressable (for pay-per-view). Semiconductor content of the home box is estimated at $140 initially.

Opportunities exist for supplying semiconductor functions that do the following functions:

- Upconverter/downconverter functions (950 to 1,500 MHz)
- Modulator/demodulator functions (for example, QFSK)
- Multiplex/demultiplex (TDM, among others)
- MPEG-like encode (functions, ASICs)
- MPEG-like decode (low-cost function)
- Digital video chip sets (various integrations; see the computer digital video section of this report)
- Digital audio encode/decode (Dolby digital, among others)

Companies building ground-based DBS equipment include: GEC Plessey, General Instruments, Compression Labs, Siemens NEC, Scientific Atlanta, Oak Communications, Pico Modem, TE Products, Digital Sound, Eidak, Macrovision, Electroline, Pioneer Communication, and Zenith Cable.

Cable. Although cable is available in other parts of the world, especially parts of continental Europe, North America has 60 million subscribers and has plenty of active upgrade programs. In the United States, cable service providers such as TCI and Time Warner are hard at work upgrading existing cable technology. IBM and Toshiba have invested into Time-Warner with the desire to provide hardware to be used to support interactive services to be offered by the cable company. As mentioned earlier, they are battling with video rental stores (such as Blockbuster), phone companies, and DBS companies. They are investing in expanded bandwidth and services such as pay-per-view, video-on-demand, and CD-quality music in an effort to retain and expand their market.

On the music side of cable, International Cablecasting Technologies (ICT) claims more than three million subscribers to its cable-based DMX music system. The setup involves a service provided by local cable companies where 30 channels of CD-quality stereo can be acquired for $10 per month (residential). Included in the service is a tuner (with remote control option) manufactured by Scientific Atlanta, which also manufactures the head-end equipment. ICT claims that it will have eight million subscribers by the end of 1992 in the United States alone. ICT is introducing the service to Canada and Europe this year.

Over the next one to two years, cable companies will bolster the existing copper-cable capability with bandwidth enhancing technologies such as MPEG-like compression. The longer-range plan is to install fiber-optic cable to the curb and eventually into the house. This not unlike the B-ISDN capability that telcos have in mind. Because of this overlap in plans, there could be increased alliances and equity positions (up to 5 percent is allowed) between cable companies and telcos.

As in DBS, opportunities exist to provide MPEG-like encode (head-end/studio) and decode functions (low cost in home box). A joint R&D effort of North American cable companies called Cable Television Labs in Boulder, Colorado, is due to define a common cable compression algorithm later in 1992. The lab will also define the digital packet structure, bit rate, error correction coding (ECC), modulation, and channelization of feature cable equipment. Many North American companies mentioned as DBS equipment providers are mentioned for cable.

Interactive and On-Demand Services. There is probably no limit to the number of services and accompanying hardware in this category. Perhaps the most visible examples of interactive systems used today are France's Minitel and computer network services such as Prodigy (IBM/Sears). Voice-response systems also comprise a form of interactive system but are not discussed here explicitly. Interactive services that utilize multiple data types such as video and sound include the following:

- Home banking and shopping on the TV
- Home classroom for high school, vocational, college, adult education courses
- Ticket ordering for entertainment and sports; reservations for airlines, hotels, and rental cars
- Videotext-bulletin boards, and others (for example, Minitel in France)
- TV audience game show participation for prizes; sporting event prediction of score and key play outcomes, among others
- Opinion polls

The most visible interactive TV system to date is being promoted by TV Answer of Reston, Virginia, along with its hardware partner Hewlett-Packard. The system utilizes an RF link to base stations for two-way communication. The system is based on an 8086 processor and looks like a video game that sits atop the home TV. Assuming that advertisers get behind the concept as a means of selling product, HP estimates that the market could jump to more than 1 million units in 1993 with a start in late 1992. The initial price will be about $800. The FCC is allowing 1,468 license in 734 service areas.

Another company, Interactive Network of Mountain View, California, has a competing proposal with a $199 approach oriented toward specific game shows such as *Jeopardy* and sporting events. GE/NBC is a major investor. The device is selling at major electronic retailers.

On-demand refers to the delivery of video and audio entertainment when wanted by the consumer, or as close as possible. The rollout compression technology is allowing the delivery of hundreds of channels, each carrying different movies or music themes to select from. Hollywood and the recording industry like the concept because it helps in keeping track of royalty revenue.

On the video side, one company, USA Video of Beverly Hills, California, is testing this summer with Southwestern Bell a system that would store pay-per-view compressed movies on gigabyte-class disk drives connected to a network of geographically dispersed supercomputers. The system would compress an entire movie down to 3 minutes and would deliver to a home decompression box at 45 Mbps. The compression technology relies on Intel's DVI PLV algorithm. The technology would furthermore require B-ISDN class switches and fiber-optic transmission to the home. The company is projecting a 1994 rollout, infrastructure permitting.

The DBS and cable companies are also turning to on-demand because they use added channels to offer pay-per-view selections with staggered schedules 10 minutes apart. Once again, this is an attempt to tap into the video rental revenue.

Multimedia Home Communication Analyzed. Taken to its extreme, a home could end up with six or seven terminals tied to the outside world. Today there is generally one terminal—besides broadcast radio and TV—and that is usually satellite or cable terminal. We believe that this will continue to be the case in the near term as DBS and cable companies improve and provide many of the benefits consumer want, including choice, interactivity, and affordability. We further believe that N-ISDN to the home is nearing reality (that is, mass line shipments) and will serve other multimedia needs to homes.

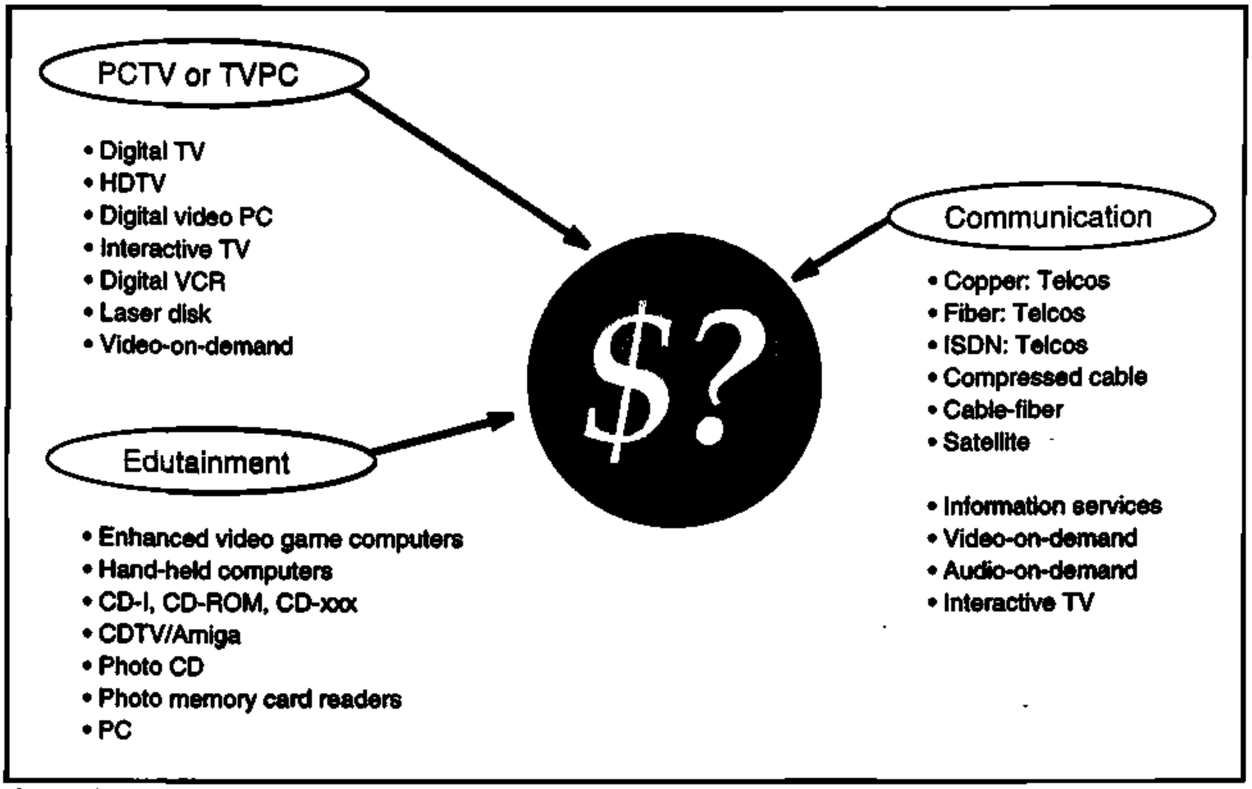
Consumer Multimedia Hardware Opportunities

Multimedia in home use presents huge opportunities for introducing new hardware. Consumer electronics companies are motivated to break the recession/saturation slowdown they have endured for the last two years: Multimedia and interactive systems are growth opportunities that can breathe new life into the market. Sony, Matsushita, and more recently IBM and Toshiba are investing in companies that create either multimedia or interactive source material such as movies, TV shows, and software titles. This section explores the opportunity involving multimedia and interactive technologies and related areas.

Household Opportunities and Confusion

Consumer electronics companies and service providers are in a full tilt battle for the discretionary household dollar. In particular they are struggling to provide video and interactive hardware and services. Figure 3-14 shows the myriad choices facing the consumer.

Figure 3-14
Consumer Electronics Choices



Source: Dataquest (September 1992) G2001592

Interactive Education and Entertainment

Video games and PCs are serving the role of interactive education and entertainment. Until recently these systems and the software titles that ran on them were limited to simple animation and sound. The consumer now has an array of choices, which are described in the following sections.

CD-I. Compact disc interactive (CD-I) is a TV-top system that incorporates a CD player capable of interactive output of CD-quality sound, animation, images, and limited motion video. The player can use regular CD audiodisks, a CD-I disk, and a PhotoCD disk (a feature jointly developed with the Eastman Kodak Company that allows customers to send photos to a service bureau such as Kodalux for encoding onto a disk for display on the home TV set at a cost of $29 service for 24 exposures). Kodak also is producing a dedicated PhotoCD player.

About 60 titles are available for CD-I in the United States, with a total of 100 expected by the end of 1992, and 200 by the end of 1993. The title prices range from $20 to $60 and comprise children, game, and informational offerings. CD-I is targeted at middle-income families and will be available through 2,000 consumer electronic outlets in the United States by the end of 1992. Philips also has a business/industrial version of CD-I. As of summer 1992, CD-I is being rolled out in Japan and Europe after being introduced in the United States in October 1991. Because multimedia is highly dependent on culture and language, regional titles need to be developed. CD-I associations have been set up in each region to work with title developers. The suggested retail U.S. price as of September 1992 was $699.

Planned upgrades include a plug-in MPEG decompression module for full-motion, full-screen video (up to 74 minutes) that is due out late in 1992. Future CD-Is could incorporate other interactive features such as modems for dial-up access a la video/teletext. The technology (called Green Book) is licensed with several Japanese consumer electronics companies including Sony (cofounder), Nintendo, Kyocera, Sanyo, JVC, Japan Marantz, Matsushita, and Yamaha. These companies are expected to enter the market in 1992 and 1993, with many variations, including hand-held.

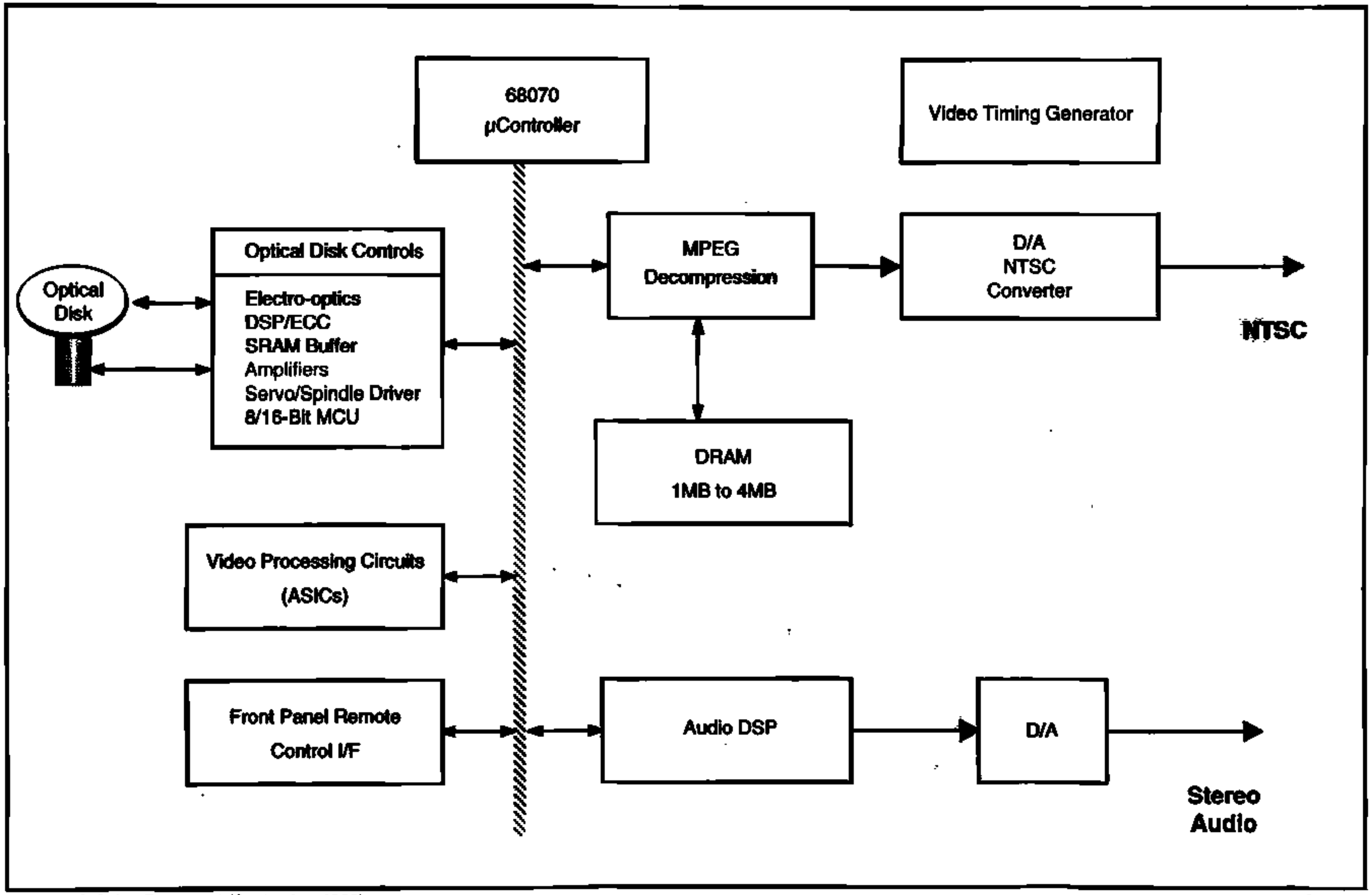
The CD-I player centers on the Motorola 68000 architecture and employs a 68070 16-bit processor, several custom ASICs, 1MB of RAM, and 8KB of EEPROM. We can expect the architecture to move to 32 bits and integrate the MPEG/DVI decoder module functionality for full-motion support. Figure 3-15 shows a block diagram.

CDTV. Commodore Dynamic Total Vision (CDTV) conceptually is similar to CD-I. Commodore claims 92 titles, with that many more on the way. It also claims that it has 1,000 outlets in the United States. CDTV is built around the Amiga 500 computer and is based on a 68000 MPU and three video-processing ASICs, with 1MB of RAM. Commodore has begun to roll out the A750 disk CD-ROM drive ($600), which attaches to existing Amigas and allows them CDTV capability. Underscoring the latter opportunity are the 3 million installed Amigas.

Tandy, working with Microsoft and its Windows software, has just introduced a home interactive system called Video Information System. Anchored on a CD-ROM variant, and employing several ASICs, the system will be priced at about $700. Claiming that 50 software titles are on the way, Tandy hopes to leverage its large retail presence and user familiarity with Windows to its advantage.

CD-ROM Enhanced Video Games. The TV video game business also is moving into multimedia. Dataquest estimates that 16.5 million TV video games were produced in 1991 in Japan, which dominates production. About half were the new 16-bit variety on a unit basis. Nintendo has an estimated 73 percent share of the unit market; Sega (JVC manufacturer) has 22 percent. NEC, Sharp, and NEO-GEO round out the list of secondary manufacturers. Growth in the video game business is toward CD-ROM enhanced versions with 650MB storage capability. CD-ROM brings the capacity to greatly enhance the animation and to add images and motion video, plus CD-quality sound.

Figure 3-15
CD-I Player Block Diagram



Source: C-Cube, Dataquest (September 1992)

G2001593

The video game industry has stated that it could ship 1 million units of CD-ROM attachments ($200 to $300 retail) from mid-1992 through mid-1993. Title development is still under way to support further growth. Dataquest further estimates that about 90 percent of the TV video games shipped in 1996 will incorporate CD-ROM or CD-I. Plans include moving to 32-bit architectures and perhaps adding communications capability such as built-in modems to tap into the TV-based video/teletext movement.

Enhanced Multimedia PCs. PC-based video game playing is a sizable business, as the million-plus Sound Blaster cards already shipped worldwide can attest. We expect this to continue, along with further home penetration as users hunger for improved quality including 16 bits and sampled sound (when the price is right).

Hand-Helds. Discounting for now the personal information technology devices such as Apple's Newton, there will be a variety of interactive, hand-held devices with multimedia capabilities. Sony's Discman has come out with text-to-speech capability ($499 retail).

Specialized Entertainment—Karaoke

Karaoke machines are an important embodiment of multimedia. Karaoke systems and portable players are very popular in Asia as well as in bars and clubs in the United States and Europe. The systems allow an audience member to sing the voice track of a famous performer's music video. These sophisticated systems are based on laser disks with MPEG compressed video and instrument tracks. Pioneer is believed to be the leading supplier of these systems. The market for these sophisticated versions of Karaoke systems is estimated to be about 5,000 annual units. More-compact home versions could garner a market of millions.

A Rationalization

Nintendo is a household word across the world when it comes to TV-based game entertainment. There is no doubt that Nintendo, Sega, and others will succeed at migrating a majority of their installed base to CD-ROM basic versions. We believe that CD-I will succeed as a higher-performance standard and may even become synonymous with video games by the mid-1990s as titles develop. The CD-I price premium will be justified, in our opinion, because it appeals to adults and doubles as a CD-audio player and PhotoCD device.

Multimedia Semiconductor Market Forecast

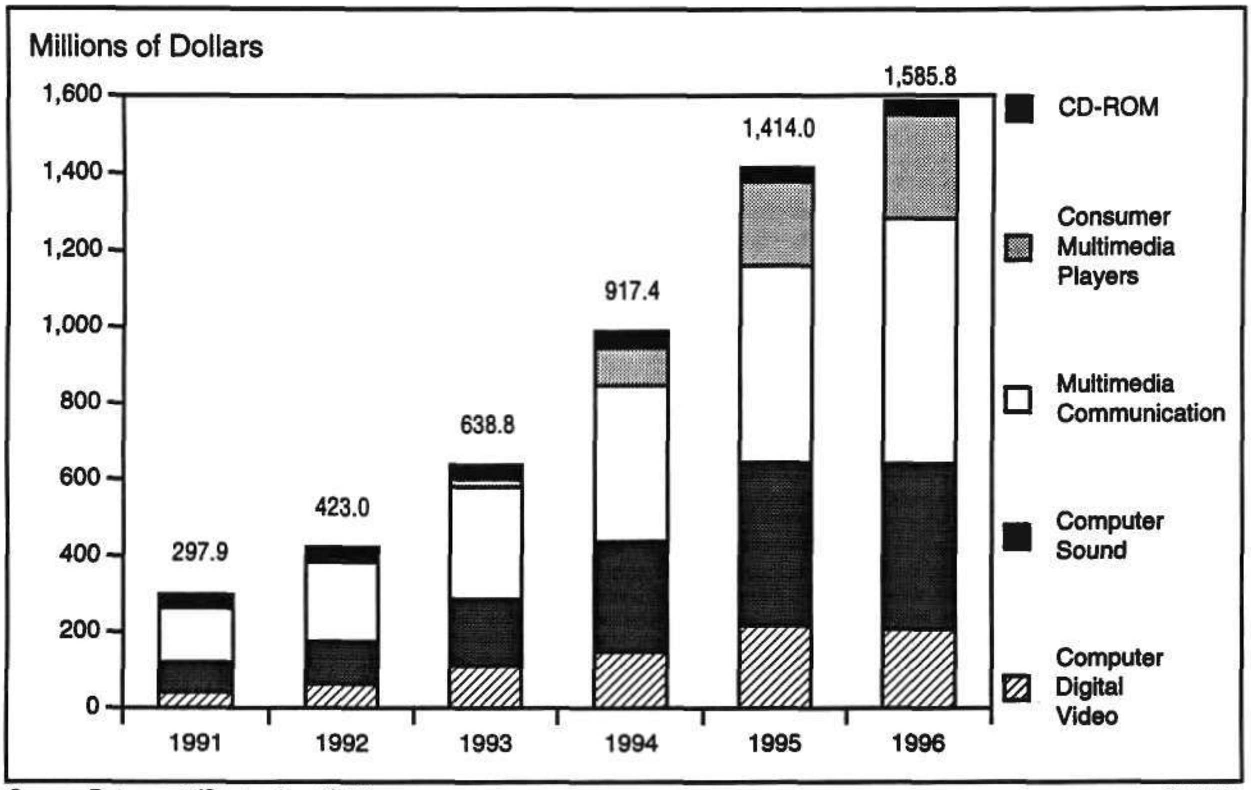
Figures 3-16 and 3-17 present Dataquest's forecast for semiconductors used in selected multimedia hardware applications on a worldwide basis. We expect this heavily North American market to diversify as other regions ramp up production during the next few years.

Computer Digital Video

Table 3-5 and Figures 3-18 and 3-19 describe the semiconductor opportunity for digital video. Key assumptions and observations include the following:

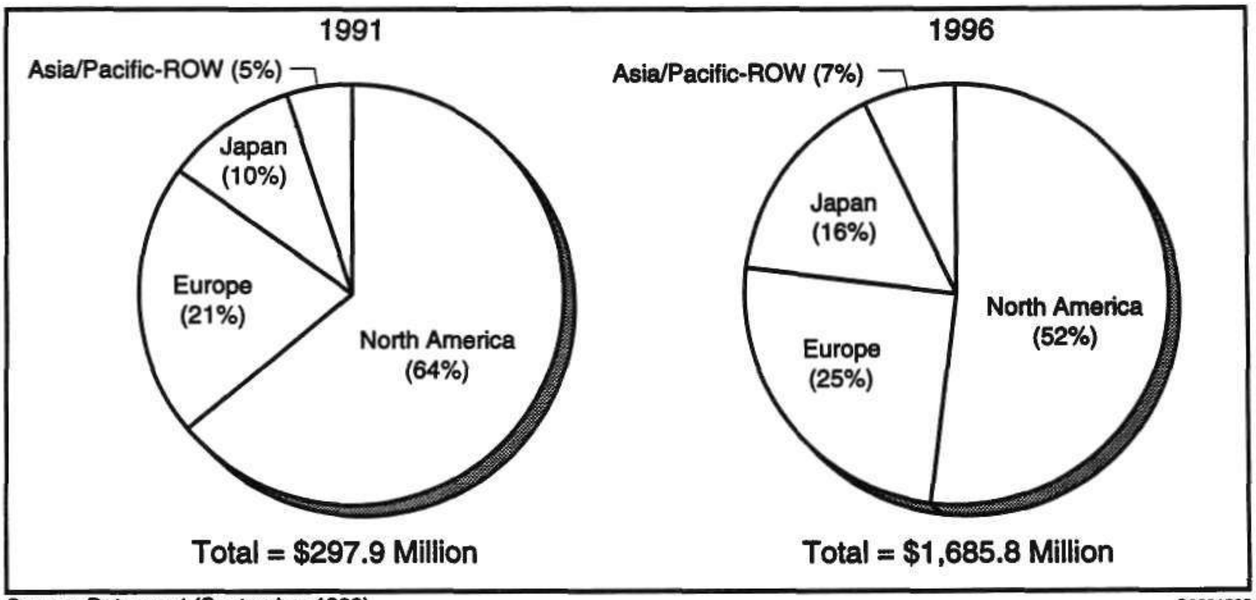
- Remains principally an evolving add-in board business through forecast period.

Figure 3-16
Worldwide Multimedia Application Semiconductor Forecast



Source: Dataquest (September 1992)
G2001594

Figure 3-17
Worldwide Multimedia Application Semiconductor Forecast Consumption, by Region



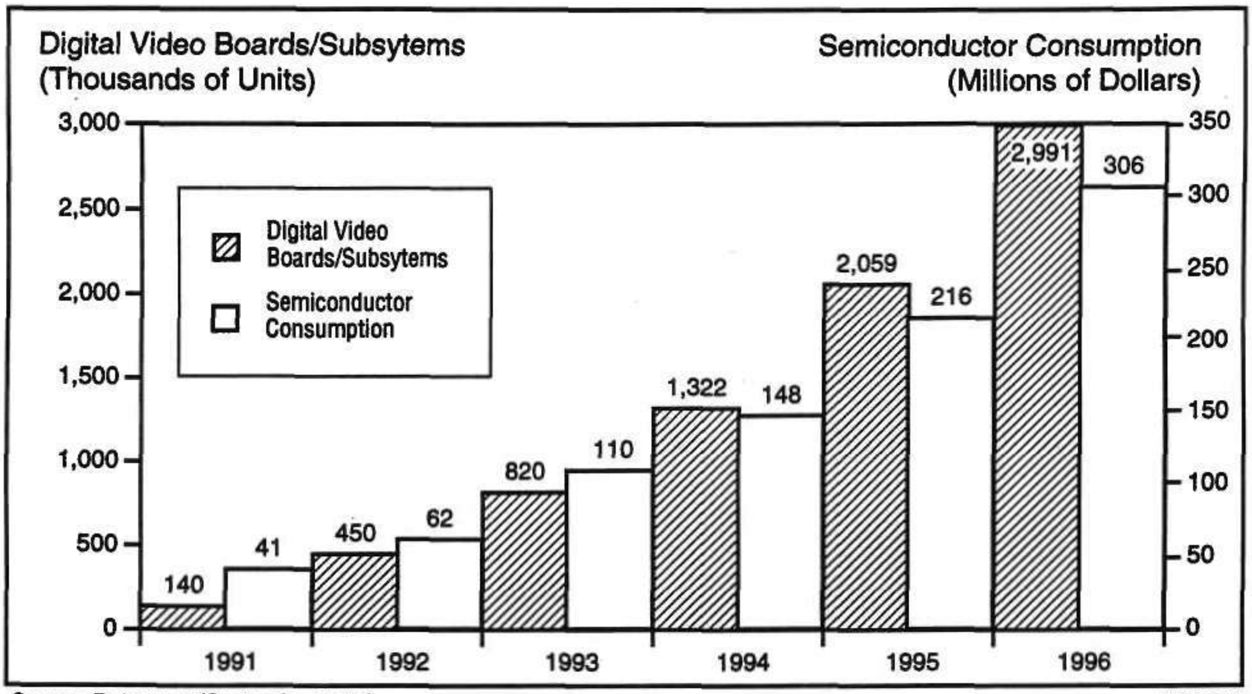
Source: Dataquest (September 1992)
G2001595

Table 3-5
Worldwide Computer Digital Video Semiconductor Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Buffer (V/DRAM, SRAM)	23.6	34.8	59.5	77.3	109.4	152.2	45
EPROM/Flash	1.0	1.4	2.5	3.2	4.6	6.3	45
Digital Video Functions	13.3	19.6	33.5	43.5	61.5	88.8	46
Compression Funtions	1.9	4.1	9.2	15.1	27.5	40.1	85
PLD/FPGA	0.6	1.2	2.6	4.0	6.2	8.9	69
Interface	0.6	1.2	2.9	4.5	7.1	10.1	74
Total	40.9	62.2	110.2	147.6	216.3	306.4	50

Source: Dataquest (September 1992)

Figure 3-18
Worldwide Computer Digital Video Semiconductor Forecast



Source: Dataquest (September 1992)

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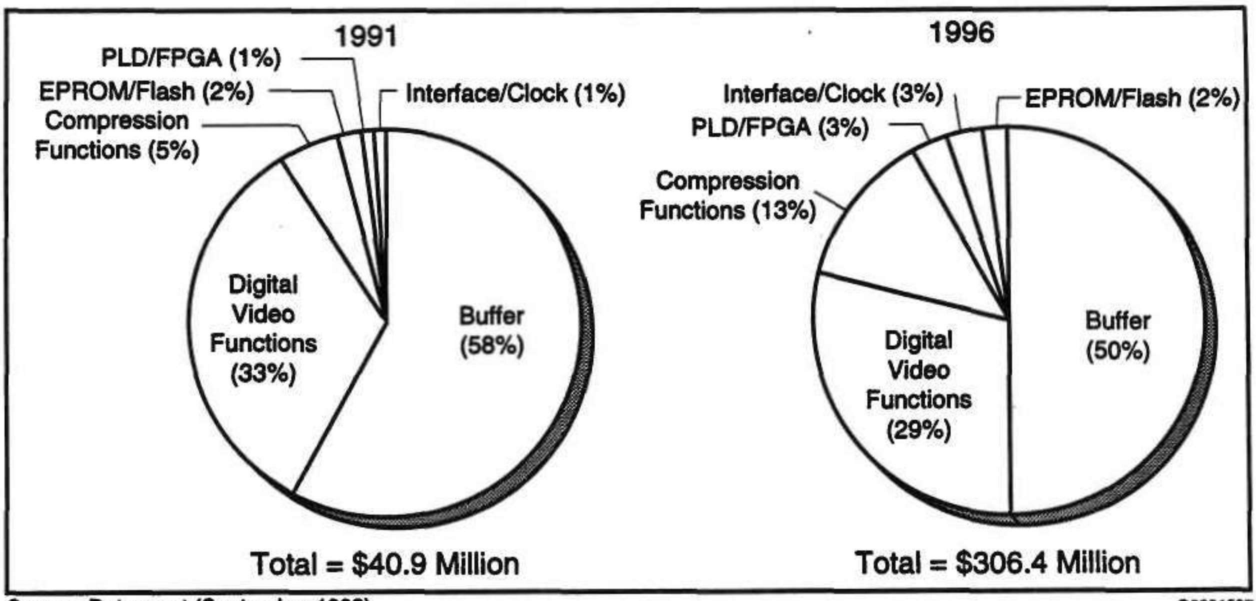
Figure 3-19
Worldwide Computer Digital Video Semiconductor Forecast, by Type



Source: Dataquest (September 1992)

G2001597

- Principal users initially will be publishing professionals (journalism and advertising, among others), professional training (for example, auto mechanics) and education; will eventually gain corporate acceptance as a business tool for more effective internal and external communication.
- Critical mass of software development will take place as major operating system vendors support images and video; authorware/courseware will become increasingly user-friendly and significant source material will become available.
- By the end of the forecast period, digital video will be merging with graphics control and buffers on a local "video-graphic bus."
- Phasing of capability will start with frame grabbing and TV windows and will migrate to more digital processing, ultimately including full-motion, full-screen, compressed video.
- Largest semiconductor opportunity is for DRAM/VRAM because it remains about 50 percent of the video subsystem content.
- Hardware decompression will become less of an enabler as software decompression dominates usage initially; silicon compression will play a vital role in encoding and later as an accelerator of the software functionality of AVI (Microsoft) and QuickTime (Apple).
- Digital video functions for data conversion, TV signal encode/decode, color space conversion, scaling, and output mixing will remain solid opportunities throughout the forecast period.

Computer Sound

Table 3-6 and Figures 3-20 and 3-21 present the semiconductor opportunity for sound processing on computer platforms. Key assumptions and observations include the following:

- Demand for sound processing (principally voice and music input and output) will migrate from home upgrades to business audio.
- Critical mass of uses will develop, including existing applications that incorporate sound annotation; sounds will become treated as objects within operating system environments (that is, sound icons).
- Sound will become a standard feature on nearly every motherboard toward the end of the decade. DSP-based subsystems that can be shared with fax/modem will be employed utilizing software-processing algorithms.
- Compressed 16-bit and stereo sound applications will become more prevalent.
- Sampled sound and other more sophisticated techniques will eventually replace FM synthesizers in MIDI applications.

Multimedia Communication

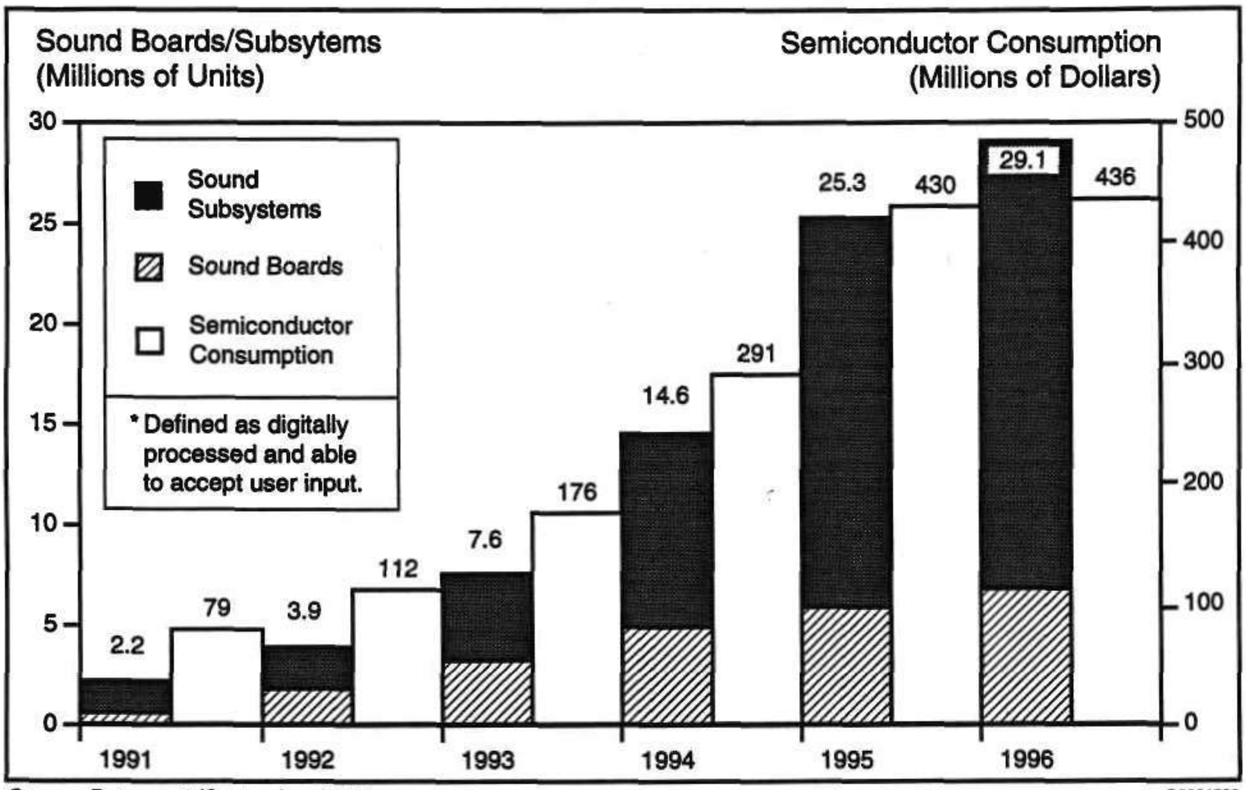
Table 3-7 and Figures 3-22 and 3-23 present the worldwide forecast for semiconductor markets that will be stimulated by the need for

Table 3-6
Worldwide Computer Sound* Semiconductor Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Data Conversion	23.8	32.6	49.3	81.6	116.1	117.8	38
Functions (ASIC/ASSP/DSP)	47.5	68.5	110.9	183.5	279.4	283.5	43
Interface and Others ($)	7.9	11.2	15.8	26.2	34.4	34.9	35
Total	79.2	112.3	176.1	291.3	429.8	436.1	41

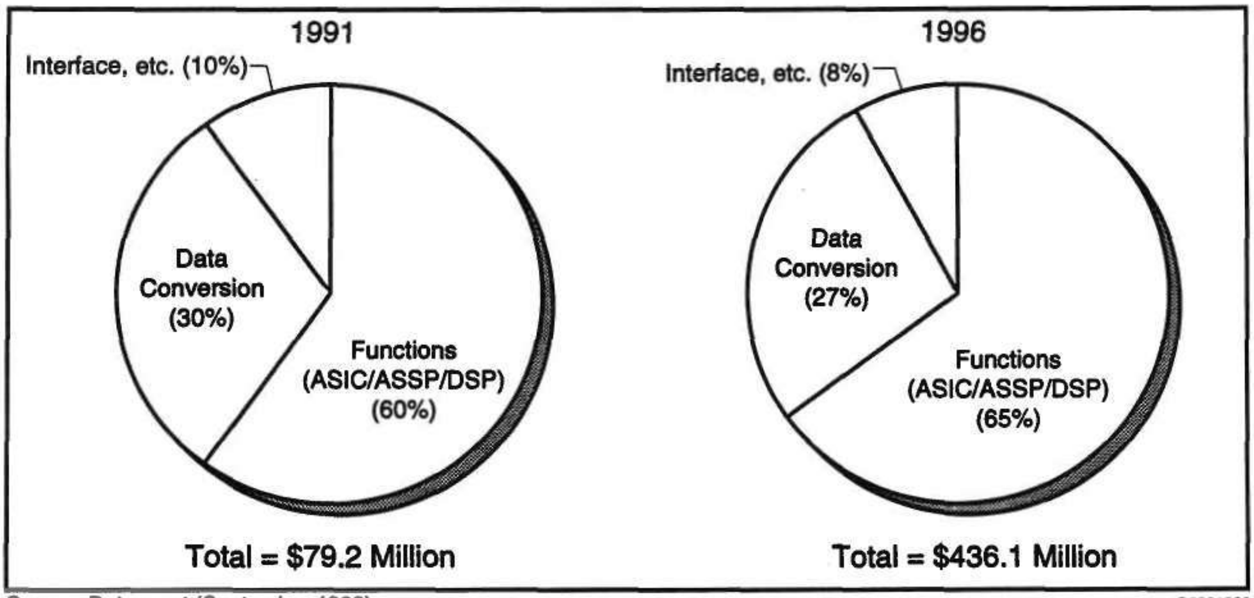
*Defined as digitally processed and able to accept user input
Source: Dataquest (September 1992)

Figure 3-20
Worldwide Computer Sound* Semiconductor Forecast



Source: Dataquest (September 1992) G2001598

Figure 3-21
Worldwide Computer Sound Semiconductor Forecast, by Type



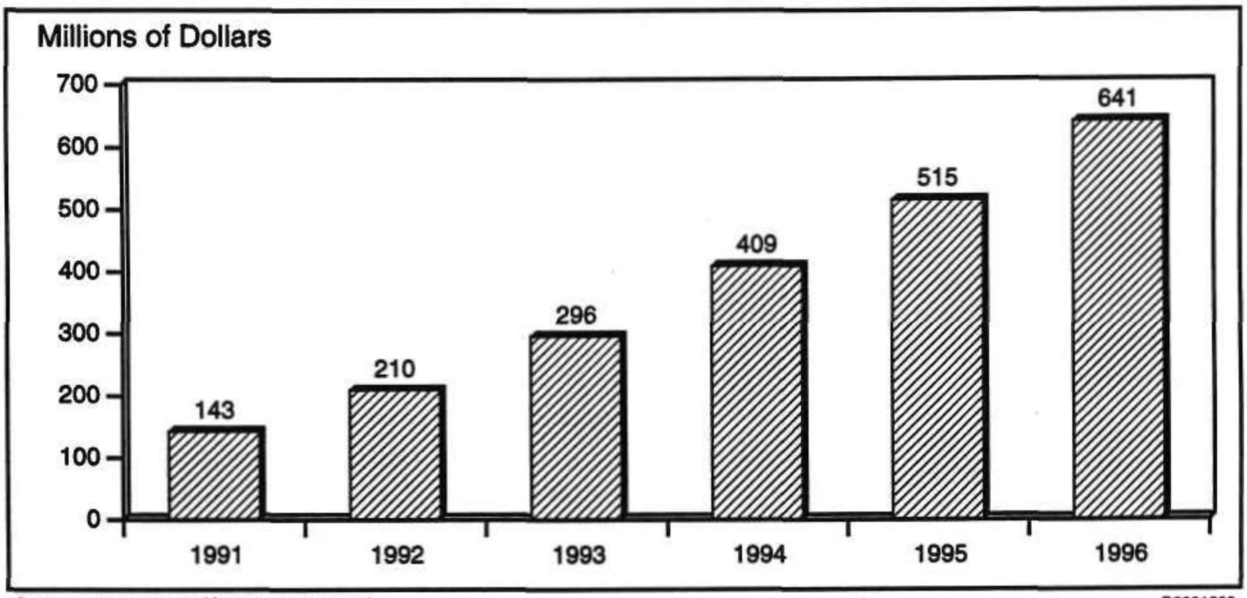
Source: Dataquest (September 1992) G2001599

Table 3-7
Worldwide Multimedia Communications Semiconductor Forecast

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
ISDN Revenue ($M)							
S/T Interface	24.4	25.7	34.1	45.4	59.4	72.1	24
U Interface	37.2	42.4	45.0	46.8	50.8	54.3	8
Link Controller	9.4	14.7	25.2	42.0	55.5	68.6	49
Total ISDN	70.9	82.8	104.3	134.2	165.7	194.9	22
ISDN Units (Millions)							
S/T Interface	4.7	5.6	8.5	13.0	19.8	26.7	42
U Interface	1.2	1.6	2.0	2.4	2.9	3.5	24
Link Controller	1.8	3.2	6.3	12.0	18.5	25.4	70
Total ISDN	7.7	10.4	16.8	27.4	41.2	55.6	
B-ISDN (ATM/SDH) Revenue ($M)	18.0	27.0	40.5	60.8	97.2	155.5	54
FDDI Chip Sets							
Revenue ($M)	40.0	62.8	100.0	145.8	162.4	175.0	34
Units (Millions)	0.2	0.4	0.9	1.8	2.8	3.5	81
Video Conferencing/Phones							
Revenue ($M)	13.6	36.9	50.7	68.4	89.3	115.2	53.3
Total ($M)	142.6	209.5	295.5	409.2	514.5	640.7	35

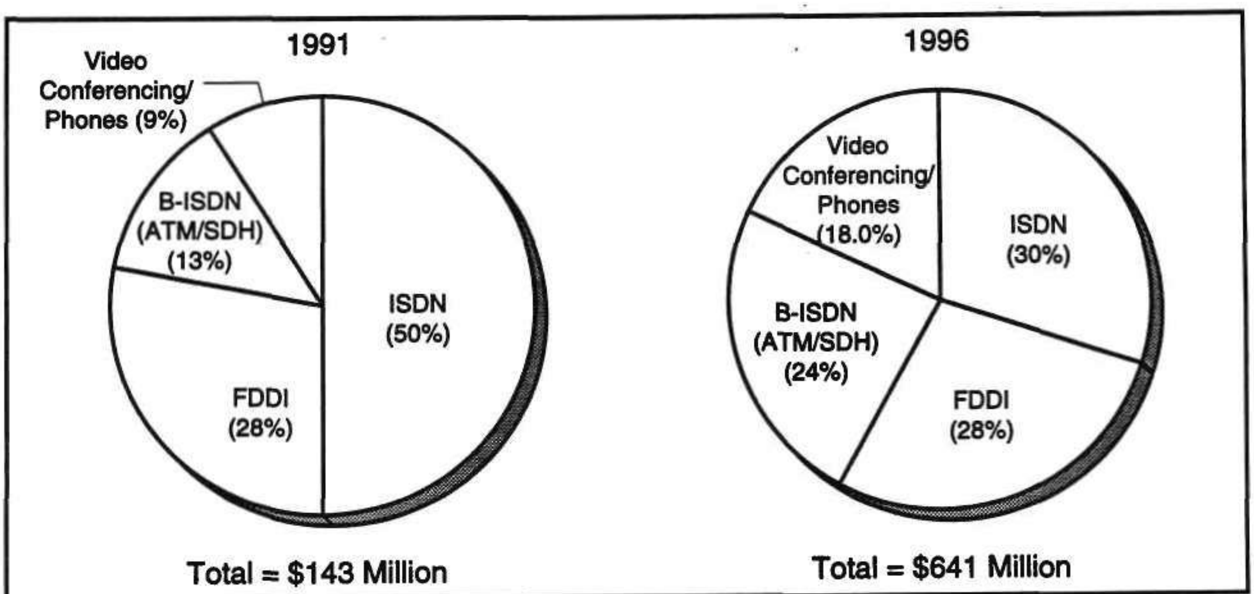
Source: Dataquest (September 1992)

Figure 3-22
Worldwide Multimedia Communications Semiconductor Forecast



Source: Dataquest (September 1992)
G2001600

Figure 3-23
Worldwide Multimedia Communications Semiconductor Forecast, by Type



Source: Dataquest (September 1992)
G2001601

multimedia communication. The focus is on ISDN, video teleconferencing, and FDDI networking/internetworking. Key assumptions and observations include the following:

- Basic rate 2B + D ISDN (N-ISDN) lines will continue to roll out in Japan and Europe initially, with the United States and other countries to follow in the latter part of the decade.
- B-ISDN based on ATM/SONET technology will start to roll out after 1995 or when standards for an isochronous cell-based system are firmed up.
- FDDI, although not isochronous, will see continued growth to serve surging premise networking bandwidth demands.
- Video conferencing/telephones will continue growing in capability and dropping in price. ISDN rollout will directly impact volume ramp-up.

Consumer Multimedia

Table 3-8 and Figures 3-24 and 3-25 present the outlook for consumer interactive multimedia players. Key assumptions and observations include the following:

- Sufficient and compelling titles will continue emerging for the CD-I/CDTV-type players.
- Interactivity will become more popular in the home; ISDN, DBS, and cable will serve this need in the long run but dedicated interactive communications systems will find a modest near-term market.
- Upgraded DBS and cable distribution and terminals will continue being a lucrative market for chip suppliers.
- The video game industry will turn toward these more margin-laden players because the systems also can manage CD audio and compressed images/video.
- Consumer volumes will most likely make audio and motion video (MPEG) compression a cost-effective solution other markets.

Multimedia Semiconductor Forecast by Functionality/Technology

Tables 3-9 and 3-10 as well as Figures 3-26 and 3-27 present a forecast of key functions used in multimedia applications. Key assumptions and observations include the following:

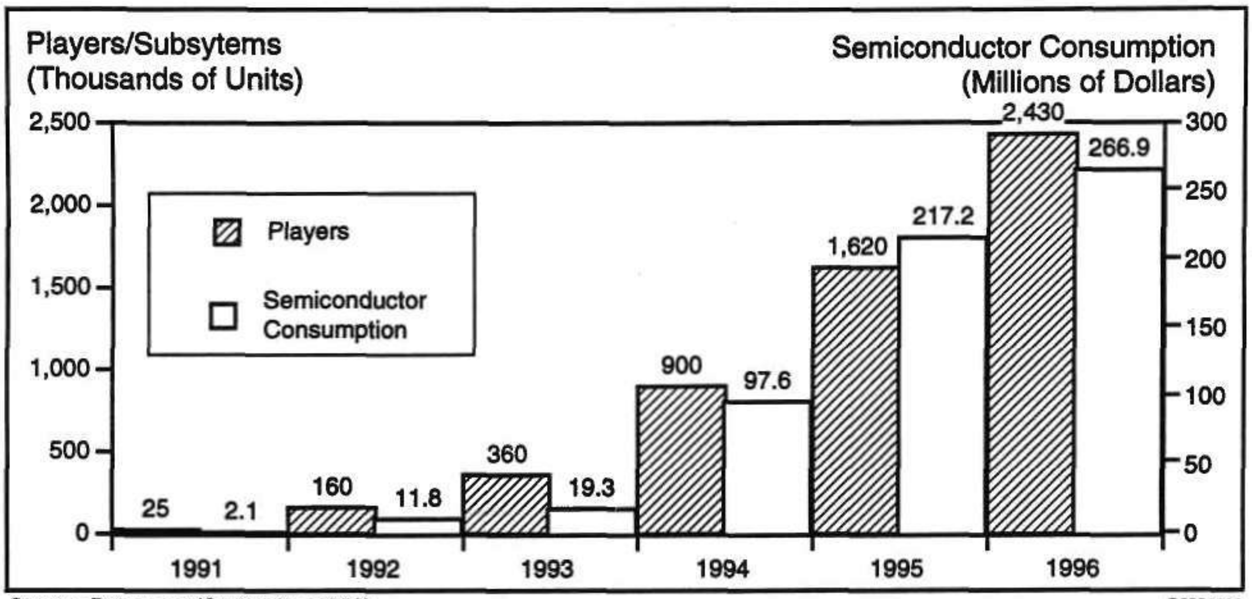
- CMOS will be the principal technology employed for the digital components; cost-effective 0.5-micron or better technology will enable further integration and feature enrichment at similar price points.
- Compression functions will be driven mainly by consumer multimedia players and satellite/cable systems.
- Mixed analog and digital ICs will become commonplace as data conversion functions merge with digital processing functions.
- Memory pricing will stay on the same or a slightly less aggressive price-per-bit curve.

Table 3-8
Worldwide Consumer Multimedia Player Semiconductor Forecast (Millions of Dollars)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
SRAM/DRAM	0.3	1.4	2.7	15.6	34.8	42.7	178
EE/Flash/ROM	0.3	1.4	1.9	8.8	19.6	24.0	148
MPU	0.3	1.8	2.7	12.7	28.2	34.7	155
Functions (ASIC/ASSP)	1.0	5.4	9.4	48.8	108.6	133.5	167
Analog/Discrete	0.3	1.8	2.5	11.7	26.1	32.0	151
Total	2.1	11.8	19.3	97.6	217.2	266.9	162

Source: Dataquest (September 1992)

Figure 3-24
Worldwide Consumer Multimedia Player Semiconductor Forecast



Source: Dataquest (September 1992)

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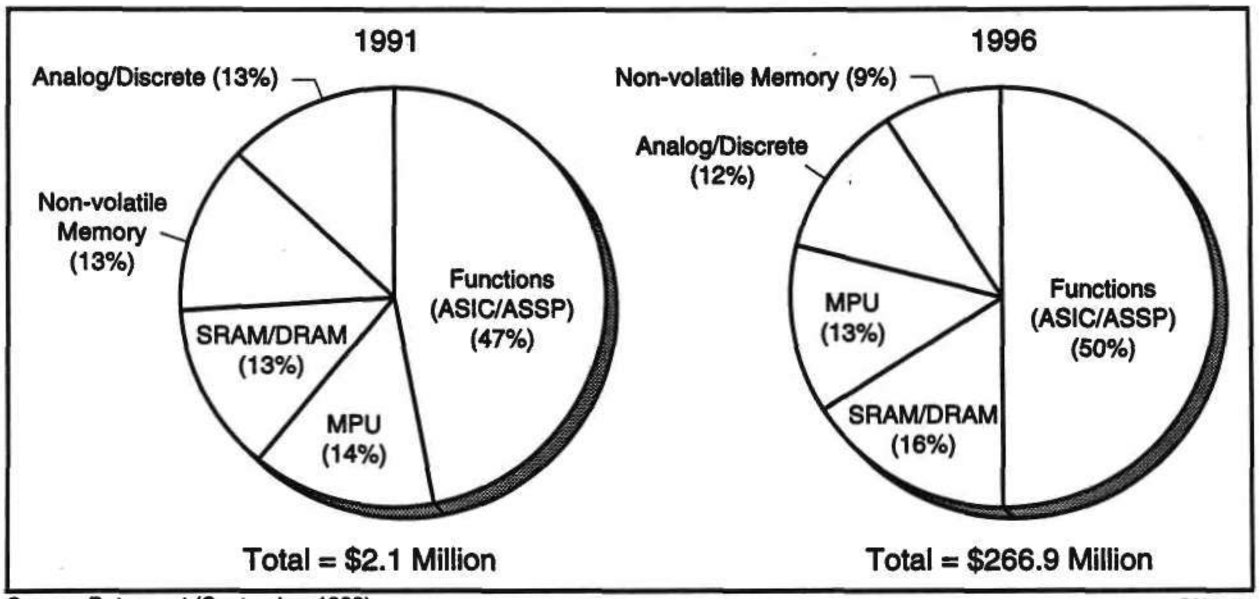
Figure 3-25
Worldwide Consumer Multimedia Player Semiconductor Forecast, by Type



Source: Dataquest (September 1992)

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Table 3-9
Worldwide Digital Video Compression Semiconductor Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Full Motion (MPEG-Like)							
PC and Workstation	3	9	33	265	927	1,645	258
Players (CD-I, Karaoke, Others)	0	40	310	1,525	3,450	4,710	NM
DBS/Cable	0	65	420	1,470	3,234	5,821	NM
HDTV	0	0	5	250	480	780	NM
Kiosks/Arcade Games	0	25	165	363	726	1,089	NM
Total	3	139	933	3,873	8,817	14,045	449
Still Frame							
Boards/Platforms	20	108	263	384	391	419	147
Video Teleconferencing/Phone	6	85	138	218	366	628	157
Total Video Compression	28	332	1,334	4,474	9,574	15,091	252

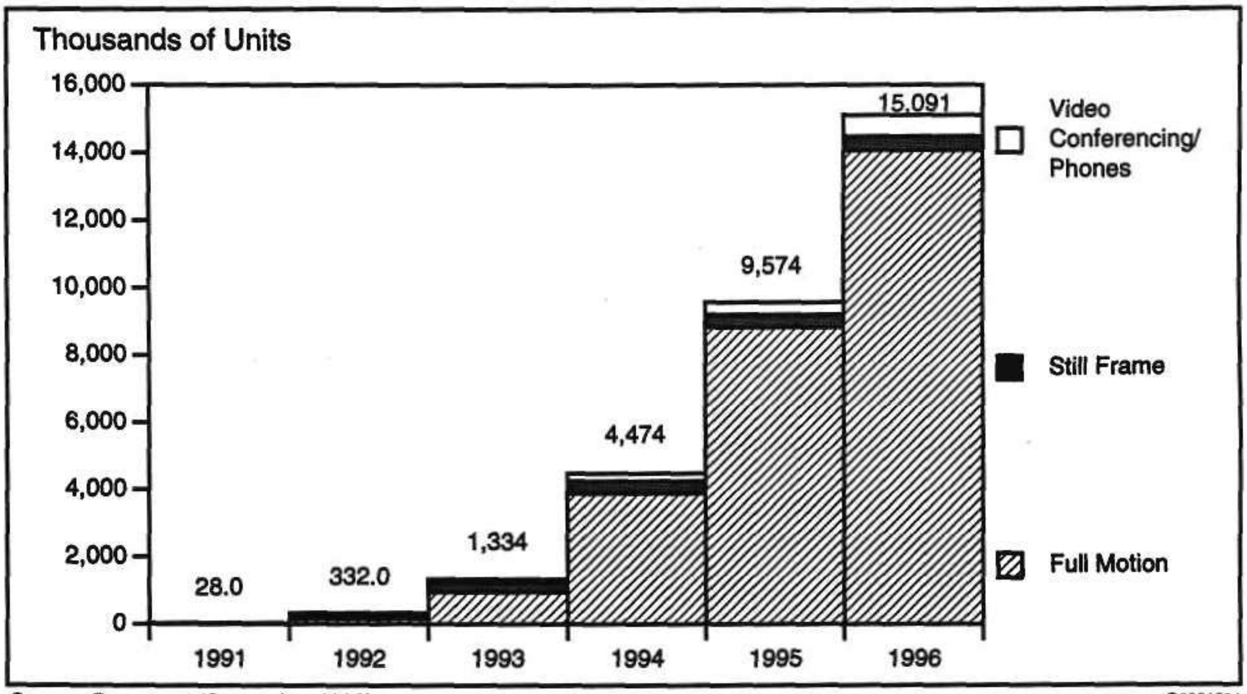
NM = Not meaningful
Source: Dataquest (September 1992)

Table 3-10
Worldwide Mulitmedia Application Semicondutor Forecast

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Digital Video Function Sets							
Millions of Dollars	13.3	19.6	33.5	43.5	61.5	88.8	46
Thousands of Units	140.3	450.0	820.3	1,322.3	2,059.8	2,990.5	84
Computer Sound Function Sets							
Millions of Dollars	71.3	101.1	160.2	265.1	395.4	401.3	41
Millions of Units	2.2	3.9	7.6	14.6	25.3	29.1	68

Source: Dataquest (September 1992)

Figure 3-26
Worldwide Digital Video Compression Semiconductor Forecast



Source: Dataquest (September 1992)

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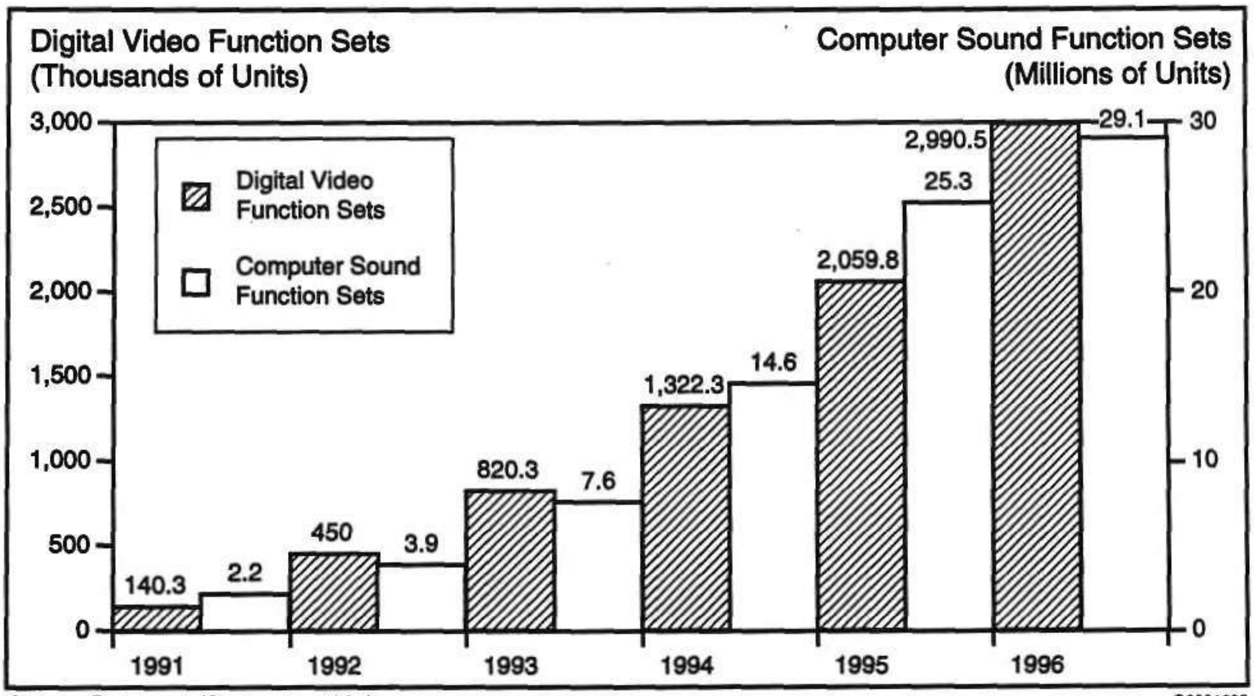
Figure 3-27
Worldwide Multimedia Application Semiconductor Forecast



Source: Dataquest (September 1992)

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Vendor Profiles

This section provides profiles of major companies involved in multimedia semiconductors. The profiles present the following information:

- Corporate statistics
- Overview of company status
- Financial and market position in multimedia products
- An overview of the company's multimedia market strategy
- Multimedia product overview
- Dataquest analysis of where the company stands in its multimedia efforts

C-Cube Microsystems Corporation

Corporate Statistics

Headquarters Location: San Jose, California

President/CEO: Bill O'Meara

Founded: 1988

1991 Revenue: $7 million (estimate)

Number of Employees: 60

Overview

C-Cube Microsystems was founded with $20 million in start-up capital. The company is fabless but controls the design process. It has key relations with Chips & Technologies for products merging VGA graphics and digital video, and has another relationship with Philips and JVC for MPEG compression chips for full-motion CD-I upgrade.

Financials and Market Position

The company had an estimated $7 million in multimedia revenue in 1991. Revenue could at least double in 1992 if MPEG decoder shipments develop early.

Products

The company has single-chip implementations of video (MPEG) and image (JPEG) compression functions, as well as compression software and demo-boards, as follows:

- CL550 integrated JPEG compression IC
- CL450 MPEG decoder IC
- Development boards
- Compression software and drivers

Strategy

The company intends to be the leader in single-chip implementations of standards-based (JPEG and MPEG) compression technology. It targets consumer applications (for example, CD-I) as its early volume opportunity. Look for the company to offer variants of its core offerings that extend MPEG I performance and incorporate other features such as audio and variable color space conversion.

Dataquest Perspective

The company has a leadership position in IC-based compression technology and has the only integrated MPEG decoder chip shipping ($50 in volume quantities) on the market. The strategy of using the consumer sector to leverage into other applications is theoretically good, but early high volumes will be delayed as CD-I full-motion capability is delayed until 1993. Other markets such as cable TV compression could come to its rescue. In the meantime, the JPEG chip is well designed in the computer digital video community. A major risk the company will need to manage is the potential market migration from MPEG to MPEG-like standards supported by the operating system environments.

Philips Components

Corporate Statistics

Headquarters Location: Eindoven, Netherlands

Major Subsidiary: Sunnyvale, California

President: James Dykes

Founded: 1976

1991 Revenue: $2 billion (semiconductor only)

Number of Employees: 7,000

Overview

Philips Components has facilities all over the world, with much of the consumer electronics activity driven out of Eindoven. Chip R&D is shared between the Europe and U.S. groups.

Financials and Market Position

Estimated multimedia chip sales for 1991 were $10 million, which is expected to at least double in 1992 based on volume projections of digital video boards.

Products

A variety of digital video and audio products include the following:

- TDA8707 A/D converter
- SAA7191 luma/chroma, sync/clock processor
- SAA7197 clock generator
- SAA9065 D/A and filter
- TDA4680 video switch
- SAA7186 resizer

Strategy

Philips' key strength is its vertical orientation to the consumer video/audio market. It designs and sells systems and chips for those systems. This gives the company an advantage in defining chips that the market will want. In the meantime, the company continues to fill holes in its digital video line.

Dataquest Perspective

Philips is the dominant supplier of digital video functions but is expected to experience competition soon from others, including Brooktree and the Japanese video electronic giants. Philips has two weaknesses that it will need to manage to stay on top: be quicker to develop new products; and develop future products from the computer graphics/video standpoint rather than from principally a digital TV standpoint. We believe that Philips will retain significant share of the digital video functions market as video remains a core competence of the corporate entity.

Cirrus Logic Inc.

Corporate Statistics

Headquarters Location: Fremont, California

Chairman: Dr. Suhas Patil

President/CEO: Michael Hackworth

Founded: 1984

1991 Revenue: $152 million

Number of Employees: 475

Overview

Cirrus Logic is a major player in the computer peripheral controller markets including graphics (especially strong in LCD for notebooks) and rigid disk (Conner, among others). The company has had recent mergers with Crystal (data conversion, mixed signal) and Pixel (imaging). The company has a relationship with Media Vision to develop and sell a digital audio chip set.

Financials and Market Position

The company did not have any significant multimedia revenue in 1991. The 1992 run rate for these new products is estimated at $3 million to $5 million.

Products

Several multimedia products were introduced in 1992, including the following:

- CL-PX2070 programmable video processor
- CL-PX2080 RAMDAC and video stream mixer
- Digital audio chip set (with Media Vision)

Strategy and Direction in Multimedia

Cirrus is attempting to leverage its expertise in graphics subsystems into products that will manage the merger of graphics pixel streams with video pixel streams. The company will most likely continue new variants involving the mixed-signal expertise of its other subsidiary, Crystal. Expect the company to continue to work custom arrangements in this market, too (the Media Vision deal is a good example).

Dataquest Perspective

Cirrus Logic continues to be a well-managed company with an incredible knack for uncovering new market niches. The niche may not be exclusively its own this time around, but pre-existing account presence at many board houses and its computer graphics expertise will probably benefit it. As with Brooktree, mastering mixed-signal technology is a competitive edge for new, integrated products.

Integrated Information Technologies (IIT)

Corporate Statistics

Headquarters Location: Santa Clara, California

President/CEO: Chin-Shin Wang

Founded: 1987

1991 Revenue: $35 million (estimated)

Number of Employees: 70

Overview

IIT was principally known as a 287/387 math coprocessor provider until last year, when it announced its relationship with Compression Labs on video conferencing. The company also is a player in the VGA controller, Windows accelerator, lossless data compression markets. The market transition to 486 systems that incorporate the floating point unit has hastened IIT's need to find other markets like multimedia.

Financials and Market Position

Estimated 1991 revenue for multimedia products was $3 million. The 1992 run rate revenue could be double that amount.

Products

The company has a programmable compression processor family capable of executing multiple standards, as follows:

- Vision processor—Programmable video compression IC
- Vision controller—Companion processor
- Compression modules that integrate the two products described

Strategy

The company's most notable patron is Compression Labs, which employs IIT's programmable technology on most of its offerings, including the AT&T new video phone product. Compression Labs' position as the market leader in video teleconferencing creates a tangible base to grow revenue and develop new products. We can expect the company to move into other digital video/audio functions, creating new integrations coupled with its Vision Processor.

Dataquest Perspective

The Compression Labs arrangement appears to be a good one in that real products are shipping and market feedback is being incorporated into new products. The programmable approach is also a good one for now, as the compression standards remain unstable. The company may need to move toward higher-performance, focused functions as soon as those standards become firm.

Intel Corporation

Corporate Statistics

Headquarters Location: Santa Clara, California

Chairman: Gordon Moore

President/CEO: Andrew Grove

Founded: 1968

1991 Revenue: $4.02 billion (semiconductor)

Number of Employees: 21,700

Overview

Intel is best known as the designer and the principal supplier of the x86 family of microprocessors. In 1988 Intel acquired from General Electric the New Jersey-based DVI organization and technology, a group that specialized in image/video compression. Intel then commercialized DVI (an Intel trademark) and created (with IBM) chip sets and boards employing the technology.

Intel also has a multimedia operation in Chandler, Arizona, that is responsible for marketing the company's other products, such as the i960 embedded controller, into multimedia applications.

Financials and Market Position

Dataquest estimates that Intel will have $20 million in multimedia applied revenue in 1992 from all its products; 1992 revenue from the DVI chip set is estimated to be $3 million.

Products

Intel's compression offerings revolve around its evolving DVI chip set, as follows:

- i750 B-Series video processor chip set (2)
- ActionMedia II video/audio capture and playback PC boards
- AVK programming interface
- PLV encoding services for CD-ROMs, among others
- Microcontrollers—i960 et al.
- Flash memory

Strategy

Intel has positioned its cornerstone i750 chip set as a programmable compression "engine" capable of running most current and future compression algorithms. It has moved beyond supporting only the PLV and RTV algorithms and is supporting JPEG; it plans to support other motion standards such as MPEG, QuickTime, and Microsoft's AVI. It views its product as a hardware accelerator of what will perhaps become a software-driven function in the near term. Expect Intel to follow an x86-like product strategy as it introduces the next upwardly compatible versions of the 750 with higher performance. The company is already working with PictureTel on a next-generation product targeting the real-time rigors of full-frame/frame-rate video teleconferencing.

Intel's principal patrons have been IBM and NCR. Both companies are using DVI in vertical markets such as kiosks and IBM's Ultimedia products work. Intel also claims a whole host of other design wins for DVI including: Fluent Machines, New Video, Fast Electronics, and ACE Coin (arcade games). Microsoft, Macromedia, and Asymetrix head the list of software companies supporting DVI interfaces.

Dataquest Perspective

Intel has done a good job of positioning its DVI i750 technology as a general-purpose compression engine, as evidenced by noting the number of design wins and software support programs (programming interfaces). It appears to be taking advantage of the trend where software environments will dictate the compression algorithm winner. In the meantime, vertical applications are paying the bills.

Brooktree Corporation

Corporate Statistics

Headquarters Location: San Diego, California

Chairman/President/CEO: James Bixby

Founded: 1981

1991 Revenue: $84 million

Number of Employees: 540

Overview

Brooktree is a key provider of mixed-signal data conversion ICs and pioneered the single-chip palette DAC (RAMDAC) market for computer graphics. It recently purchased Rockwell's T1/E1 and ISDN IC product line and also recently sold to Pioneer a video compression line based in Bristol, England. The company contracts out its IC fabrication needs.

Financials and Market Position

Estimated 1992 digital video related revenue is in the $2 million to $3 million range.

Products

The company has an array of specialized offerings targeted at multimedia applications, including RAMDACs and video encoders, as follows:

- Bt855/858—NTSC/PAL video output encoders
- Bt481/482—True-color RAMDACs
- Bt484—True-color RAMDAC (1280 x 1024 resolution)
- Bt496—RAMDAC with CMYK-RGB color-space conversion
- T1/E1 and HSDL transceivers and controllers

Strategy

Brooktree will continue to leverage its strengths as the market leader in mixed-signal, feature-rich, RAMDAC technology into related aspects of digital video encoding and pixel stream sizing and mixing. Its emerging presence in digital telecom will benefit from the higher bandwidth WAN requirements in multimedia communication.

Dataquest Perspective

Brooktree is well positioned to capture the video/image wave as it merges with computer graphics because of its success in managing the complex nature of designing and delivering reliable RAMDAC technology, and its understanding of the computer graphics market. Its principal competition in encoding/decoding will be Philips, whose experience base comes from the other side—that is, understanding video from a high-volume, consumer electronics viewpoint.

Dataquest Analysis

We believe that we have presented a realistic projection of the future for multimedia semiconductor applications. Opportunities include the following:

- Clear and present opportunities exist in the sound area for add-in and embedded DSP functionality. Firming standards are creating fertile ground for a chip set market to develop.
- Digital video will emerge more modestly than will sound as compression standards settle. Chip companies have an opportunity to make digital video economical with intelligent integration of chip sets.
- As moderate-performance video conferencing offerings move to implement CCITT standards, there is once again an attractive chip set opportunity.
- FDDI equipment is a near-term opportunity because multimedia bandwidth demand is knocking on the door. N-ISDN and ultimately B-ISDN (ATM/SONET) will continue to unfold throughout the decade as public bandwidth needs break down the price premium of this capability.

- Consumer interactivity and multimedia in the form of terminals and players is a developing opportunity as the consumer sorts out a multitude of options.

Success with any of these opportunities will depend on well executed strategy and tactics, including the following:

- Maintain close scrutiny of important standards such as software compression and operating system support of multimedia features. As Apple, Microsoft, IBM, and the UNIX community migrate their standards, a successful chip company should migrate as well. New operating systems such as Windows NT, Power-Pink (IBM/Apple), and new versions of UNIX bear close following as they emerge.
- Maintain flexible cell libraries of core functions such as DCT so that custom/semicustom business can be obtained. In the near term, custom opportunities will be a substantial part of the market.
- Maintain access to an array of processes technologies, especially mixed signal.

It is impossible to prescribe a recipe for success, but we believe that the companies to find the greatest success will execute well on most of these factors.

Chapter 4
Multimedia Authoring Software and Applications

Introduction

It is frequently said that multimedia computing has been slow to take off in the business arena because there are so few multimedia-enabled software applications. Users are hesitant to buy multimedia systems until they can see commercially available software applications running on them—not games or reference collections, but applications that solve real business problems.

There are several hundred multimedia software applications and titles on the market. Some of them are tools and utilities for creating multimedia applications, but it is a fact that most are geared toward entertainment, reference, and educational use. You can count on one hand the titles that can be considered business productivity applications (SmartHelp for 1-2-3 from Lotus and Multimedia-enabled Microsoft Works would be two candidates in the business productivity category; Lotus Notes: Document Imaging is moving in this direction).

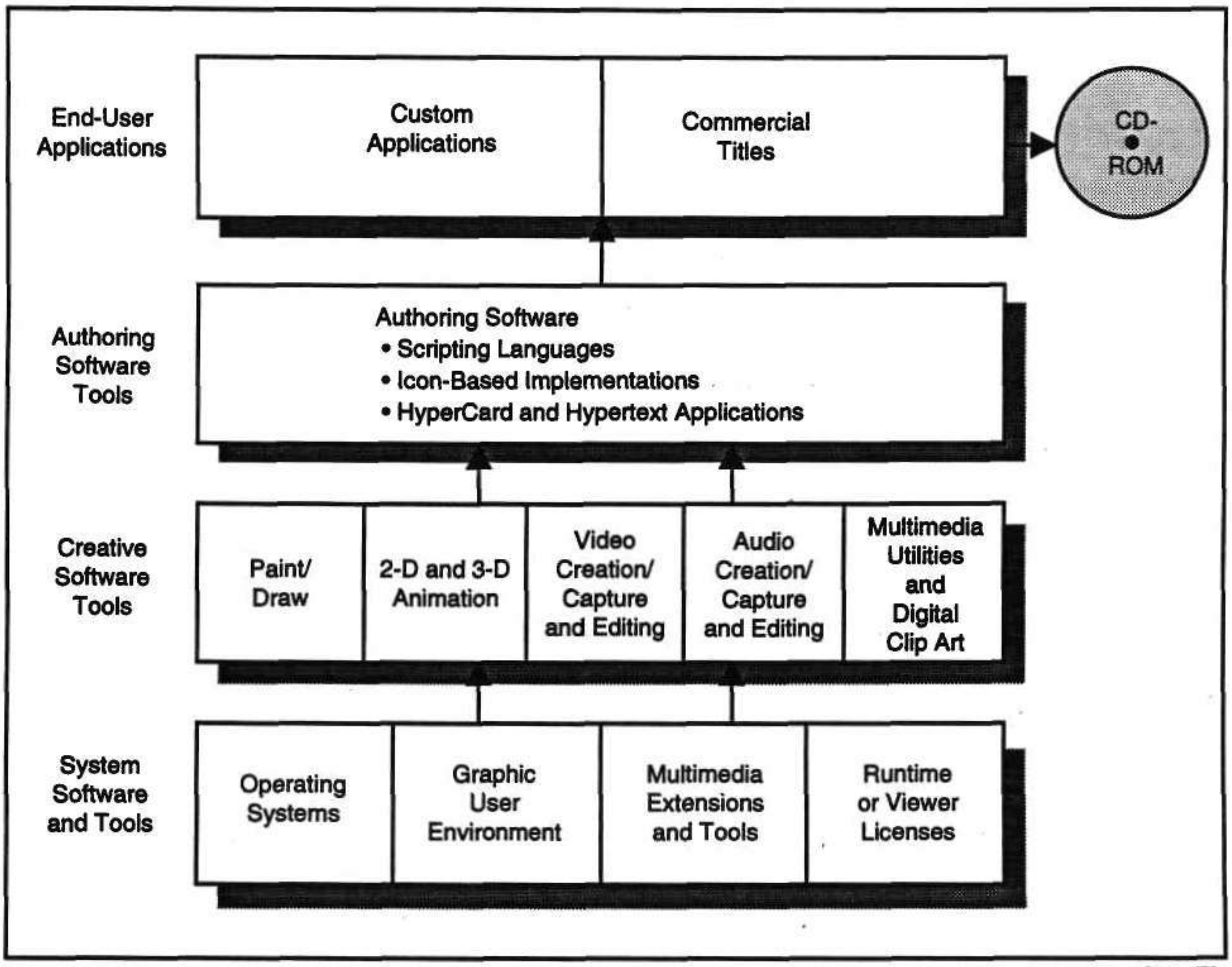
We do not agree that the business multimedia market will languish until that killer application hits the scene, however. In fact, there will probably never be such a thing. Instead, we believe that multimedia is an enabling technology that will be integrated into existing software products like word processors, presentation graphics, spreadsheets, groupware, desktop communications, desktop publishing, and databases. Rather than spawning a whole new school of software, multimedia will add capabilities that enhance communication, provide deeper levels of information access, and delight the senses. This evolution is already beginning and during the next 18 months many multimedia-enabled software products for business will come onto the scene.

This chapter takes a look at the multimedia software market as it stands today. It reviews the various software components that comprise multimedia software, discusses factors that will cause the market to grow, provides an analysis of the size of the market with five-year growth forecasts, and profiles leading multimedia software companies.

Multimedia Software Categories

It is not possible to discuss multimedia software as a single category of products, tools, or applications. As shown in Figure 4-1, there are

Figure 4-1
Multimedia Software Layers



Source: Dataquest (September 1992) G2001573

four levels of software used to create and deliver multimedia applications and programs, as follows:

- System and graphical interface software
- Creative software tools
- Multimedia authoring tools
- Multimedia applications and titles

Table 4-1 lists some of the software products that fall into these categories, and the following paragraphs explain the multimedia software categories in more detail.

System and Graphical Interface Software

As with all computer applications, some operating system and user interface software must be present on PCs and workstations in

Table 4-1
Multimedia Software—Representative Products by Category

Category	Platform	Product Name
System Software	IBM PC	MS DOS/Windows 3.1 with Multimedia Development Kit OS/2 2.0 and Presentation Manager
	Macintosh	System 7 with QuickTime
Creative Software		
Paint/Draw	IBM PC	CorelDRAW (Corel) PC and Publisher's Paintbrush (ZSoft) Impala (Time Arts) Lumena (Time Arts)
	Macintosh	MacDraw (Claris) CA-CricketDraw (Computer Associates) PixelPaint (SuperMac)
2-D/3-D Animation	IBM PC	Animator Pro (Autodesk) Multimedia Explorer (Autodesk) 3D Studio (Autodesk) Mannequin (Humancad) Designer (Humancad) Animation Studio (Gold Disk)
	Macintosh	Magic (MacroMedia) Three D (MacroMedia) Swivel 3D (MacroMedia)
Video Editing	IBM PC	Personal Picture Process (Montage)
	Macintosh	MediaMaker (MacroMedia) Premiere (Adobe) Soft F/X (Digital F/X)

(Continued)

Table 4-1 (Continued)
Multimedia Software—Representative Products by Category

Category	Platform	Product Name
Audio Editing	IBM PC	Wave for Windows (Turtle Beach)
	Macintosh	MacRecorder (MacroMedia)
Authoring Software	IBM PC	IconAuthor (AimTech)
		Quest (Allen)
		Multimedia Toolbook (Asymetrix)
		Authorware (MacroMedia)
		Guide (Owl)
	Macintosh	Director (MacroMedia)
		Course Builder (TeleRobotics)
		Plus for Mac (Spinnaker)
		LiNX (Warren-Forethought)
Commercial Applications and Titles	IBM PC	SmartHelp for 1-2-3 (Lotus)
		Multimedia Encyclopedia (Compton's)
		Berlitz Think and Talk Series (Hyperglot)
		Great Cities of the World (Interoptica)
		Bookshelf (Microsoft)
		Multimedia Beethoven (Microsoft)
		Amanda Stories (Voyager)
	Macintosh	Mammals (National Geographic)
		Wraptures (Form and Function)
		Dictionary of the Living World (Media Design Interactive)
		Desert Storm (Warner New Media)
		Webster's Talking Dictionary (Highlighted Data)
		Great Literature (Bureau Development)
		Spaceship Warlock (Reactor)

Source: Dataquest (September 1992)

order to run, develop, deliver, and use multimedia applications. In the IBM PC environment, this is either OS/2 with Presentation Manager or MS-DOS and Windows 3.1 with multimedia extensions. The Microsoft Development Kit for Windows provides a set of APIs that C programmers can use to add multimedia elements including sound, animation, video, and photo images to Windows applications. In the Apple Macintosh environment, this includes the System 7 operating environment with QuickTime's multimedia extensions that facilitate the addition of sound, video, and animation to Macintosh applications. The UNIX workstation operating systems (HP's HP-UX, IBM's AIX, NeXT's NeXTstep, and Sun's Solaris, for example) also handle the integration and display of multimedia elements in a fashion proprietary to each vendor's implementation of UNIX. Likewise, the Commodore Amiga operating system provides for the integration, handling, and display of multimedia elements through extensions used by Amiga software developers to create Amiga applications. Most end-user software applications are delivered with runtime or player versions of the operating software to enable end-user workstations to play back and use the applications.

Creative Software Tools

Next, comes software that enables the development of multimedia applications by providing separate tools for creating and editing the 2-D and 3-D animations, raster and vector graphics, sound, and video files that will be imported into multimedia applications. Multimedia clip-art libraries containing noncopyrighted animations, videos, and sounds also fall under this category. There are hundreds of these software products on the market. Most have previously been sold into creative and advertising professions for building advertising and sales videotapes, movies, and corporate presentations, and into technical professions for product modeling, design, and simulation. Today, their use is expanding as tools to build the component graphic, animation, sound, and video elements that will be incorporated into multimedia programs and applications. (Note that animation, graphics, video, and audio software were described at length in the "Executive Overview" section of this report—please refer to it for complete details of the features that these programs provide).

Multimedia Authoring Tools

Authoring software provides a set of tools that pull together text and data, animations, graphics, scanned images, still and full-motion video images, sound files, and multimedia clip-art to build end-user applications. It must provide for the integration of all these elements to be considered *multimedia* authoring software. Because much of the authoring that has been done in the past focused on building education and training applications, many authoring software programs also provide APIs for building online tests, for scoring tests, for validating test results, and for producing summary reports. Table 4-2 provides a list of the major multimedia authoring products on the market including capabilities and price.

Table 4-2
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
AimTech Corp. Nashua, NH (603) 883-0220	IconAuthor	Authoring software for creating CBT, presentations, and information kiosk applications that integrate multiple data types and interactivity	MS-DOS/Windows UNIX/Motif	$4,995 $7,500 single user; $15,000 for four-user license
Aldus Corporation Seattle, WA (800) 332-5387	SuperCard	HyperCard-style authoring tool for integrating animations, graphics, sound, text, and graphics to create hyperlinked "projects" (stacks)	Macintosh	$299
Allen Communication Inc. Salt Lake City, UT (801) 537-7800	Quest Authoring System	Courseware authoring software for creating CBT and interactive video presentations	MS-DOS	$3,995 (includes unlimited runtime players)
Apple Computer Cupertino, CA (408) 996-1010	QuickTime Developer Kit and QuickTime Starter Kit	Multimedia extensions to Apple's System 7 operating system; allows users to synthesize and synchronize animation, video, and sound, and incorporate results into Macintosh applications	Macintosh	Developer kit has been provided at minimal cost (shipping fees) and through public bulletin boards Starter Kit retails for $169
Asymetrix Corp. Bellevue, WA (206) 734-2553	Toolbook	Software construction set for building interactive presentations (does not support video)	MS-DOS/Windows and OS/2	$395
	Multimedia Toolbook and Multimedia Toolbook, Education Edition	Software construction set for building multimedia training, applications, and presentations	MS-DOS/Windows	$695 and $265, respectively

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
Claris Corp. Santa Clara, CA (408) 987-7000	HyperCard	Hypercard software for storing text, graphics, sound, animation, and other data types on electronic index cards	Macintosh	$49-$199
Commodore Business Machines West Chester, PA (215) 431-9100	AmigaVision Authoring System	Icon-based authoring tool for integrating text, graphics, animation, video, and sound elements into Amiga applications	Amiga	$112
Computer Teaching Corp. Champaign, IL (217) 352-6363	TenCORE Producer	Menu-driven authoring tool to create lessons with graphics, animation, video, and answer judging	MS-DOS/Windows	$1,800, with $430 per year maintenance fee
	TenCORE Language Authoring System	System for creating interactive courseware for PC delivery using graphics and video	MS-DOS/Windows	$2,400, with $570 per year maintenance fee
Courseware Applications Inc. Champaign, IL (217) 359-1878	Unison Author Language	Specialized programming language for producing CBT that integrates color, animation, video, audio, interaction, and response analysis	MS-DOS/Windows	$345
FourMat Corp. Provo, UT (801) 377-9186 (expect to relocate to Salt Lake City, UT 10/92)	The FourMat Learning Processor	Authoring software for creating interactive training and education modules	Macintosh (MS-DOS/ Windows version under development)	$895 (industrial kit includes one developer license and five user seats) $895 (educational kit includes five developer licenses and unlimited user seats)

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
Gain Technology Inc. Palo Alto, CA (415) 885-1700	GainMomentum	Authoring software for business, training, and professional use; creates SQL links to graphics, sound, animation, audio, video, and image objects	UNIX and Sun SPARC platforms	$15,000
Gold Disk Inc. Torrance, CA (310) 320-5080	Animation Works Interactive	Multimedia authoring system for blending 2-D animation, full-motion video, interactivity, and sound into presentations, training, and information systems	MS-DOS/Windows	$495 (includes unlimited runtime players)
	Animation Works	Multimedia development software for Macintosh; no interactivity	Macintosh	$200
	AddImpact! (will ship 10/92)	Presentation enhancement product to bring multimedia elements including voice, sound, graphics, and video into any Windows application	MS-DOS/Windows	$149
	HyperBook	HyperCard-like authoring application with emphasis on very simple-to-use interface	Amiga	$100
IBM Corp. Multimedia and Education Division White Plains, NY	Audio Visual Connection	High-end multimedia authoring language to combine and edit sounds, pictures, and text into stories and presentations	OS/2	$495

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
	Storyboard Live!	Multimedia authoring tool for creating on-screen presentations incorporating text, images, video, animation, sound, digitized still photos, drawings, and paintings.	MS-DOS	$495
Impulse Inc. Minneapolis, MN (612) 425-0557	Foundation	HyperCard-like authoring tool for creating "frames" (stacks) into which graphics, animations, and sounds can be pasted; hypertext is a strong suit	Amiga	$300
Informatics Group Inc. West Hartford, CT (203) 953-4040	ACT III	Interactive multimedia presentation development tool for non-programmers	MS-DOS	$495 (no runtime or maintenance fees)
Innovative Communication Systems Minneapolis, MN (612) 531-0603	Ask•Me 2000	Entry-level ultimedia authoring tool/flat file database; no video capabilities	MS-DOS/ proprietary windowing	$495 (retail channel)
	Ask•Me Professional	Professional authoring tool for incorporating all multimedia elements including live motion video; based on object-oriented relational database	MS-DOS/ proprietary windowing	$1,795 (VAR channel)
Innovatronics Dallas, TX (214) 340-4991	CanDo	HyperCard-like authoring program for creating "decks" (applications) that integrate the various multimedia elements	Amiga	$150

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
MacroMedia, Inc. San Francisco, CA (415) 595-0525	Authorware Professional	Professional-level icon-based authoring tool for creating courseware and presentations that integrate text, audio, video, graphics, and animations	MS-DOS/Windows and Macintosh	$8,000 ($1,200 per year maintenance) $3,995 (developer price) $995 (education price)
	Authorware Star	Personal authoring tool for creating multimedia presentations and courses	MS-DOS/Windows	OEM product—sold bundled with upgrade kits only
	Director	Professional authoring tool for creating distributed interactive applications, multimedia presentations, and animations	Macintosh	$1,195
Microsoft Corp. Redmond, WA (206) 882-8080	Windows 3.1, Multimedia Extensions	Multimedia system software with extensions for incorporating multimedia elements into Windows programs	MS-DOS/Windows	$150
	Multimedia Development Kit	Developer APIs for enhancing Windows' graphical environment by incorporating sound, animation, near-photo image quality and the storage qualities of CD-ROM	MS-DOS/Windows	$500
	Microsoft Viewer	Authoring environment that enables developers and titles publishers to enhance traditional text-based titles with hypertext, full-text search, and multimedia elements; runtime included	MS-DOS/Windows	Included in Multimedia Development Kit (Microsoft is considering unbundling this product)

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
Ntergaid Inc. Fairfield, CT (203) 368-0632	HyperWriter!	Interactive hypermedia and courseware authoring software	MS-DOS (Windows version under development)	$495
	HyperWriter! for Training	Same capabilities as HyperWriter! but also includes testing and scoring capabilities	MS-DOS (Windows version under development)	$995
Owl International Inc. Bellevue, WA (206) 747-3203	Guide	Hypermedia authoring software for creating interactive multimedia documents	MS-DOS/Windows	$495
Paradise Software Inc. Princeton Junction, NJ (609) 275-4475	Mediawrite	Authoring software from creating interactive, online documents that contain multimedia elements including graphics, still images, audio, and video	Sun	$995 (runtime license fees vary)
Right Answers Inc. Torrance, CA (818) 840-8021	The Director	Script-based authoring language for creating Amiga applications that integrate a variety of multimedia data types	Amiga	$129
Spinnaker Software Corp. Cambridge, MA (617) 494-1200	Plus for Windows and Plus for Mac	Hypercard-based toolkit that allows users to create hypercard applications built on cards, stacks, buttons, scripts, graphics, text, database fields, icons, and integrating video, animation, and sound	MS-DOS/Windows and Macintosh	$495 (both versions)

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
Technology Applications Group Troy, MI (313) 649-5200	SAM (System for Authoring Multimedia)	Multimedia courseware authoring system geared for novice users	MS-DOS	$99 (evaluation/student version) $2,875 (industrial VGA version $2,500 (industrial CGA version) $2,750 (industrial EGA version)
TeleRobotics International Inc. Knoxville, TN (615) 690-5600	Course Builder	Visual authoring language to create interactive training and multimedia presentations	Macintosh (MS-DOS under development)	$995 (educational) $1,495 (standard)
	Video Module	Adds interactive video capability to Course Builder through connection to videodisk or VCR	Macintosh (MS-DOS under development)	$495
Tiger Media Inc. Los Angeles, CA (213) 721-8282	CATS MEOW	Sun SPARC-based multimedia authoring software tool	UNIX and Sun SPARCstations	$2,050 per workstation for developer's software; $100 per seat for playback software
Vision Imaging Fountain Valley, CA (714) 965-7122	Media Master	Authoring program to create multimedia interactive runtime applications for corporate training, kiosks, real estate, and other information presentation systems	MS-DOS	$995 (includes unlimited runtime versions)
	Image Base	Image database	MS-DOS	$195

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

Vendor	Product Name(s)	Capabilities	Operating Environment	Price
	Multimedia Studio	Allows users to create and distribute self-running (noninteractive) multimedia applications that combine text with images, digital-quality sound, and motion picture quality video and animation	MS-DOS	$295
V_Graph, Inc. Westtown, PA (215) 399-1521	VirtualVideo Producer	Authoring software for creating interactive multimedia presentations that play back motion video, sequence still video images, and superimpose scrolling text, animation, and graphics images	MS-DOS	$199 (VGA version) $695 (Targa chip set version)
	Interactive VirtualVideo	Includes features of VirtualVideo Producer plus touch screen, videodisk, and speech recognition controls	MS-DOS	$2,500 (VGA version) $4,500 (Targa chip set version) $1,000 (royalty-free runtime)
Warren-Forethought Inc. Angleton, TX (409) 849-1239	LiNX Industrial	WYSIWYG multimedia authoring system to create CD-ROM navigation interface, hypertext, or multimedia reference works, electronic document management systems, interactive training, and presentations	Macintosh	$9,000 (includes unlimited runtime players)

(Continued)

Table 4-2 (Continued)
Multimedia Authoring Software

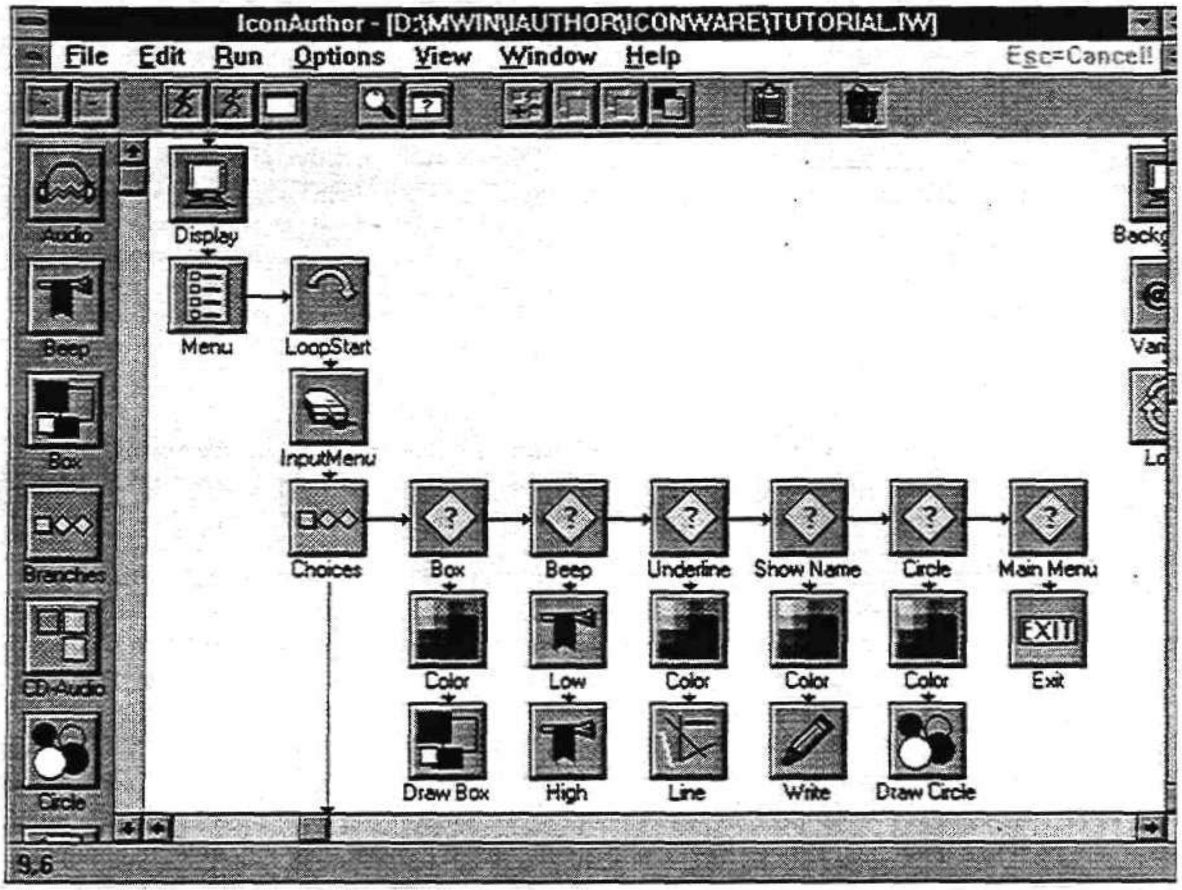
Vendor	Product Name(s)	Capabilities	Operating Environment	Price
	LiNX Lite	Scaled down version of LiNX Industrial for building CBT and full-motion video presentations	Macintosh	$239 per copy; $939 for a 10-user lab pack sold to education buyers
	LiNX Test Factory	Program for building interactive multimedia testing instruments	Macintosh and MS-DOS/ Windows	$939 ($139 for single workstation player)

Source: Dataquest (September 1992)

Authoring software varies widely in how technical a person has to be to use it. After all, these products are really programming and scripting languages in disguise, aiming at a mass audience. Their developers have been challenged to build easy-to-use front ends that provide powerful applications-building capabilities that can be used by nonprogrammers. Some products like Microsoft Viewer, whose main users are developers, provide scripting languages that require the user to have some level of technical proficiency and programming skills. Other products like MacroMind's Authorware or AimTech's Icon Author (see Figure 4-2) have been built around a graphical flowchart model that uses icons to represent the various data elements being combined into a multimedia presentation. The user points, drags, and drops in the pieces to create a finished presentation. All tools claim to be easy to use. The truth is that some are easier than others, but all still have a long way to go before the casual user can pick one up and painlessly produce a finished application or presentation the same day.

Authoring tools also vary widely in the features and capabilities they provide. Many vendors offer two levels of product—personal

Figure 4-2
IconAuthor's Icon-Based Interface for Multimedia Authoring



Source: Aimtech Corporation

tools and professional tools. Personal tools provide basic authoring capabilities for creating presentation and training applications without too many glitzy bells and whistles. Personal tools generally cost between $99 and $500. Professional tools are geared toward commercial developers, industrial-strength users, MIS departments, and professional creative users. These provide authoring capabilities mingled with a wide assortment of special effects. Professional tools usually cost between $500 and $20,000, depending on the platform on which they run and the number of users they support.

HyperCard, hypertext, and hypermedia software probably also fit best into the authoring tools category. This software enables a developer or user to create HyperCard stacks or hypermedia applications which link any word, icon, graphic, or image displayed on-screen to an unlimited number of other elements in the system's database. It creates an intricate web of interrelated information elements. Hypermedia applications allow users to browse as deeply into a subject as they desire by exploring the various levels of information associated with topics or graphics on screen.

Multimedia Applications and Titles

The final result of the authoring process is the multimedia application or title. There are two types of applications, which users view and sometimes interact with, but which they cannot modify: custom applications and commercially available titles.

Custom Applications

These are in-house applications developed using the authoring tools described previously. Today, these consist mainly of training and courseware, presentations, and information kiosk systems. These applications were developed internally or on a contract basis for a particular client's use and are not commercially available products. Sometimes they are visible in public places, however, as in the case of information kiosks that are starting to appear at trade shows and exhibitions, airports, stores, and shopping malls.

Commercial Titles

Commercially available applications developed using authoring software are commonly called titles. These have been created by professional developers (called authors) that focus on creating multimedia applications for the mass market. They are usually distributed on CD-ROM rather than floppy disks. This is because multimedia applications include millions of pieces of information and CD-ROM is a reliable, compact distribution medium for large amounts of data and mixed data types. The commercial titles on the market today fall into these categories: recreational programs such as games; information and reference programs; educational programs; online tutorials and help systems for using software applications; and multimedia-enabled business applications.

Another way of thinking about multimedia software is that it is used either to create multimedia or to deliver it:

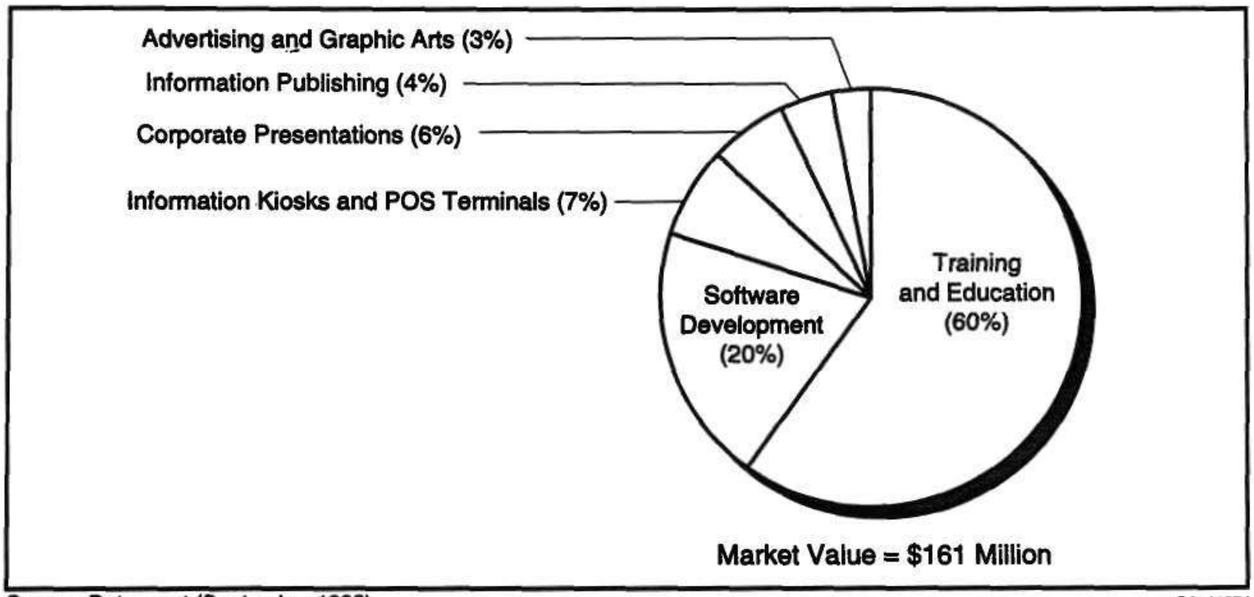
- Software for *creating* multimedia applications—Includes operating system tools and graphical user interface software; creative software for creating and editing animations, video clips, and sound files; and multimedia authoring tools
- Software for *delivering* multimedia applications—Includes custom-developed applications and commercially available titles

End-User Markets

Historically, training was the application that drove the development of the multimedia applications market. Course designers, classroom instructors, and learning professionals have long recognized the value of using a variety of stimuli to help people learn more quickly and retain what they learn longer. The availability of PCs in training labs and classrooms propelled the development first of interactive courseware, and then courseware combining various media types to engage the learner's senses.

Today, trainers and educators still dominate as the primary users of multimedia authoring tools. However, during the past couple of years, authoring tools have begun to find their way into the hands of other professional users such as software developers graphics artists, information publishers, and the developers of kiosk applications. Figure 4-3 provides Dataquest's estimates of the mix of applications currently being developed using multimedia authoring tools.

Figure 4-3
1992 Authoring Tools Penetration by Applications



Source: Dataquest (September 1992)

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This picture is already beginning to change because the notion of multimedia computing has grabbed the imaginations of people who develop software for just about every profession. During the next 12 to 18 months, we estimate that more than 300 new CD-ROM-based commercial multimedia titles will join the 225 titles already on the market (includes PC and Macintosh titles). In addition, thousands of new in-house applications, for every discipline imaginable, will be created using authoring tools. And finally, largely due to a "flood" of personal authoring software packages getting into people's hands through upgrade kit distribution (discussed below), hundreds of thousands of average end users will begin to play around with this technology, we suspect mainly to create more interesting presentations.

In the various market segments, we envision hundreds of innovative uses, including:

- Business—Commercial PC and groupware applications including spreadsheets, databases, desktop publishing, word processing, presentation graphics, desktop conferencing, and draw and paint programs will be embellished with multimedia capabilities. The ability to add multimedia elements to documents will become commonplace, and multimedia documents will be routed freely around networks. Network CD-ROM servers will provide access to corporate information and reference sources, and desktop CD-ROM drives will be used for playing applications needed by individual users.
- Engineering—Product design, simulation, revision control management, and testing will all be enhanced by multimedia. Engineers at distant locations will be able to share ideas and simultaneously work on new product designs using desktop video conferencing tools. CAD's current 2-D and 3-D design capabilities will be enhanced by some of multimedia's emerging technologies such as virtual reality.
- Financial Services—Banks and financial institutions will provide customers a new dimension of services through interactive kiosks that supply real-time rate schedules, provide loan information, process applications for credit cards, bank accounts, and loans, and enable customers to pay bills electronically. Financial analysts and investment brokers will also use real-time multimedia simulations to track financial market conditions and indicators.
- Insurance—The addition of multimedia data types to insurance claims files (voice interviews and depositions, video clips, and freeze-frame video, for example) will provide levels of detail unavailable through paper case files.
- Health Care—Hospitals and doctors offices will provide interactive kiosks to help patients with everything from hospital admissions and insurance paperwork processing, to presurgical information videos. Patients' case files will be enhanced by the ability to include a variety of data types into a single digital file (x-rays and electrocardiograms, mammograms, handwritten notes, doctors' voice notes, photographs, video clips, and so on). Virtual reality will provide a tool to train new doctors and assist surgeons assess the patients condition prior to actual surgery.

- Real Estate—Multimedia guided tours of homes and properties listed in the multiple listings will save time and money for both prospective buyers and brokers alike.
- Retail Sales—Information kiosks and point-of-sale terminals will provide customers with information on store promotions, dispense money-off coupons, and provide customer assistance and merchandise/store location information.
- Travel and Tourism—Travelers will be able to preview travel destinations, tour hotel and restaurant facilities, and book airline tickets from multimedia terminals installed at the travel agent's desk.

There is no doubt that we are at the beginning of an adoption curve that will see multimedia penetrate almost every facet of commercial and technical applications throughout the rest of the decade. (For detailed descriptions of current and expected applications for multimedia, please refer to the "Market Dynamics" section in Chapter 2 of this report.)

Market Dynamics

The road to complete adoption of multimedia is not free of rocks, however. In the software area, a number of barriers must be cleared before multimedia applications will find their way onto everyone's desktops. Some of the major software issues are described below.

Lack of Applications

As mentioned previously, we do not believe that multimedia will evolve a new breed of application that will make everyone gasp, "Now I get it! Now I *want* it!" Instead, multimedia's multisensory capabilities will be integrated into the productivity and groupware applications that business people use everyday, making them more useful, creative, and fun to use. Still, until this happens, it will remain difficult for the average business person to visualize just how compelling this technology can make an application. We expect to see tremendous progress toward integrating multimedia into business applications during the next 12 to 18 months because most major software developers are working on multimedia versions of their current products.

Platforms

The dominant platform for running multimedia applications is also still up for grabs. It is a statistical fact that IBM PCs running the MS-DOS/Windows operating environment outnumber the Macintosh by a factor of 10:1, and other workstation platforms by more than 100:1. This market momentum would seem to indicate that the MPC standard will prevail.

But multimedia is a highly *creative* technology, and we have observed that the majority of very early in-house implementors have favored the more intuitive Macintosh platform over the PC. Further, the MS-DOS/Windows environment lacks the horsepower to run industrial-strength, networked multimedia applications. Macintosh's System 7 with QuickTime, on the other hand, is a multitasking operating system which supplies both developer and end-user extensions for integrating multimedia elements. But the network instability of System 7 has delayed widespread adoption of it.

The role that Windows NT, the Kaleida Script operating system, and the Power PCs from Taligent will play in this equation further muddies the water. Given the current lack of business applications and unsettled platform issues, we suspect that all but the most forward-thinking corporate users will probably decide to sit back and wait.

Standards

File interchange and cross-platform compatibility are critical issues affecting multimedia software. Authors want to be able to use their favorite graphics, text, animation, and video editors to create the clips that they will integrate into the finished multimedia application. As it stands today, every authoring program on the market is compatible with only certain creative tool file formats or selected "standard" file formats. Worse yet, the authoring tools generate proprietary file formats that are incompatible with other authoring tool file formats. This means that if you have created a presentation using one product, it is not possible to lift a piece of that presentation and copy it into another authoring tool-created presentation.

The Interactive Media Association's (Washington, D.C.) Compatibility Project is working to address this and other compatibility and interchange issues. The Compatibility Project team comprises members from most leading computer hardware and software companies, consumer electronics companies, software developers, government, and institutions. The team's charter is to generate standards and recommendations to promote portability of multimedia applications across different hardware platforms. Specifically, technical working groups address key technology areas including cross-platform architecture, distributed multimedia systems, object-oriented multimedia specifications, digital audio, and digital video.

Hopefully, the efforts of industry associations like the IMA will generate cooperation and standards among multimedia hardware and software vendors, which, in turn, will move the industry forward.

User Understanding and Evangelism

With anything new, there is a familiarization and acceptance curve. Multimedia is a very broad topic that spans hundreds of application areas ranging from home and school to business offices and laboratories. It has been difficult for the average consumer to sort out the common denominators, much less understand "what multimedia means to me."

Some of the leading consumer electronics companies such as Philips and Sony, leading multimedia computer companies and organizations such as Apple and the MPC Marketing Council, and leading software companies such as Microsoft and Lotus have already taken on the role of industry evangelists to help educate consumers and corporate buyers. For example, Microsoft's annual International Conference and Exposition on Multimedia and CD-ROM brings together forces in the MPC and consumer electronic world every year to share information and display products. But such conferences are still largely centered around technology rather than solutions. We suspect that, as with other new ideas that have blossomed into industries, user understanding and acceptance is driven by being able to see working solutions rather than technology (desktop publishing and document imaging are two examples).

Market Statistics

For the purposes of this report, Dataquest has sized the multimedia software market to include only the software authoring tools used to create multimedia applications and titles. We have not factored in operating systems, creative applications, or end-user titles. This is because it is not clear at this point what proportion of installed operating system software is currently being used on systems whose main purpose is to develop or use multimedia. Likewise, it is not clear what proportion of installed creative software is being used to create animations, videos, and sound clips for multimedia applications versus for standard, noninteractive video presentations and movies. Future Dataquest surveys of multimedia developers will help answer these questions and create a well-rounded multimedia software database.

Market Segmentation

Dataquest segments the multimedia authoring software market into two categories: personal and professional authoring software. The characteristics of each are described below.

Personal Authoring Software

Personal authoring software is composed of a set of low-end authoring tools that provide basic multimedia creation capabilities. The personal tools are aimed at end-user multimedia creators rather than professional-level content developers. As a result, it is critical that these products be simple to use with step-by-step documentation explaining how to use them. They generally provide basic multimedia creation capabilities such as templates, text processing and editing, story boarding, and import/sizing/placement of multimedia objects. They are probably best suited for building presentations, interactive demonstrations, and information kiosks. They range in price from $99 to $500 dollars retail.

A trend is for the major authoring software vendors to bundle their personal authoring software with the PC upgrade kits and multimedia-enabled PCs that are beginning to flood the market. MacroMedia, for example, distributes Authorware Star through agreements with 13 upgrade kit and multimedia-ready PC vendors. Under this type of distribution arrangement, the authoring tools vendors are practically giving away the software (average royalty fee is estimated to be $20 to $40 per copy in an OEM distribution agreement), this represents a way to penetrate the market very deeply with minimal sales effort. It also "seeds" the market with copies that hopefully will give people a taste of multimedia authoring so they will come back for professional products later on.

Professional Authoring Software

Professional authoring software provides advanced tools for creating professional-quality multimedia applications and programs. These products have largely been sold to creative professionals (advertising and graphic arts), professional multimedia titles developers (programmers), corporate MIS users (for building in-house applications), and to advanced end users. Besides basic authoring capabilities, these tools provide additional capabilities including: software capabilities to import, manipulate, and enhance a wide variety of file formats from animation, graphics, audio, and video software programs; interactivity and branching; ability to create long lessons and presentations; professional special effects; learner testing and feedback analysis; and some programs supply built-in graphics and animation programs. Most professional tools run on IBM PCs and Macintoshes as primary development platforms, but a few have been ported to host processor environments or have been developed to run on UNIX workstations. Professional software tools range in price from $500 to $20,000 for a developer license.

Current Market Size

Dataquest estimates that approximately 40 vendors are in the business of providing multimedia authoring software as we have defined it in this report. Table 4-3 lists the estimated 1991 revenue and current installed base for the major providers of multimedia authoring tools. Dataquest estimates that the market was worth approximately $86 million in 1991 and that, as of August 1992, there were about 144,000 copies of authoring software installed worldwide. Two companies dominate the authoring software market:

- MacroMedia—Estimated 1991 revenue of $25 million and about 85,000 copies of authoring software products (Authorware Star, Authorware Professional, and Director) installed
- Asymetrix—Estimated 1991 revenue of $15 million and about 10,000 copies of Multimedia Toolbook installed

The remaining players are, for now, niche players. Many are very small companies employing between 2 and 20 employees. The sale of authoring software is in many cases peripheral to their main line of business, which is developing custom courseware and presentations for end-user customers. This work, rather than the sale of software, in fact generates the bulk of their revenue. Other companies such as Gold Disk and Spinnaker Software offer a range of software products, so their total revenue is buoyed by other software offerings.

We look for IBM to aggressively enter the multimedia software tools market toward the end of 1992 and into 1993 as its Ultimedia Tools Series program kicks into production. IBM is lining up a stable of third-party developers whose tools will be marketed and distributed by IBM under the Ultimedia Tools Series logo (see IBM profile later in this section for more details). Aggressive telemarketing and direct selling of these tools should significantly boost IBM and its partners' share of this business by the end of 1993.

Table 4-3
Vendor Revenue and Installed Base-Multimedia Authoring Software Providers

Vendor/Product	Estimated Total Vendor Revenue for 1991 ($M)	Software First Shipment Date	Installed Base 8/92 (Number of Copies Installed)
AimTech *IconAuthor*	3.2	1988	2,000
Allen Communications[1] *Quest*	5.8	1984	2,000
Apple Computer *QuickTime*	2.0	1992	100,000
Asymetrix *Multimedia Toolbook*	15.0	1991	10,000
Computer Teaching Corp.[2] *TenCORE Language Authoring System*	2.7	1985	1,000
Courseware Applications[3] *Unison Authoring Language*	0.5	1985	750
FourMat Corp. *The FourMat Learning Processor*	1.0	1992	300
Gold Disk *Animation Works Interactive*	1.5	1991	500
IBM *Storyboard Live!* *Audio Visual Connection*	3.0	1989 (AV Connection) 1991 (Storyboard Live)	1,500 (AV Connection) 10,000 (Storyboard Live)
Informatics Group *Act III*	1.0	1983	2,000

(Continued)

Table 4-3 (Continued)
Vendor Revenue and Installed Base-Multimedia Authoring Software Providers

Vendor/Product	Estimated Total Vendor Revenue for 1991 ($M)	Software First Shipment Date	Installed Base 8/92 (Number of Copies Installed)
Innovative Communication Systems *ASK·ME 2000* *ASK·ME Professional*	0.5	1990	2,550 (ASK·ME 2000) 450 (ASK·ME Professional)
MacroMedia[4] *Authorware Star* *Authorware Professional* *Director*	25.0	1989 (Authorware)	50,000 (Star) 10,000 (Professional) 25,000 (Director)
Microsoft *Multimedia Development Kit and Viewer*	0.5	1991	1,000
Ntergaid *HyperWriter!*	1.0	1989	7,400
Spinnaker Software[5] *Plus for Windows* *Plus for Mac*	15.0	1990	1,250
Technology Applications Group *SAM*	0.5	1986	1,000
Telerobotics *CourseBuilder*	1.0	1987	2,000
Tiger Media *CAT'S MEOW*	0.5	1991	150
Vision Imaging *Media Master*	1.0	1990	1,000

(Continued)

Table 4-3 (Continued)
Vendor Revenue and Installed Base-Multimedia Authoring Software Providers

Vendor/Product	Estimated Total Vendor Revenue for 1991 ($M)	Software First Shipment Date	Installed Base 8/92 (Number of Copies Installed)
V_Graph *Interactive Video Producer* *Virtual Video Producer*	0.5	1985	9,000 (Interactive VP) 1,000 (Virtual VP)
Warren-Forethought *LiNX Industrial* *LiNX Lite*	0.7	1991	48 (LiNX Industrial) 2 (LiNX Lite)
Others	5.0	-	2,000
Total[6]	86.9	-	144,000

Notes:
1. More than 50 percent of Allen Communication's revenue is derived from custom courseware development.
2. A portion of Computer Teaching Corporation's revenue is derived from custom courseware development.
3. Courseware Application's main business is custom courseware development.
4. MacroMedia's revenue reflects combined revenue for AuthorWare and MacroMindoParacomp; the two companies merged to form MacroMedia in 1992.
5. An estimated 80 to 90 percent of Spinnaker's revenue is for nonmultimedia software titles (PFS series) marketed by the company.
6. Note that the revenue shown in this column is for total software and services provided by the vendors listed. We estimate that 1991 revenue for sales of authoring software alone was around $41 million.

Source: Dataquest (September 1992)

Figure 4-4 shows the break out of currently installed authoring software by operating environment. We estimate that approximately 85 percent of this software is running on IBM and compatible PCs under MS-DOS; 12 percent runs on the Macintosh; 2 percent runs on IBM and compatible PCs under OS/2, and 1 percent runs on technical workstations under UNIX.

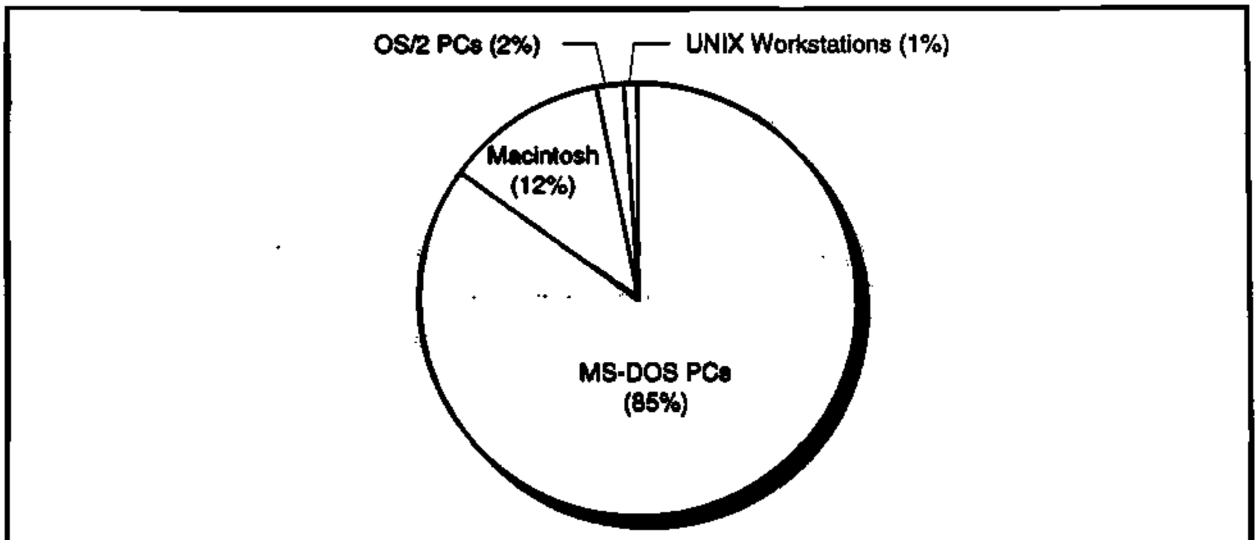
Market Forecast

Dataquest's five-year forecasts for the growth of the worldwide authoring software tools market are shown in Table 4-4. The forecast is divided into the personal and professional software tool segments and presents the following data:

- Authoring software license shipments
- Average (per copy) software selling price
- Factory revenue for sales of software (does not include services)
- Total installed base of authoring software licenses

As shown in Figure 4-5, the unit shipment volume of authoring software was very small in 1991, only about 36,000 copies. However, 1992 marks the year when the market will take a dramatic upswing to an estimated 729,000 units shipped. The bulk of new units shipped will be personal authoring software tools. The cause for this sudden upsurge is the PC upgrade kit market.

Figure 4-4
Authoring Installed Base by Operating Environment



Source: Dataquest (September 1992)
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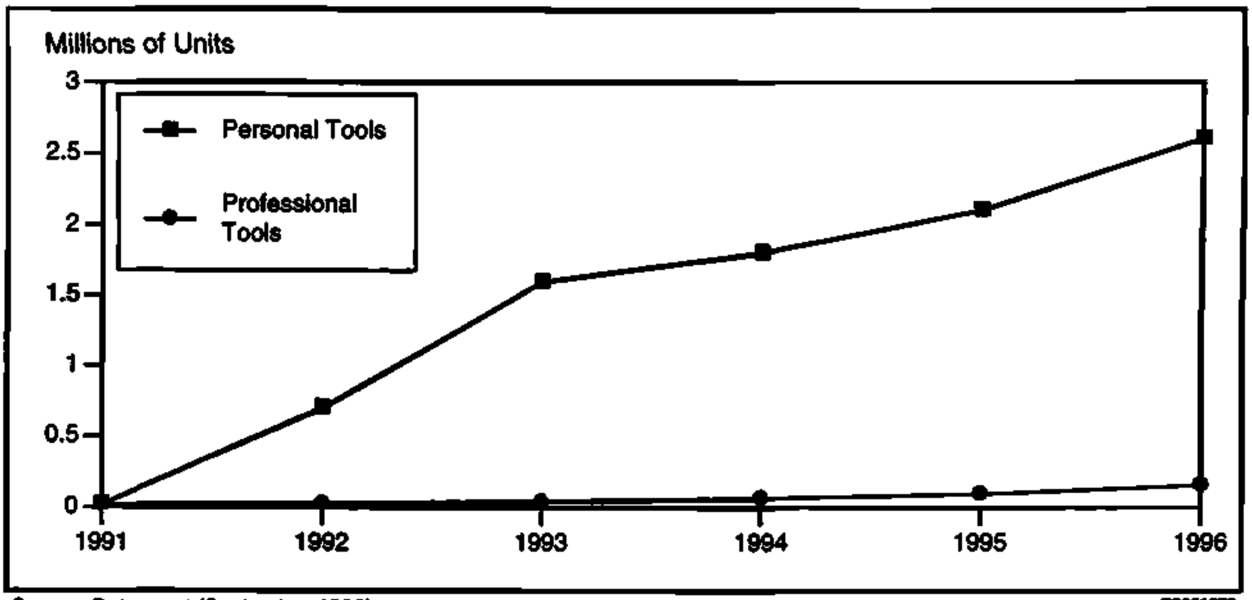
Table 4-4
Multimedia Authoring Software Tools Market Forecasts—Worldwide

	1991	Midyear 1992	1992	1993	1994	1995	1996	1992-96 CAGR (%)
License Shipments								
Personal Authoring Tools	18,480	63,340	703,074	1,687,378	1,771,746	2,126,096	2,551,315	38.0
Professional Authoring Tools	17,920	24,570	25,799	38,698	59,982	95,970	158,351	57.4
Total Authoring Tools	36,400	87,910	728,872	1,726,075	1,831,728	2,222,066	2,709,666	38.9
Average Selling Price ($)								
Personal Authoring Tools	500	150	100	100	90	80	70	-8.5
Professional Authoring Tools	4,330	3,500	3,500	3,500	3,250	3,000	2,750	-5.9
Total Authoring Tools	2,250	1,825	1,800	1,800	1,670	1,540	1,410	-5.9
Factory Revenue ($K)								
Personal Authoring Tools	9,240	9,501	70,307	168,738	159,457	170,088	178,592	26.2
Professional Authoring Tools	77,680	85,995	90,295	135,442	194,940	287,911	435,466	48.2
Total Authoring Tools	86,920	95,496	160,602	304,180	354,397	457,999	614,058	39.8
Unit Installed Base								
Personal Authoring Tools	32,012	95,352	798,426	2,485,804	4,257,550	6,383,646	8,934,961	82.9
Professional Authoring Tools	24,078	48,648	74,447	113,144	173,126	269,096	427,447	54.8
Total Authoring Tools	56,090	144,000	872,873	2,598,948	4,430,676	6,652,742	9,362,408	81.0

Source: Dataquest (September 1992)

Figure 4-5
Multimedia Authoring Tools Shipment Growth Forecasts



Source: Dataquest (September 1992) G2001576

PC upgrade kits bundle components including CD-ROM drives, video and audio cards, microphones, earphone headsets, speakers, and software into a kit that, when installed on a 386-class or above PC, turns it into a multimedia-enabled workstation. Bundling authoring software and a few CD-ROM titles with the upgrade kit is an important addition because it gives the user something right out of the box to *play* on the multimedia machine.

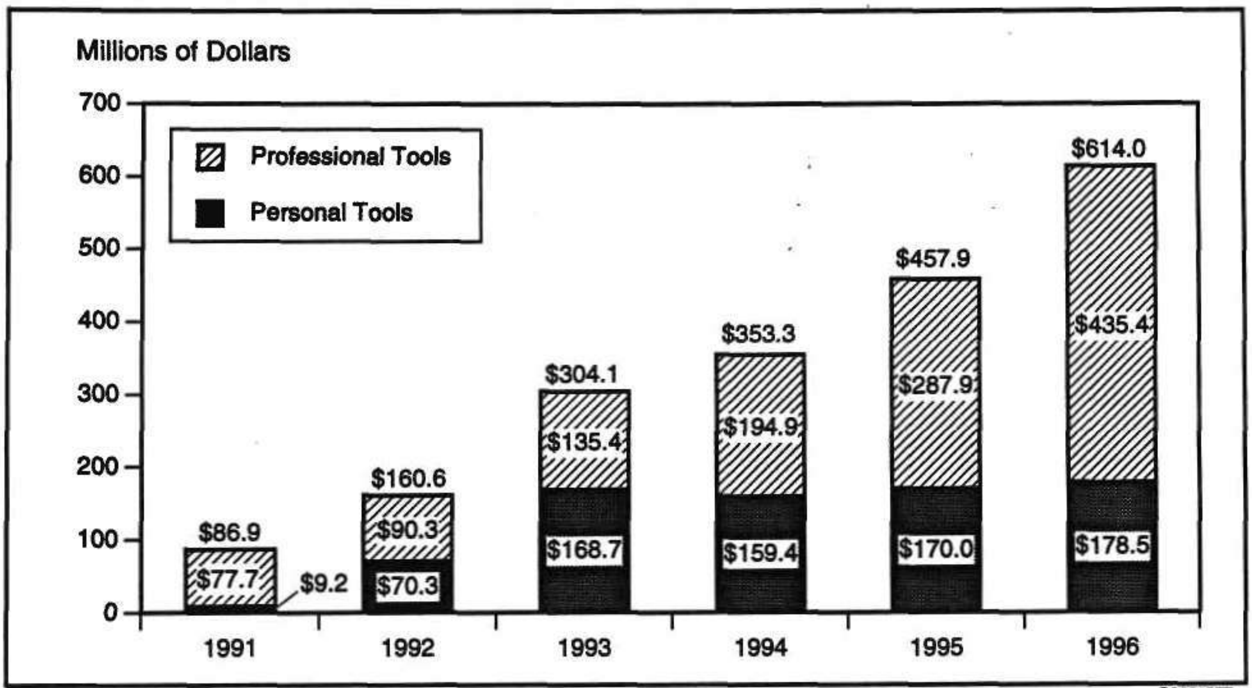
The MPC Marketing Council is forecasting that its member companies will ship between 750,000 and 1 million MPC-compliant upgrade kits in 1992. Creative Labs, one of these members, stated in its August 1992 initial public offering statement that it will ship 300,000 upgrade kits this year. Media Vision, another MPC upgrade kit vendor, forecasts that it will ship between 75,000 and 100,000 kits in 1992. Dataquest's audit of orders for upgrade kit components such as CD-ROM drives that have already been placed by the upgrade kit vendors seem to confirm that these vendors are manufacturing all the necessary components to indeed deliver nearly 1 million units this year.

All of this upgrade kit activity is very significant to Asymetrix and MacroMedia, which have forged alliances with most of the vendors that are shipping upgrade kits into U.S. and international markets. Each sale of an upgrade kit means a sale of their software. It is through this channel, then, that the bulk of authoring software will move during the next few years.

On the professional tools side of the market, we also expect growth to be steady but not nearly as astronomical as on the personal tools side. Here, sales will continue to be primarily to professional end users and developers. We forecast an overall growth rate of 57 percent in this segment, from approximately 26,000 units shipped in 1992 to 158,000 shipped in 1996.

Expected growth in factory revenue for the sale of authoring software is shown in Figure 4-6. We expect that overall revenue will grow by 39 percent between 1992 and 1996, from approximately $160 million to $614 million. The revenue scene will be dominated for the next couple of years by sales of personal authoring tools, as described previously. But due to the higher average selling price of professional over personal tools, as the professional market takes off, its revenue will eclipse that of personal tools. This should occur within the next two years.

Figure 4-6
Multimedia Authoring Tools Revenue Growth Forecasts



Source: Dataquest (September 1992)

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Vendor Profiles

This section provides profiles of major companies involved in multimedia software development. Each profile presents the following information:

- Corporate statistics
- Overview of the company's multimedia focus
- Company financials and market position in the multimedia software market
- An overview of the company's multimedia strategy
- Multimedia product overview
- Dataquest analysis of where the vendor stands in its multimedia software efforts

Apple Computer Inc.

Headquarters Location: Cupertino, California

Chairman, CEO, and Chief Technology Officer: John Sculley

Founded: 1977

Fiscal 1991 Revenue: $6.3 billion

Number of Employees: 14,432 worldwide

Ownership: Public

Overview

Apple probably takes exception to Dataquest's definition of a multimedia-capable PC (besides certain levels of performance, it must have a *CD-ROM* drive) and would argue that the Macintosh—with its inherent audio and graphics capabilities—has been providing multimedia computing mixing sound, graphics, animations, text, and data practically since Day 1.

Definitions aside, no one will argue with the fact that Apple has embraced multimedia as a key corporate imperative. In hardware, its plans encompass not only desktop multimedia on the increasingly powerful Macintosh and other emerging desktop platforms, but also consumer multimedia through personal digital assistants (PDAs) that are being jointly developed and produced with Japanese partners. In software, the QuickTime extensions to the System 7 operating system enable users to integrate digital video with all of the other data types supported by the Macintosh to run full multimedia productions. Apple's investment of money and resources in Kaleida aims at developing the next-generation operating environment for multimedia computing, one that will power PCs and PDAs alike.

Financials and Market Position

Apple reported net sales totaling $6.3 billion dollars in 1991. Determining the multimedia portion of this revenue is tricky because until the September 1992 release of new Macintosh platforms featuring built-in CD-ROM drives, Apple was not shipping multimedia-ready PCs, by Dataquest's definition. But this is academic to the purposes of this chapter, which looks at software rather than hardware. We focus on Apple's QuickTime revenue.

When Apple introduced QuickTime in January 1992, it was made available to any interested party for only the cost of shipping, and it was also available through public computer bulletin boards. The QuickTime Starter Kit, introduced in May 1992, is being sold to end users for a retail price of $169. Apple claims that QuickTime's installed base is around 2 million copies. Given the number of developers using it (around 1,000) and the number of available QuickTime applications and titles (approximately 150, with 150 more under development), we estimate that the actual base of real QuickTime users is more like 100,000. We estimate that Apple's revenue to date for sales of this software module are around $2 million.

Strategy

Apple's multimedia strategy is frequently articulated by John Sculley, Apple's CEO and Chief Technology Officer. He believes that computing is on the brink of a digital revolution and that by the end of the 20th century, 98 percent of all information content will be available in digital format. Combined with this are steady advances in miniaturization that continue to produce ever smaller and yet more powerful computing devices. The next revolution in computing will combine digital information with miniature devices, and give rise to new classes of portable computing devices for work, communication, and play. Digital information resources will encompass entertainment, publishing, computing, consumer electronics, and telecommunications—the convergence of which, Sculley believes, represents more than a trillion dollar opportunity.

Apple is therefore a company in transition from being a single-product PC manufacturer to a multibusiness company. Its long-term strategy for playing in the new digital world order is three-pronged:

- Build ever more powerful multimedia computing platforms—This includes continually upgrading the Macintosh computer family as well as investing in next-generation products (such as Taligent's PowerPC platforms) built from the ground up (Mr. Sculley has stated that he expects Apple's Macintosh core business to still be Apple's single largest revenue and profit business by the year 2000).
- Enter the consumer electronics arena—Design and build miniaturized devices that combine capabilities found on separate machines today (for example, combining the capabilities of a cellular telephone, modem, computer, and fax machine) and leverage on one of Apple's greatest skills—the ability to make computers easy to use—so that the devices appeal to the mass market; team with Japanese manufacturers to be able to offer these devices at a popular price point

- Participate in creating an open digital operating environment—Promote and work toward the development of a common operating system to power all digital devices—from PCs to hand-held personal digital assistants; Apple's involvement with Kaleida, as well as its efforts to gain acceptance for QuickTime file formats, are examples of the company's efforts in this arena.

Products

Though Apple is primarily a hardware manufacturer, its System 7 operating system software with QuickTime plays a crucial role in the development of multimedia applications for Macintosh.

QuickTime is simultaneously an architecture, multimedia extensions to System 7, and a set of tools for incorporating digital video into Macintosh applications. It is designed to provide essential multimedia services so that developers are freed to write applications using it and do not have to concern themselves about also building peripheral drivers and compression/decompression schemes. QuickTime's multimedia extensions include the following services:

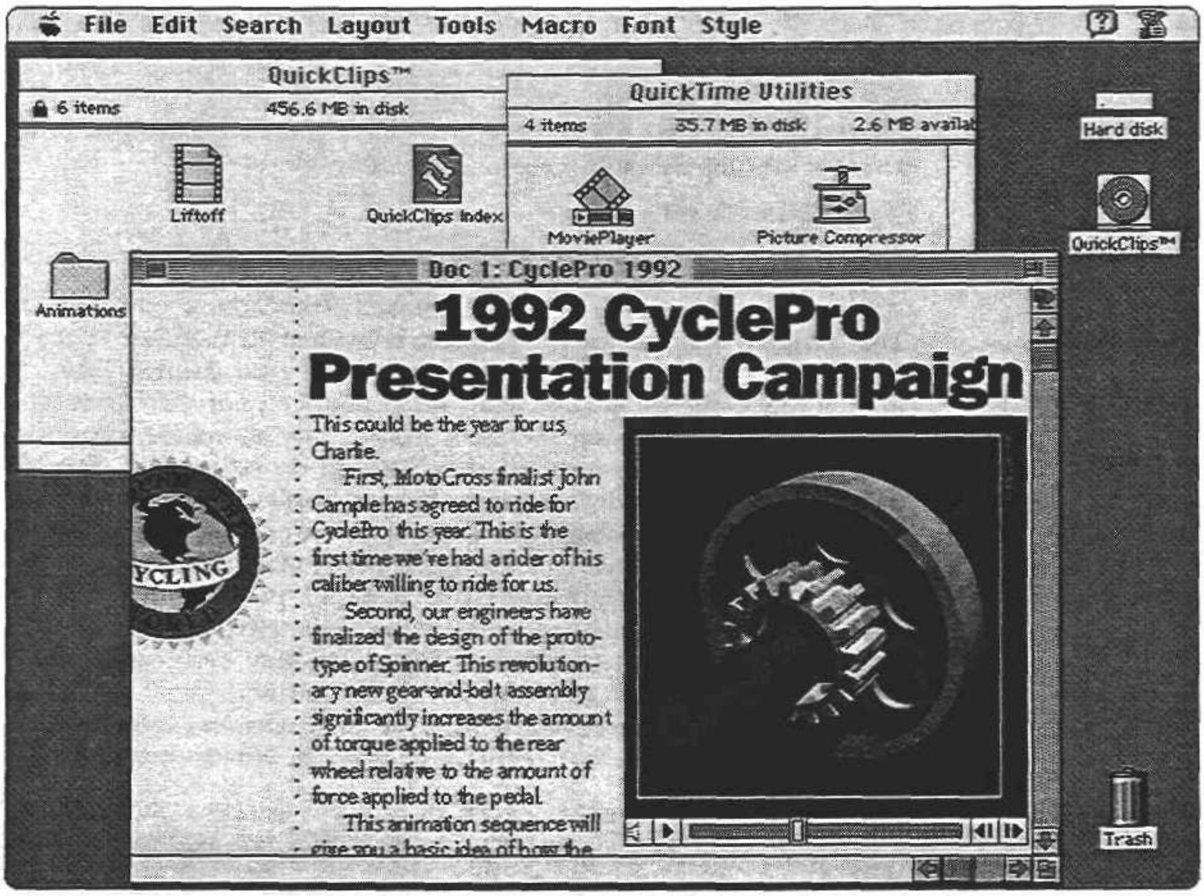
- Component Manager—An interface between the operating system and the physical hardware (Macintosh and peripherals) that supplies drivers for a wide variety of peripherals and thereby provides device independence for QuickTime applications
- Image Compression Manager—Operating system-level services that manage the essentials of image compression so that QuickTime applications do not have to provide these features; includes a photo compressor, an animation compressor, a video compressor, and a graphics compressor
- Movie Toolbox—A set of developer APIs for incorporating digital video into applications

The QuickTime Starter Kit is a simple toolkit that enables end users to play video clips within applications (see Figure 4-7). It includes a set of multimedia data management utilities called MoviePlayer, Movie Converter, Movie Recorder, and Picture Compressor, documentation and online help, and a collection of QuickClips movie clipart provided on CD-ROM.

QuickTime supports its own file format for multimedia data types called the Movie Format. This stores audio, freeze-frame video, full-motion video and preview clips as separate time-based "tracks" for ease of access and use. It is expected that Apple will add MIDI, close-captioned text, and interactive controls to the list of supported tracks in the next release of QuickTime. Apple has proposed that the Movie Format be adopted as the IMA's cross-platform file format.

Apple believes that cross-platform compatibility for QuickTime is essential. It has developed the QuickTime Movie Exchange Toolkit to enable developers to incorporate QuickTime Movie Format files into non-Macintosh applications for MS-DOS machines, as well as

Figure 4-7
Apple's QuickTime Playing a Video Sequence Within a Document



Source: Apple Computer Inc.

workstation and mainframe applications for Cray, Digital, IBM, Silicon Graphics, and Sun platforms. Apple is also working on the QuickTime Player, which would enable QuickTime applications to be played on DOS/Windows PCs, among other platforms.

Dataquest Perspective

Apple is destined to be a prime mover in the multimedia market and will expand its territory far beyond the PC market. Mr. Sculley may be optimistic about the pervasiveness of digital media by 2000, but we agree that digital will replace analog during the decade, and that miniaturized, interactive devices will be found everywhere from shopping carts to executive's briefcases. A cross-platform operating environment is key to the success of this revolution, and Apple is positioned to help make that happen.

Asymetrix Corporation

Corporate Statistics

Headquarters Location: Bellevue, Washington

Chairman and CEO: Paul Allen

Founded: 1985

Fiscal 1991 Revenue: $15 million

Number of Employees: Approximately 160

Ownership: Private

Overview

Asymetrix was started in 1985 by Microsoft cofounder Paul Allen. The company's allegiance to Microsoft is evident to this day in the fact that it focuses its development efforts solely on creating tools for the MS Windows environment. Allen had a vision that what is missing from the software market is easy-to-use, affordable software that lets people "focus on what they want to do rather than how they do it." Allen brought together a team of developers charged with exploring new technologies such as object-oriented programming, graphical user interface design, hypertext, artificial intelligence, and multimedia, to help create intuitive, productivity-enhancing software tools and applications. Asymetrix shipped its first software product, Asymetrix ToolBook, in May 1990 concurrent with the release of MS Windows 3.0. In the ensuing years, several more complementary software tools have been released, including a multimedia version of ToolBook that shipped in November 1991.

Financials and Market Position

Asymetrix has been one of the more successful developers of multimedia software tools. Approximately 90,000 copies of ToolBook have been shipped, and the installed base of Multimedia ToolBook numbers approximately 10,000 copies. Dataquest estimates that Asymetrix's 1991 revenue totaled approximately $15 million. Asymetrix forecasts that revenue will double in 1992. In 1991, Multimedia ToolBook accounted for 5 percent of Asymetrix's total revenue, while in 1992 it currently accounts for 50 percent of overall revenue. The MPC Marketing Council estimates that ToolBook was used to develop more than 25 percent of all announced or shipping MPC-compliant titles in its software catalog. Asymetrix is growing fast, currently employing more than 160 people—a number that has doubled in the past 12 months.

Strategy

Asymetrix targets its products at no specific niche market, but instead intends to reach a mass audience ranging from technical to nontechnical PC users. The company relies heavily on partnering to penetrate the PC software market. One successful move was to bundle its DayBook software with MS Windows 3.0, thereby bringing this set of personal organizer tools to the desks of millions of users. Asymetrix ToolBook is also bundled with MPC upgrade kits distributed by NEC. Other strategic alliance partners include IBM, Intel, and Turtle Beach Software. In addition to software bundling, Asymetrix products are sold internationally through 25 distributors including Egghead Software, Ingram Micro D, Merisel, and Tiger Software. Intending to be an international company, Asymetrix provides English, French, German, and Italian versions of ToolBook.

Asymetrix reports that users of ToolBook include large corporations such as ARCO, Chevron, Compaq, IBM, NEC, and Tandy; government agencies including the United States Department of Defense; nonprofit organizations such as the Monterey Bay Aquarium; and dozens of universities, independent software developers, and small to midsize companies. ToolBook users span the gamut from professional C programmers and developers to university professors, students, and corporate training personnel.

Products

Asymetrix personal productivity tools run only in MS-DOS/Windows environments. They are listed and briefly described below:

- ToolBook—A software toolkit for building custom Windows applications; provides a graphical user interface, Asymetrix OpenScript object-oriented programming language, and hypernavigation among various data types (does not support video)
- Multimedia ToolBook—Comprises ToolBook plus extensions for integrating and hyperlinking video, sound, animation, images, and text files within a ToolBook application
- DayBook+—Personal calendar and time organizer software
- Instant Database—A low-end database intended for use by small businesses and home users for assembling and maintaining mailing lists, custom forms and reports, and customer lists
- Multimedia Make Your Point—Software for creating and delivering graphical presentations that integrate and hyperlink text with video, sound, animation, and images
- Media*Blitz!*—Multimedia utility for editing and arranging audio, animation, pictures, and text into a self-running multimedia show

Dataquest Perspective

Through developing relationships with industry heavyweights and bundling its software in multimedia PC upgrade kits offered by a number of partners, Asymetrix is assaulting the PC Windows development market. Its international strategy is clear. The availability of foreign-language versions of its product, as well as its established relationships with marketing partners in Europe, should further ToolBook's spread into the very young international multimedia market. We question the long-term wisdom of focusing solely on DOS/Windows multimedia but assume that Asymetrix's close working relationship with IBM gives it visibility into the work on multimedia PCs and operating environments going on at Taligent and Kaleida.

IBM Corporation

Corporate Statistics

Headquarters Location: Armonk, New York

Chief Executive Officer: John Akers

Vice President and General Manager Multimedia Division: Lucie Fjeldstad

Company Founded: 1911

Multimedia Division Founded: Summer 1990

Fiscal 1991 Revenue: $64.8 billion

Number of Employees: Approximately 330,000 worldwide

Ownership: Public

Overview

IBM's multimedia vision is "to personalize the information revolution." This means providing hardware and software products and solutions that help all levels of users—from the technically unsophisticated to the highly technical— quickly, easily, and affordably get at the information they need. IBM believes that multimedia's blending of text, sound, motion video, photographs, graphics, and touch represents the "ultimate in media," which gives rise to its multimedia product trademark—Ultimedia. IBM Ultimedia products will embody three key elements: natural user interfaces; the combining of all hardware and software elements into a cohesive, integrated whole; and highest possible product quality.

IBM's multimedia marketing and development activities occur in several locations worldwide: marketing is based in Atlanta, Georgia; and development goes on in labs in Boca Raton, Florida; Mountain View, California; Austin, Texas; Raleigh, North Carolina; and Hursley, England. There are 10 IBM Area Multimedia Centers located in cities around the United States. Multimedia sales are supported by more than 300 IBM Ultimedia sales representatives and 300 dedicated IBM multimedia dealers.

Financials and Market Position

IBM's most successful multimedia authoring software offering has been Storyboard Live!, which has an estimated installed base of 10,000 copies. Audio Visual Connection, a high-end authoring tool, has sold about 1,500 copies. We estimate that IBM's total revenue for sales of authoring software in 1991 was around $3 million.

Strategy

IBM's penetration of the Multimedia market has largely been on PC platforms and is focused on the following areas: education and training (both classroom instruction and corporate training); desktop networking for desktop video conferencing; and merchandising (information kiosks and point-of-sale kiosks in stores). Its focus has been to help users optimize information impact in learning environments where multisensory appeal holds great promise to educate, and in consumer environments where it helps sell products. The Ultimedia PC platform has been criticized for being too expensive for its target markets (especially public education) and just another case of IBM saying "if IBM didn't build it, it's no good."

After getting its feet wet delivering initial multimedia applications, IBM is poised to move. During the latter half of 1992, IBM will turn up the heat by offering a full-featured suite of multimedia development tools (see "Products" below). IBM will be joined by more than a dozen third-party software developers who will offer software conforming to Ultimedia specifications.

As a computer systems company, IBM's long-term strategy for Ultimedia goes far beyond what is envisioned by the PC hardware and software players in this market. IBM's goal is to provide multimedia computing on systems ranging from desktop to mainframe. The ultimate vision is enterprisewide multimedia computing.

Products

Not surprisingly, IBM's hardware products for multimedia are largely of its own design and manufacturing. The PS/2 Ultimedia Model M57 SLC forms the basis of the system. This is configured to conform to IBM's Ultimedia specifications, which dictate a minimum 386 SLC 20-MHz processor, 4MB of memory, a CD-ROM XA drive, a 160MB SCSI rigid disk, a 2.88 MB/3.5-inch flexible drive, XGA graphics, a CD-quality audio subsystem, and microphone. The required operating systems is OS/2 version 2.0 with Presentation Manager/2, which supports both MS-DOS and Windows applications.

On the software side, IBM has offered two internally developed software tools for creating multimedia applications:

- Audio Visual Connection—A high-end multimedia authoring language to combine and edit sounds, pictures, and text into stories and presentations
- Storyboard Live!—A multimedia authoring tool for creating on-screen presentations incorporating text, images, video, animations, sound, digitized still photographs, drawings, and paintings

This picture will change dramatically at COMDEX/Fall in November 1992 when IBM will formally announce the first 16 members its Ultimedia Tools Series partner program. Ultimedia Tools Series members are independent software vendors (ISVs) that initially will provide a total of 37 software tools for the Ultimedia platform, with more to come as more ISVs sign up for the program. The initial Tools Series software products will fall into these categories:

- Authoring tools—17 products will be announced
- Animation tools—4 products will be announced

- Audio tools—3 products will be announced
- Graphics tools—10 products will be announced
- Video tools—1 product will be announced
- Multimedia utilities—2 products will be announced

The Ultimedia Tools Series program will provide an interoperability specification for data interchange against which all products will be measured before being authorized by the program. The goal is to create applications that are cross-compatible and can freely exchange information. This means that an application or file created in one Tools Series application will be able to run within other Tools Series programs.

IBM will provide a number of benefits to its Tools Series members. The main benefit will be an IBM telemarketing channel through an IBM affiliate called Media Sorcery. Media Sorcery will provide the following services: manage the catalog of Tool Series products; provide knowledgeable telephone support for helping prospective customers to determine which products best suit their needs; manage telephone ordering services; and distribute the products by mail.

Dataquest Perspective

The division of IBM corporation earlier this year into separate business units responsible for their own destinies was advantageous for the multimedia division. Rather than forcing the group to conform to monolithic corporate standards for how to conduct business, it gave the group creative freedom to go after business opportunities in ways that make sense for multimedia computing. IBM's aggressive Tools Series program is an example of this. We expect that this approach will simplify the purchasing Ultimedia software and spur software sales.

IBM's commitment solely to OS/2 and its own computing platforms may prove a stumbling block in the multimedia area, however. Competition is tough in this young market already divided into warring camps (MPC versus Apple versus IBM). The MPC platform is by all counts winning the initial skirmishes in terms of number of placements. MPC may not be as powerful as IBM's Ultimedia PC, but it is a lot cheaper and has a consortium of vendors behind it. Acceptance of OS/2 is growing since the release of 2.0, but we don't expect it to be a long-term winner once Windows NT from Microsoft and PowerOpen systems from Taligent/Kaleida arrive on the scene. In fact, Ultimedia's relationship to the joint Apple-IBM ventures also remains obscure.

Kaleida Labs Inc.

Corporate Statistics

Headquarters Location: Mt. View, CA

Chief Executive Officer: Nat Goldhaber

Founded: 1991

Fiscal 1991 Revenue: NA

Number of Employees: 40

Ownership: Private

Overview

Kaleida is usually described as the Apple-IBM "multimedia joint venture." In the summer of 1991, the two companies announced that they would work together to develop a next-generation multimedia computing environment. Since then, they have hammered out an agreement to focus funds and resources on developing multimedia software tools and runtime modules for industry-wide licensing.

Financials and Market Position

Kaleida is currently in the start-up phase. Its impact on the market so far has mainly been to keep developers and industry pundits alike guessing at what the outcome of its development efforts will be.

Strategy and Products

Specifically, Kaleida's mission is to develop a common multimedia operating environment for both computer and consumer electronics products. In the computer area, Kaleida's operating system will first support Apple and IBM platforms. Over time, it will support any operating environment (UNIX, DOS, OS/2, Macintosh, and Taligent). This would attract third-party developers because it guarantees that software developed under Kaleida specifications would run on a wide range of computer systems with cross-platform compatibility. An interactive media scripting language called Kaleida Script is currently under development and will form the core of Kaleida's technology.

Kaleida has also targeted the consumer products arena. Kaleida Script is designed to be an open operating system to power products such as the Newton personal digital assistant demonstrated recently by Apple. Newton is the result of joint product development between Apple and Sharp Electronics of Japan. Apple also recently announced a deal with Toshiba to develop a hand-held device that will play multimedia education, entertainment, and business software. Code-named "Sweet Pea," this device will support compact discs containing video, audio, graphics, and text. The Kaleida Script operating system will undoubtedly drive this device also.

Kaleida's operating system is also expected to power the next-generation multimedia PCs being developed at Taligent. Taligent's

PCs are expected to ship in late 1993. Apple is also evaluating bringing its voice recognition technology (code-named "Casper") over to Kaleida.

Dataquest Perspective

Conceptually, Kaleida is a great idea. Two arch-rivals in PC computing working together to pool resources, funds, and talent to create an operating environment common to all is a lofty and noble purpose. After a slow start, the company is finally moving forward. Kaleida named Nat Goldhaber as CEO in June 1992, and filled in most of its corporate officer slots in July. The company says that it plans to double its staff in the next 12 months and will become proactive about getting its message to the marketplace. Of course, it remains to be seen how effective Kaleida's development efforts will be. But if successful, the Kaleida OS could solve the interoperability problem that has plagued computing since the first system drew its proprietary breath.

Lotus Development Corporation

Corporate Statistics

Headquarters Location: Cambridge, Massachusetts

Chairman and Chief Executive Officer: Jim Manzi

Founded: 1982

Fiscal 1991 Revenue: $829 million

Number of Employees: 4,200 (3,100 in the United States and 1,000 in international locations)

Ownership: Public

Overview

Lotus is one of the world's leading application software development companies. Its name is synonymous with its first product, the Lotus 1-2-3 spreadsheet program, which was released in 1983. Throughout the years, Lotus has increased its product portfolio by adding software applications and services such as the Symphony integrated software application, Ami Pro word processor, and Freelance graphics software—all geared at enhancing the productivity of professional users. Lotus believes that networking and organizational computing are strategic computing imperatives for the 1990s. As a result, the company's software development focus today is centered largely on delivering groupware applications. The Lotus Notes program is its vehicle for addressing the groupware market.

Financials and Market Position

Lotus total revenue in 1991 was $829 million. Its multimedia-enabled products have been shipping for less that six months, so the multimedia component of its 1992 revenue are expected to be very small.

Strategy

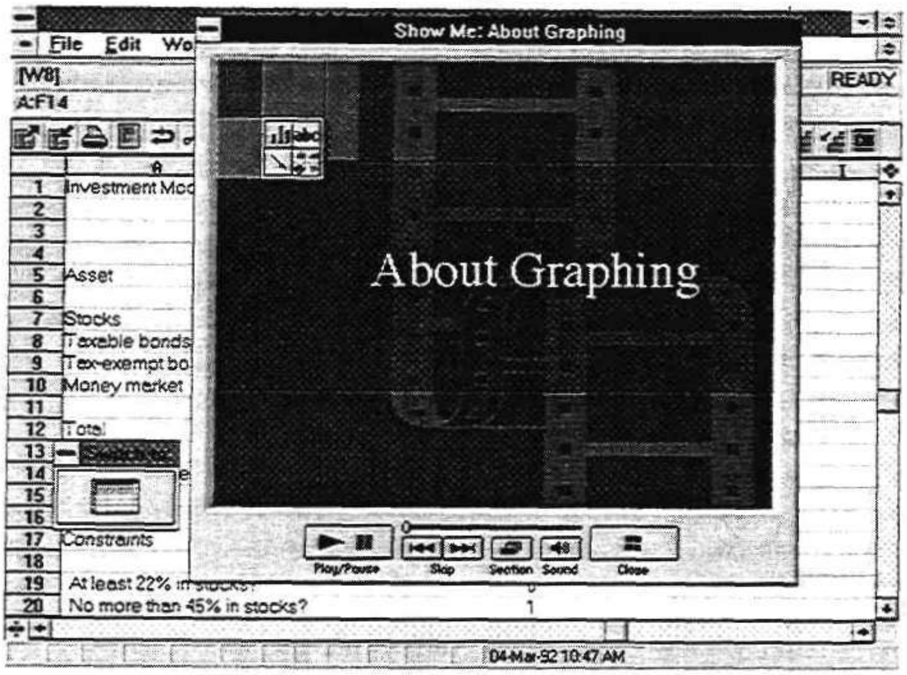
Lotus defines multimedia quite simply as "a set of capabilities that includes some mixture of digital standard computer text, sound, pictures, and movies. Multimedia applications capture, edit, transmit, and play back each of these data types."

Lotus' multimedia strategy is to integrate multimedia capabilities into its core MS Windows software applications. Each product will be enhanced to suit its individual capabilities. Initially, multimedia elements will be added to Lotus applications as "annotations." This will function like an electronic yellow sticky note that will let users attach multimedia files (for example, audio, video, animations) to a Lotus application file. Lotus Notes: Document Imaging is an example of this concept. This add-on module to Lotus Notes enables users to attach scanned images to Lotus Notes files. Lotus also plans to add multimedia elements such as animation, sound, and video to Freelance's SmartMaster presentation templates. This will enable users to build business presentations that integrate preconfigured multimedia elements.

Lotus is also involved in networked multimedia through its CD/Networker network server software that enables the network delivery of CD-ROM-based multimedia applications through daisy-chained CD-ROM drives. Through this capability, the network users have access to '"jukeboxes full" of CD-ROM titles on the network rather than relying on a standalone CD-ROM drive.

Finally, it should be noted that Lotus has delivered one of the first business productivity applications on CD-ROM with Multimedia SmartHelp for 1-2-3, announced in March 1992 (see Figure 4-8).

Figure 4-8
Lotus 1-2-3 and Multimedia SmartHelp



Source: Lotus Development Corporation

Products

Lotus' multimedia software offerings include the following:

- Multimedia SmartHelp for 1-2-3 for Windows—A CD-ROM-based, interactive help and tutorial for using Lotus 1-2-3 featuring the following: a "guided tour"; "show me" movies that demonstrate how to use the product; and "online books" complete product documentation
- CD Network Server—Software that enables network users to tie into CD-ROM databases stored on network servers
- Lotus Sound—Sound annotation software that enables users to link or embed audio messages or music in any Windows OLE (object linking and embedding)-enhanced application, including Ami Pro and Lotus Notes documents

Dataquest Perspective

As an application software solutions provider, Lotus' primary interest in multimedia is to enable its own product suite with multimedia capabilities. In addition, Lotus views CD-ROM publishing as a critically important way to get software and information out to users. As a result, its focus on building CD-ROM titles and server applications is also strong.

We believe that Lotus has a jump on the market with its CD Network server concept and software. Lotus believes that like other peripherals such as scanners, printers, and FAX machines, it should not be necessary for every user on the network to have a CD-ROM drive to play multimedia applications. Lotus' view differs from that of the MPC Marketing Council (comprised of a number of CD-ROM drive manufacturers) which believes that standalone drives are necessary. We think that Lotus' approach makes sense. It will save money, make a wider selection of titles available to everyone, and distribute multimedia much more widely within organizations than standalone drives ever will.

MacroMedia Inc.

Corporate Statistics

Headquarters Location: San Francisco, California

Chairman and CEO: Jim Mott

President and CEO: John C. (Bud) Colligan

Founded: 1984 (MacroMind)/1987 (AuthorWare)

Fiscal 1991 Revenue: $25 million (combined revenue)

Number of Employees: 150

Ownership: Private

Overview

MacroMedia was formed in April 1992 when two leading developers of multimedia software tools—Authorware Inc. and Macro-MindoParacomp Inc.—merged resources, products, and personnel.

The mix of products from each company is very complimentary, as shown in Figure 4-9. Authorware's products are authoring tools focused largely toward training and professional users. Macro-MindoParacomp focuses on providing desktop animation, video, and presentation tools for creative users in advertising and design professions. Both companies offer products for PC and Macintosh environments.

Financials and Market Position

Besides having a synergistic product mix, both companies are equally balanced on the revenue side. Authorware's sales have doubled every year since it began shipping product in 1989. We estimate that its revenue was $12 million in 1991. Macro-MindoParacomp's revenue was approximately $13 million in 1991. Combined revenue for the merged company was an estimated $25 million in 1991. The company predicts that this will grow by 80 percent in 1992.

Strategy

MacroMedia's vision is that interactive multimedia tools will be an instrumental force to improve the way that people communicate and learn. Its initial thrust was to sell its products into learning (Authorware) and creative (MacroMindoParacomp) environments, placing authoring tools directly in the hands of the end users who

Figure 4-9
MacroMedia Overview

	Authorware	MacroMind • Paracomp
Primary Customers	Learning Professional	Creative Professional
Core Technologies	Visual Programming Multiplatform Architecture	Animation 3-D Scripting
Products	Authoring Learning Management Media Management	Authoring Graphics Presentations
Primary Channels	Corporate Sales	Retail
Systems and OEM Partners	IBM, ACER, Toshiba, NEC ICL, Samsung, ASCII	Microsoft, Canon, Sony, Apple, IBM, Fujitsu

Source: MacroMedia Inc. G2001578

are responsible for creating courseware and presentations. An important part of this strategy was to make tools available on both Macintosh and IBM PC/compatible platforms in order to reach the widest possible audience. The company believes that its products are distinguished from those of its competitors by the following factors: interactivity, compatibility, platform independence, ease of use, and media integration.

As familiarity with multimedia has grown, MacroMedia has broadened its sales strategy and product mix to reach a broader corporate audience. MacroMedia distributes its products by bundling them with multimedia PC upgrade kits from 17 OEM partners (OEM partners include: Aztech Systems, Creative Labs, MediaSonic, and Media Vision, in the United States; ASCII and NEC in Japan; Olivetti in Italy; ICL in the United Kingdom; Toshiba in Europe; and Acer and Samsung worldwide); through a Creative Partners Program that provides special services, pricing, and marketing opportunities to creative professionals who wish to build applications using MacroMedia tools; through retail dealers and distributors; and through direct sales.

Products

MacroMedia offers more than 20 different software products to suit a wide range of personal and professional multimedia creation uses. Its products are listed below by name, product category, and the computer platform on which they run.

- Multimedia authoring software
  - Authorware Star for Windows—Personal authoring software for MS-DOS/Windows environments
  - Authorware Professional for Windows—Professional authoring software for MS-DOS/Windows environments
  - Authorware Professional for Macintosh—Professional authoring software for the Macintosh
  - Director—Professional authoring tool for creating distributed interactive applications, multimedia presentations, and animations in Macintosh environments
  - Windows Player—Converts Macintosh applications created using Director to run on MS Windows PCs
- Animation
  - FilmMaker—High-end animation software for use in the Macintosh environment
- Presentations
  - Action!—Presentation creation software for combining a variety of multimedia data types in MS-DOS/Windows environments
  - Magic—Software for developing interactive kiosk, storyboards, and training materials in Macintosh environments

- Modeling, rendering, and drawing
  - Three-D—Professional 3-D animation software for the Macintosh
  - Swivel 3-D—3-D modeling, rendering, and animation software for the Macintosh
  - ModelShop II—Professional software for modeling and presenting spatial concepts in 3-D on the Macintosh
- Sound and Video
  - MediaMaker—Desktop video publishing software for the Macintosh
  - TitleMaker—Animated title- and credit-production software for the Macintosh
  - MacRecorder Sound System—Sound digitizing and sound editing software for the Macintosh
- Clipart
  - ClipMedia—Royalty-free, video multimedia clipart library
  - SwivelArt—3-D clipart collection

In addition, the company also provides several utility and accessory programs for enhancing multimedia development work.

Dataquest Perspective

The merger of AuthorWare and MacroMindoParacomp was an ideal marriage. By bringing together Authorware's visual authoring tools for learning and business professionals and MacroMindoParacomp's graphics, animation, and presentation tools for creative professionals, the merged company now provides "one-stop shopping" for multimedia development software that addresses a wide spectrum of users and uses. In addition, each company can leverage the other's development expertise, sales and distribution channels, management experience, and profitable financial position. This merger has created a potentially formidable competitor in the multimedia tools business.

Microsoft Corporation

Corporate Statistics

Headquarters Location: Redmond, Washington

Chairman and CEO: Bill Gates

Founded: 1975 as partnership; incorporated 1981

Fiscal 1991 Revenue: $1.8 billion

Number of Employees: More than 8,200 worldwide

Ownership: Public

Overview

Microsoft trademarked the phrase "multimedia at your fingertips." To Microsoft, these four words embody technology at its best—a vehicle that helps people to work, learn, and think in the most intuitive, productive ways possible. Unfortunately, most of today's software applications are far away from fulfilling this promise. Multimedia computing represents an essential element in making this vision come to life, and Microsoft intends to be at the center of making it happen.

Microsoft's multimedia focus extends to several areas:

- CD-ROM publishing—Through its Multimedia Publishing Group, Microsoft was one of the first vendors to bring a CD-ROM title to market. Microsoft Bookshelf is a collection of reference works including an encyclopedia, dictionary, thesaurus, and *Bartlett's Familiar Quotations*, among others. A subsequent title was Multimedia Beethoven: The Ninth Symphony. Both titles, which use sound and animation to bring the titles to life, are widely distributed in multimedia upgrade kits for PCs. Microsoft's continued investments in multimedia publishing were apparent in its 1991 agreement with London-based publisher Dorling Kindersley Ltd. to license content for future multimedia titles.
- Multimedia tools—Microsoft intends to be the premier provider of tools for adding multimedia elements to computer applications and for creating CD-ROM titles through Windows 3.1 and the Multimedia Development Kit.
- Industry influence—As a founding member of the Multimedia PC Marketing Council, Microsoft plans to set the course and direction of both multimedia compatible PC and software standards. This strategy has worked as the MPC specification currently dictates that MPC system software shall conform to the APIs, function, and performance described in the MS Windows Software Development Kit Programmer's Reference (Volumes I and II) and the Microsoft Multimedia Development Kit Programmer's Reference.

Long-term, Microsoft believes that multimedia will be the single-most important component of all future information delivery systems. By the year 2000, talking about multimedia will be academic. It will be an integral components of all business and personal communication, information, and entertainment systems. Microsoft's long-term focus embraces computers and even extends to creating a Windows-like operating environment for home appliances, games, and TVs.

Financials and Market Position

Microsoft is a major force in the software industry with annual revenue in 1991 of $1.8 billion. This revenue is derived largely from sales of its MS-DOS operating system and MS Windows graphical user environment. The multimedia component of the company's overall revenue is tricky to calculate because it theoretically includes a proportion of Windows shipments to multimedia developers, as well as runtime versions of Windows and Viewer for playing multimedia applications that run under Windows. Since this report section focuses on authoring tools, Dataquest calculates Microsoft's multimedia revenue based on shipments of its Multimedia Development Kit for Windows, a set of APIs for adding multimedia to Windows applications. We estimate that there are approximately 1,000 developers using the Development Kit to develop Windows-based multimedia applications. This represents approximately half a million dollars in revenue for this product.

Strategy

Though it is a software company, Microsoft is not currently in the business of building end-user multimedia applications (though this may change over time through work that goes on in Microsoft's Entry Business Unit, a group chartered to create easy-to-use applications for first-time computer users). Microsoft's current multimedia focus is to provide tools to enable its developer partners to create end-user applications that integrate the graphs, video, and audio elements necessary for multimedia computing.

Microsoft believes that multimedia is neither an industry nor a market. Instead, the company sees multimedia as a set of capabilities such as digital sound, animation, full-motion video, and photographs that can be integrated with text and graphics to enrich computer applications and create a more sense-involving experience when working with a computer. Multimedia is not futuristic. The building blocks are here and only need to be assembled.

Microsoft defines these building blocks as follows:

- PC hardware—Personal computers conforming to the MPC Marketing Council's multimedia PC specification
- System software—Microsoft Windows 3.1 with multimedia extensions
- Standards—Microsoft has been actively involved in defining standards for multimedia software development and has integrated both its own and outside standards into its multimedia development tools. The company an Interactive Media Association sponsor corporation and works with this organization to define common data interchange standards for software applications
- Developer tools—The Multimedia Development Kit and high-level authoring tools from Microsoft developers for authoring software applications
- Developer support programs—Conferences and seminars to encourage developers to adopt Microsoft tools and provide training and support for those that do

Products

Microsoft's tools for creating multimedia applications are as follows:

- Windows 3.1—Provides a graphical windowing environment consisting of title bars, pull down menus, pop-up windows, and desktop icons that enable users to interact with a personal computer in an intuitive and easy way—Windows boasts more than 14 million users worldwide and is the most widely implemented desktop environment on the market

- Multimedia Development Kit—Provides a set of APIs that C programmers can use to add multimedia elements including sound, animation, video, and photo images to Windows applications
  - Microsoft Viewer Author Toolkit—Included in the Multimedia Developers Kit, the Viewer toolkit lets developers create multimedia titles by enhancing traditional text-based titles with hypertext, full-text search, and multimedia elements; the Viewer runtime module for playing back titles is also included

Dataquest Perspective

With the momentum of Windows development underway, Microsoft has become an unstoppable force in PC-based multimedia computing. Time will tell how well it will transition its multimedia development machine to Windows NT, but—make no mistake about it—this company is steering its future toward the multimedia star.

Dataquest Analysis

The core of multimedia computing is *software*. When all of the hardware, telecommunications, and standards battles are won, the differentiating factor will be the multimedia machine's ability to deliver useful, engaging, and empowering software.

We believe that multimedia computing represents a huge opportunity for system software vendors, tools providers, and software developers alike. The following are some of the general trends that we expect to drive the growth of the multimedia software market.

- From a standards point of view, multimedia software developers are in a much better position than the software community has been in the past. Though most members of multimedia industry organizations and standards committees bring vested interests to the table with them, at least member companies are talking to each other and sharing ideas for bridging the many diverse technologies that comprise multimedia. It appears that the IMA's Compatibility Project will be a driving force in defining cross-platform standards for hardware and software compatibility and interchange.
- The mass multimedia software market will be driven by solutions. The average corporate buyer will not be compelled to invest in this technology until he can see demonstrable solutions.
- In the meantime, building custom applications for more forward-thinking end users represents a lucrative market for developers.
- Some in-house solutions will have such universal applicability that we expect to see some companies or business units spun off to sell these products commercially.

- Desktop PC applications such as word processors, spreadsheets, presentation graphics programs, and desktop publishers will integrate multimedia on two fronts: like SmartHelp for Lotus 1-2-3, multimedia will enliven help and tutorial programs; and through the ability to import and embed multimedia elements into application files and documents, users will be able to create true compound documents. Help applications will emerge first and multimedia-enabling will be introduced during the next 18 months.
- We expect to see low-end authoring capabilities eventually merged into productivity applications—much as better word processors now contain enough desktop publishing capabilities (multiple columns, type fonts, graphic and image import, banners, and so on) to suit the casual user.
- To appeal to the mass market, multimedia software tools must become easier to use and more intuitive. We expect that a new breed of user interface integrating video, animation, and voice will assist in making the products friendlier and easier to use.
- Using multimedia tools effectively calls for whole new skill sets that most casual users don't possess (sound mixing and video editing, for example, are not skills that most business users possess). The burden of educating users will fall to the software tools providers.

Today's multimedia authoring tools enable authors to combine digital information in wonderful new ways that delight and inform, entertain and educate. Early experimenters are creating a new breed of applications, and software will never be the same.

Dataquest®
a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Offices in
Costa Mesa, Munich,
Paris, and Seoul

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, and Taipei

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Multimedia Computing—
Unleashing the Market Opportunity

Focus Report

Part II

Semiconductor Application Markets *Worldwide*

SAWW-SVC-FR-9201
November 16, 1992

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Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

List of Figures

List of Figures (Continued)

List of Tables

Preface

Multimedia computing promises to be a multibillion dollar market during the next few years. Opportunities for the suppliers of multimedia hardware and software are abundant and the market window is wide open for small and large players alike.

Multimedia Computing—Unleashing the Market Opportunity is a two-part report that presents Dataquest's analysis of the multimedia computing market and describes critical factors for success.

Part I of the report presents an executive overview that defines, segments, and summarizes the current status of the multimedia computing market. Part I also contains in-depth analyses of semiconductor and software multimedia market requirements and opportunities.

This volume contains Part II of the report. It continues our exploration of the various technologies that comprise multimedia, including PCs and workstations, PC upgrade kits, storage and CD-ROM, and telecommunications, and provides in-depth technology and market assessments. The report closes with a view of the future. It speculates on the impact that emerging technologies such as virtual reality, HDTV, voice recognition, and computer conferencing will have on multimedia computing, and vice versa.

We believe that multimedia technologies will fundamentally affect the way that people interact with computers over the course of this decade. Multimedia computing enhances communications and streamlines delivery of information, goods, and services. Our research into multimedia technologies provides an exciting foundation for further studies.

Chapter 5

The Role of Computer Platforms and Upgrade Kits in Multimedia

To fully understand how the personal computer and workstation industries have evolved toward creating multimedia systems, it is important to identify significant industry milestones from the past decade that have helped make multimedia computing a reality.

Many acknowledge introduction of the IBM PC in 1981 as *the* milestone of the personal computer industry because it brought affordable computing to the masses—namely to the corporate, education, and home environments. The manipulation of text and data through word processing, spreadsheets, and databases resulted in productivity gains at the office, in the classroom, and at home. Apple Computer Inc.'s Macintosh extended PC capabilities in 1984. Besides offering traditional word processing and spreadsheet applications, the Mac included built-in audio and graphics capabilities. Mac's use of icons and a mouse pointing device also were revolutionary ways to maneuver about the screen.

Workstation companies such as Sun Microsystems Inc. and Silicon Graphics Inc., whose products are targeted toward the scientific and engineering communities, include advanced graphics and animation capabilities on their respective SPARCstation and IRIS workstation. Though they targeted their machines to end users different from those of the PC, these two vendors have demonstrated their desire to participate in multimedia computing, a desire that will be explored in more detail later in this chapter.

These examples show how the PC and workstation industries have progressed in technology over the past decade. End users that have demanded more out of their PCs and workstations now have an integrated platform that brings together the worlds of sound, animation, and photo-quality images with text and graphics—the multimedia computing platform.

This chapter on PC and workstation multimedia platforms discusses and analyzes a number of issues, beginning with the multimedia PC standard, a specification developed by Microsoft Corporation in conjunction with several hardware manufacturers. The standard outlines the minimum requirements for a machine to be considered a multimedia system. Note that this standard applies only to PCs. No standards currently apply to workstation manufacturers.

In Dataquest's analysis of the multimedia computing platform, we have chosen to segment the market as follows:

- Intel-based clone PCs
- Macintosh and PowerPCs
- Workstations
- Other computing platforms

This chapter identifies the market drivers and dynamics that we believe will influence growth of the multimedia hardware market. To supplement our qualitative analysis of the market, we also present a market sizing and five-year forecast of multimedia computing unit shipments and factory revenue.

Following the market analysis, we examine the trends and issues of the multimedia systems market from standards, platform, and environmental points of view. As the market evolves and more players enter the multimedia computing arena, the need to conform to standards becomes a vital issue because standards will play a key role in the growth of this burgeoning industry. Related to this are trends in multimedia technology. Technology in the multimedia PC/workstation arena will evolve, just as it has in the traditional PC and workstation marketplace over the past decade. We are in the unique position of witnessing the first generation of multimedia systems. It will be interesting to note advances in multimedia hardware technology over the next few years.

This chapter also profiles the following representative sample of PC and workstation companies now shipping multimedia systems:

- The Acer Group
- Apple Computer Inc.
- Commodore Business Machines
- Fujitsu Limited
- IBM Corporation
- Leading Edge Products Inc.
- NCR Corporation
- NeXT Computer Inc.
- Silicon Graphics Inc.
- Sun Microsystems Inc.
- Tandy Corporation

Each profile will include corporate statistics, a brief overview, company financials, the vendor's multimedia strategy, respective multimedia product, and Dataquest's analysis of each company's multimedia activities.

After examining the multimedia activities of specific manufacturers, we will turn our attention to the general multimedia PC and workstation platform, with a focus on opportunities and barriers to success. The growth potential of multimedia systems will be tempered by market acceptance. Issues such as the acceptance of new technology, the amount and variety of multimedia applications available, and the perception of multimedia are scenarios all multimedia system vendors must take into consideration when marketing their products.

The second part of this chapter deals with add-in boards for sound and video, and multimedia upgrade kits. Dataquest discusses the market and price point dynamics of boards and kits. Profiles for two of the leading board/upgrade kits are included.

Multimedia Personal Computer Standards

What Is a Multimedia PC?

The Multimedia Personal Computer Marketing Council (MPC Council) has defined minimum hardware specifications that explicitly focus on the Intel-based clone market. According to the MPC Council, a multimedia PC consists of five basic components: a PC, a CD-ROM drive, an audio board, Microsoft Windows 3.1 or 3.0 with multimedia extensions, and a set of speakers or headphones for audio output. The MPC Council's hardware specification is outlined as follows:

- CPU: Minimum requirement 386SX (or compatible) microprocessor.
- RAM: Minimum requirement 2MB of extended (linear address space) memory.
- Magnetic storage requirement: 3.5-inch high-density (1.44MB) floppy disk drive; minimum requirement 30MB hard drive.
- Optical storage requirement: CD-ROM drive with sustained 150 KB/sec transfer rate, average seek time of 1 second or less; 10, 000 hours mean time between failures (MTBF); mode 1 capability (mode 2 and form 1 and 2 optional); MSDEX 2.2 driver that implements the extended audio application programming interfaces (APIs); and subchannel Q (subchannels P and R-W optional; if R-W subchannel support is provided, additional APIs must be implemented in MSDEX driver. Specifications for these additional APIs are available from Microsoft). The driver must be capable of maintaining a sustained rate of 150 KB/sec, without consuming more than 40 percent of the CPU bandwidth in the process. This requirement is for read block sizes no less than 16K and lead time of no more than is required to load the CD-ROM buffer with 1 read block of data. MPC recommends that the drive have on-board buffers of 64KB and implement read-ahead buffering.
- Audio requirement: CD-ROM drive with CD-DA (Red Book) outputs and a front panel volume control. CD-ROM XA audio may be provided as an option.

- Requirement: 8-bit (16-bit recommended) digital-to-analog converter (DAC) with: linear PCM sampling; DMA or FIFO buffered transfer capability with interrupt on buffer empty; 22.05- and 11.025-KHz sample rate mandatory; 44.1-KHz sampling rate desirable; optional stereo channels; no more than 10 percent of the CPU bandwidth required to output 11.025- or 22.05-KHz, no more than 15 percent for 44.1-KHz.

  - Requirement: 8-bit (16-bit recommended) analog-to-digital converter (ADC) with: linear PCM sampling; 11.025-KHz mandatory (22.01-KHz, or 44.1-KHz sampling rate optional); DMA or FIFO buffered transfer capability with interrupt on buffer full; microphone input.

  - Requirement: Internal synthesizer hardware with multivoice, multitimbral capabilities, six simultaneous melody notes plus two simultaneous percussive notes.

  - Requirement: Internal mixing capabilities to combine input from three (recommended four) sources and present the output as a stereo, line-level audio signal at the back panel. The four sources are: CD Red Book, synthesizer, DAC (waveform), and an auxiliary input source (recommended but not required). Each input must have at least a 3-bit volume control (8 steps) with a logarithmic taper (4-bit or greater volume control is recommended). If all sources are sourced with negative 10dB (consumer line level: 1 milliwatt into 600 ohms = 0dB) without attenuation, the mixer will not clip and will output between 0dB and +3dB. Individual audio source and master digital volume control registers and extra line-level audio sources are recommended.

- Video requirement: VGA-compatible display adapter, and a color VGA-compatible monitor; a basic multimedia PC users mode 12Hz (640 x 480, 16 colors); and an enhanced configuration referred to as VGA Plus is recommended with 640 x 480, 256 colors. The recommended performance goal for VGA Plus adapters is to be able to bit 1, 4, and 8 bit-per-pixel device independent bit maps (DIBs) at 350K pixels/sec, given 100 percent of the CPU, and at 140K pixels/sec, given 40 percent of the CPU. This recommendation applies to run-length encoded images and nonencoded images. The recommended performance is needed to fully support high-performance applications such as synchronized audio-visual presentations.

- User input requirement: Standard 101-key IBM-style keyboard with standard DIN connector or keyboard, which delivers identical functionality utilizing key-combinations.

  - Requirement: Two-button mouse with bus or serial connector, with at least one additional communications port remaining free.

- I/O requirement: Standard 9-pin or 25-pin asynchronous serial port, programmable up to 9600 baud, switchable interrupt channel.
  - Requirement: Standard 25-pin bidirectional parallel port with interrupt capability.
  - Requirement: One musical instrument digital interface (MIDI) port with In, Out, and Thru; must have interrupt support for input and FIFO transfer.
  - Requirement: IBM-style analog or digital joystick port.
- MPC system software: The multimedia PC system software shall conform to the APIs, function, and performance described in the Microsoft Windows Software Development Kit Programmer's Reference, Volumes I and II (Version 3.0) and the Microsoft Multimedia Development Kit Programmer's Reference (Beta version, published November 15, 1991 and due to be updated at the final release of the Multimedia Development Kit).

Preconfigured Multimedia PC Suppliers

Of the 13 MPC-compatible vendors building full-system multimedia computers, 9 are shipping product (Advanced Logic Research Inc., Cumulus Corporation, CompuAdd Corporation, NEC Technologies, NCR Corporation, Olivetti Advanced Technology Center, Philips Consumer Electronics Co., Tandy, and Zenith Data Systems). These systems are configured to meet the MPC specifications and start at about $2,000. Other vendors shipping multimedia products include Acer, Apple, Commodore, IBM, Leading Edge, NeXT, Silicon Graphics, and Sun.

Multimedia Upgrade Kits

According to the MPC Council, 11 vendors manufacturer upgrade kits, with the following vendors shipping: CompuAdd Corporation, Creative Labs, Headland Technologies, Media Resources, Media Vision, NEC, Tandy, and Turtle Beach Systems Inc.

Dataquest's Definition of Multimedia

Multimedia, however, does not exist solely on IBM PCs and clones. A multimedia PC can take the shape of a workstation, an Amiga, or a Macintosh, as well as an Intel-based PC. Therefore a multimedia machine includes a computer that integrates sound, animation, video, and photo-quality images with text and graphics. Dataquest defines a multimedia computer as a computer that includes the following capabilities:

- CD-ROM drive
- Sound capabilities (either inherent or an above-board add-in)
- Video capabilities (simple replay capabilities, not necessarily real time)
- Speakers

The minimum CPU configuration also must be a 386SX 16-MHz or a 68030, with 4MB of RAM, and at least 100MB of hard disk storage.

This definition encompasses many different types of computers as well as vendors but is the basis for this report. If a PC (workstation) incorporates these requirements, then we consider it a multimedia-enabled machine (MEM).

Market Analysis

Market Segmentation

Dataquest segments the multimedia hardware market in two layers. The first layer is by hardware platform and is segmented the following way:

- Intel-based clones
- Macintosh and PowerPCs
- Workstations
- Others (Commodore and Atari, among others)

The second layer relates to the origin of the multimedia capabilities. Dataquest segments this layer in the following ways:

- Complete multimedia systems (CMS)
- Upgrade kits

In accordance with this segmentation, the multimedia hardware market comprises two layers, one that is platform-specific and one that indicates the origin of the machine's multimedia capabilities (CMS or upgrade kit). A CMS is a system that is sold as a MEM, while an upgrade kit simply changes an existing PC to a MEM, usually by adding sound capabilities and a CD-ROM drive. In addition, MEM is simply the summation of CMS shipments plus upgrade kit shipments.

Market Drivers

As with any emerging market, key drivers bring the market into mainstream prominence. Dataquest has identified the following market drivers to do just that for the multimedia market:

- Sound capabilities
- Upgrade kits
- Declining ASPs for CD-ROMs and upgrade kits
- Business application software
- Standards

Sound Capabilities

The integration of sound onto the desktop is by far the most curious feature to the end user at this time. Sound (hearing) is the easiest of the senses to integrate into a MEM (the sense of sight, real-time video, and touch are still in an incubation period). If the end user had one feature to add to a system, sound would provide the largest bang for the buck. The mainstream market largely relies on the PC internal speaker for sound (beeps and buzzes). For a few hundred dollars retail, the end user can have stereo sound blaring through minispeakers attached to the PC. In addition, the end user does not have to spend $1,500 upgrading a current system to integrate sound, because sound boards will work with older systems. As far as standards are concerned, the war has already been fought, with all mainstream boards boasting compatibility. Because sound integration is inexpensive, readily available, and compatible with older PCs as well as with other sound boards, Dataquest believes that it is a key driver in the acceptance of the multimedia market. In short, addition of sound to a PC is analogous to hearing for the first time.

Once sound has been integrated to the PC, it can be creatively added to applications to provide punch to a presentation, guidance to a computer-based training (CBT) end user, or simple entertainment. A plethora of software packages supporting sound are available: Windows, MediaBlitz, and Action, as well as nearly all games. Not only is sound an output of the PC, but it can be an input as well. Today's sound boards accept sound through a microphone, and can be manipulated and attached as a sound clip to a presentation, or training session to help personalize the application. Just as there is a market for professional database application programmers, there will be a market for sound engineers and application programmers.

However, a few inhibitors must be addressed before sound capabilities reside on corporate desktops. First, even though sound-enabled applications exist, the market needs more mainstream applications to embrace sound capabilities. In corporate America, where presentations are king, there is a need to present more than simple bar graphs and charts. The integration of sound capabilities into presentation applications will help spur the market. Also, too much sound (noise pollution) can be disturbing to people in surrounding cubicles or offices. The infrastructure of today's corporate offices is not designed to allow every desktop to have a sound-enabled PC. Headphones can be used instead of speakers, but do people really like to wear headphones?

Upgrade Kits

Upgrade kits offer the end user an alternative to scrapping previous investment to obtain a MEM. Dataquest views upgrade kits as key drivers because they are an inexpensive alternative to purchase of a CMS and because they give the user sound capabilities (another key driver). Upgrade kits include a CD-ROM drive and sound board, and most include speakers, microphone, and multimedia software on CD. The key to these kits are the CD-ROM drive, sound board, and bundled software. These elements allow the end user to experience multimedia computing instantly.

Upgrade kit manufacturers know that their potential market is comparable to the installed base of computers, plain and simple. They also know that it is not practical to target the entire installed base. So, these vendors target the most likely candidates, that is, corporations doing CBT, the government, schools, and the home market. This happens to be the same target market of most CMS manufacturers. With such a large potential market, why do kit manufacturers choose to compete with CMS vendors? Because they can! Price is the single most important issue in buying a commodity product. Multimedia technologies have not yet reached a commodity level and until they do, prices for a CMS will be out of reach of most potential buyers. This gives upgrade kit manufacturers the upper hand in the market for the next two years. Dataquest expects PCs with built-in multimedia features to become prevalent in the marketplace in 1994. CMS also will command nearly 60 percent of the year's MEM shipments by 1994, a figure expected to increase to nearly 80 percent by 1996.

Upgrade kits provide a quick fix to multimedia needs. The user does not have to invest in a new desktop system, but simply has to install a CD-ROM drive, a sound board, and a few drivers. However, eventually the user will have to upgrade the system. No matter what the processor type, it will become outdated by more powerful processors. Dataquest expects this transfer to begin taking place during 1994 and to continue through 1996.

Declining ASPs

Market acceptance for new technologies depends primarily on the price point for the new technology. In order for multimedia to be affordable for the masses, the ASPs for CD-ROM drives, upgrade kits, and standalone sound boards must continue to fall.

With the aggressive price wars occurring in the PC arena, CMS vendors must be able to justify a stabilization in price because they cannot compete on ever-declining system prices. A vendor that can offer a CD-ROM drive and/or sound board as standard equipment without having to raise the PC price will have reached the mass market acceptance price point. As other vendors continue to compete on price and diminishing margins, CMS vendors will be able to maintain higher prices while competing on added value (CD-ROM drive and/or sound board). Vendors will only be able to do so when CD-ROM drives have dropped enough in price to allow the CMS vendors to swallow the cost in the pricing of their machines.

Upgrade kit vendors must be sensitive to the declining ASPs of the CMS to remain a viable alternative. If CMS ASPs drop to where the buyer contemplates the purchase of a CMS or an upgrade kit, then upgrade kit vendors and the market will be in deep trouble. The market looks at upgrade kits as simple products (it views PCs as information systems) and in doing so is extremely price sensitive. By actively seeking to decrease ASPs, these vendors can actually prolong the life cycle of their product and market by offering an inexpensive route into multimedia. The two key components of upgrade kits (CD-ROMS and sound boards) must also continue to drop ASPs in order to allow upgrade kit vendors to compete. If CD-ROM drive and sound board manufacturers refuse to drop ASPs, CMS vendors will be in a better position to succeed because they can hide cost more easily than can upgrade kit manufacturers.

Business Application Software

The emergence of multimedia business application software will spur acceptance and define the needs of multimedia in corporations. With product development cycles of 18 months and longer, we can expect to see first-generation multimedia applications becoming available by year's end and continue through the end of 1993, when some second-generation product will become available. All software vendors hope for the "Windows" phenomenon (10 million copies shipped in one-and-a-half years) to take place and generate excitement in the multimedia market. Presentation, communications, word processing, and spreadsheets packages are all candidates for multimedia enhancements. Applications in these categories will generate excitement and stress the need for these applications to the large corporate buyers.

Standards

Standards are an important part of any new up-and-coming technology. Standards give vendors something to design to and tend to legitimize the market. The MPC Council has laid down the law as far as Intel-based multimedia qualifiers are concerned. Therefore, Intel-based PC vendors are now able to produce a machine and call it multimedia-enabled because they have a definition to design to. There is a legitimate market for Intel-based MEMs.

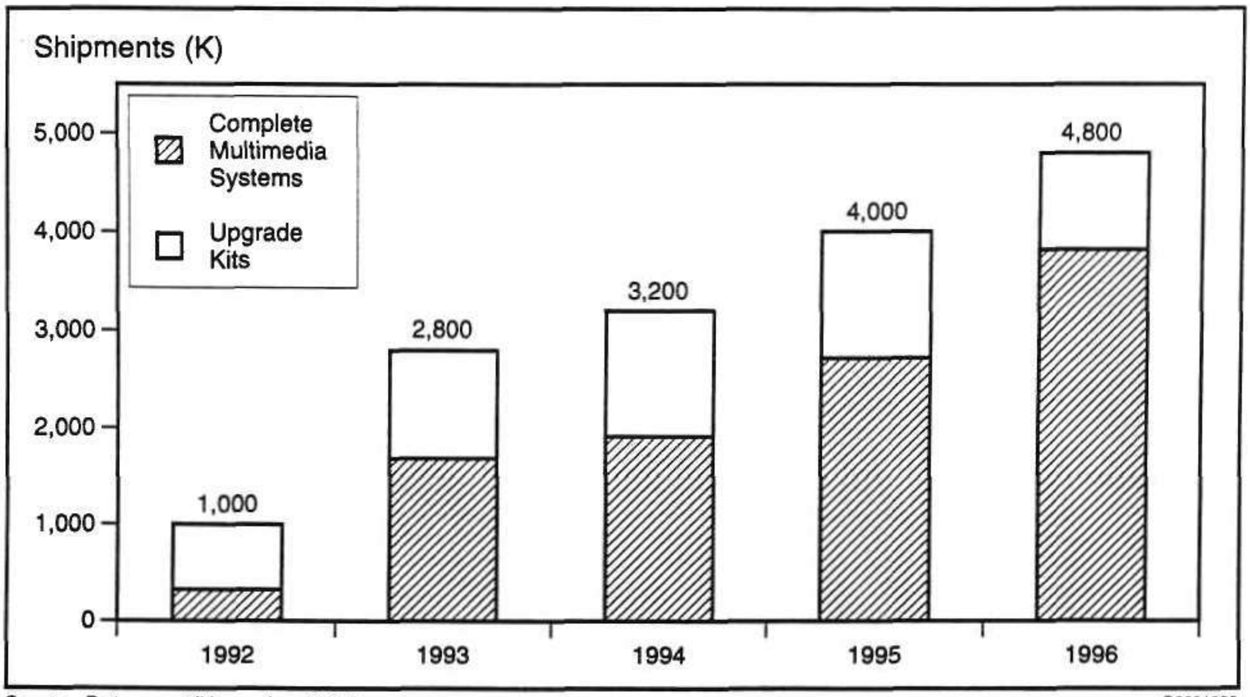
What about the Macintosh? Does it have to run System 7? Does it have to run QuickTime? What about the proposed video standards? Which ones will prevail? What about workstations? There is lots of confusion. Vendors face perplexing questions that could cost them millions of dollars if they support the wrong proposed standard. Dataquest believes that the market will gain support from vendors and end users once the standards issues near resolution. It is because standards remove much of the confusion in the marketplace that Dataquest believes standards will be a market driver.

Market Size

Dataquest expects the MEM market to reach 1.0 million shipments in 1992, collecting $1.3 billion in factory revenue. The market is expected to grow at a 48 percent compound annual growth rate (CAGR) from 1992 to 1996, reaching nearly 4.8 million MEM shipments and generating $6 billion in 1996. Figures 5-1 and 5-2 show the shipment and factory revenue forecast for MEM through 1996.

Dataquest expects shipments of CMS to start at a relatively slow rate but to pick up dramatically during the latter part of 1993 and continue strong throughout the forecast period. Overall CMS shipments are expected to be 325,000 in 1992 and to grow at a CAGR of 85 percent, reaching 3.8 million by the end of the forecast period

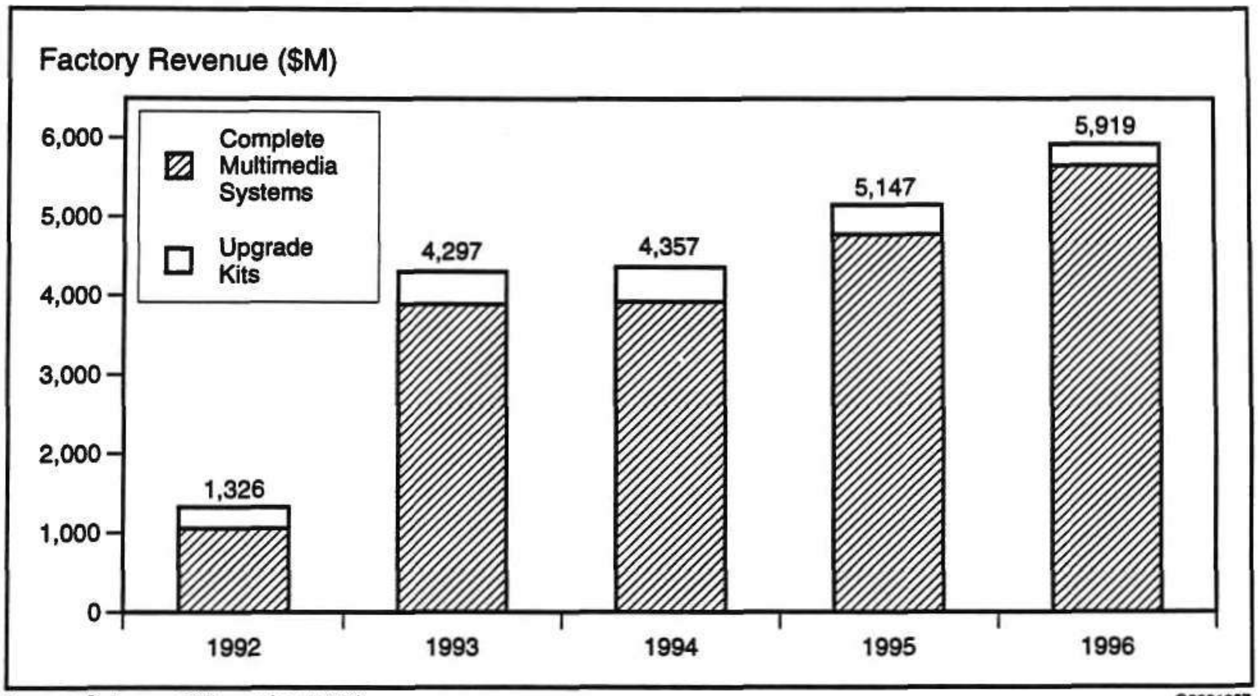
Figure 5-1
Worldwide Shipments of MEMs



Source: Dataquest (November 1992)

G2001206

Figure 5-2
Worldwide Factory Revenue of MEMs



Source: Dataquest (November 1992)

G2001207

(1996). In terms of factory revenue, Dataquest expects the CMS market to collect slightly more than $1 billion in 1992 while growing at a 52 percent CAGR and generating about $5.6 billion in 1996.

The upgrade kit market is expected to ship 675,000 units and generate $268 million in factory revenue in 1992. Dataquest expects market shipments to grow at a nearly 10 percent CAGR through 1996. Factory revenue, on the other hand, will feel the effect of intense competition and will actually experience a stagnant CAGR. Dataquest expects the upgrade kit market to ship 982,000 kits and generate $268 million in factory revenue in 1996. The upgrade kit market will peak in 1994, shipping 1.3 million units and collecting $436 million in revenue. After 1994, this market will experience a gradual decline because of the expanding presence of CMS.

Intel-Based Platform

The largest segment of the market is and will be the Intel-based clones. Participants include NCR, Leading Edge, and Tandy. Dataquest expects the Intel-based clones to control about 75 percent of the market in 1992, shipping 750,000 units. They will ship nearly 3.5 million units by 1996, controlling 72 percent of the market. Dataquest expects this market to generate $465 million in factory revenue in 1992, expanding to $2.9 billion in 1996, growing at a 59 percent CAGR.

The Intel-based CMS shipments are expected to post a 104 percent CAGR throughout the forecast period. Dataquest expects 150,000 shipments into this market in 1992, growing to 2.6 million shipments in 1996. Factory revenue for the Intel-based CMS will approach $225 million in 1992, expected to grow at an 87 percent CAGR through 1996, posting $2.7 billion in revenue (see Figures 5-3 and 5-4).

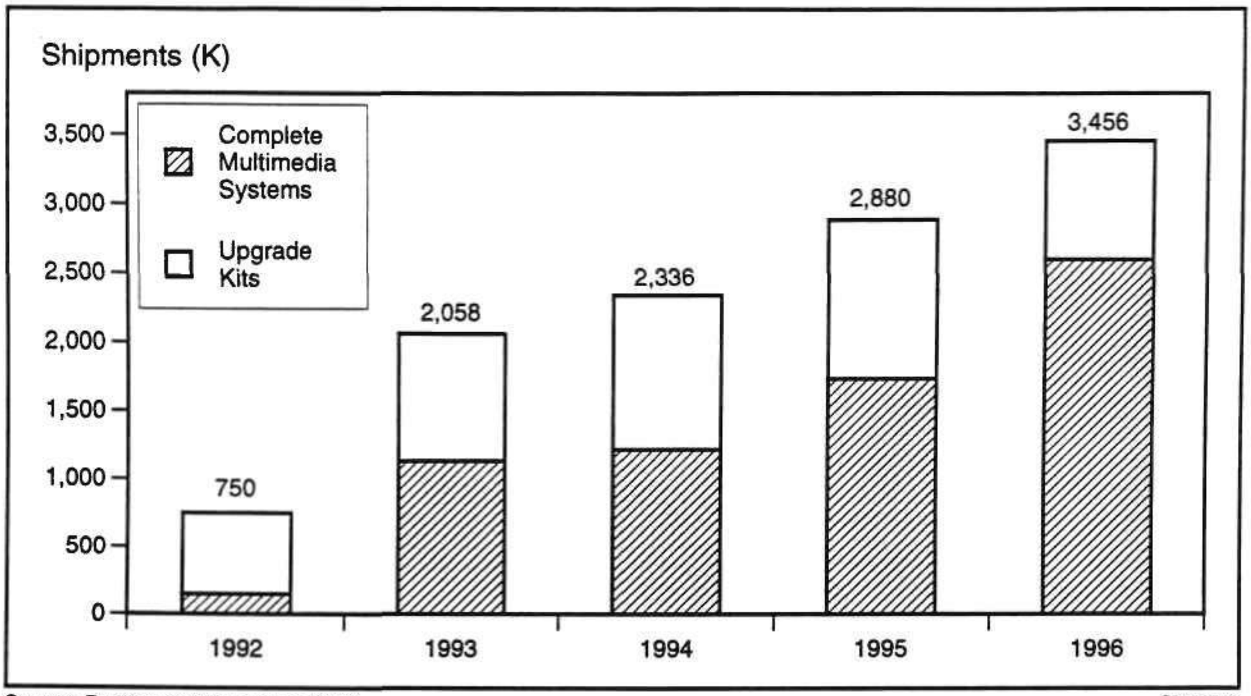
The upgrade kit market for Intel-based MEMs is a window of opportunity that will slowly close. Dataquest estimates that 80 percent of the Intel-based MEM market shipments will be upgrade kits (600,000) in 1992, with only 25 percent being upgrade kits in 1996 (864,000). Although these figures suggest room enough for a couple of top vendors, ultimately the market as we know it will stagnate under the pressure of the CMS.

Macintosh/PowerPC

Dataquest expects 150,000 multimedia-enabled Macintoshes to ship in 1992, generating slightly more than $204 million in revenue. The Macintosh platform is expected to have a 48 percent CAGR in shipments and a 44 percent CAGR in factory revenue. Shipments for 1996 are forecast to reach 720,000 and generate nearly $884 million in factory revenue.

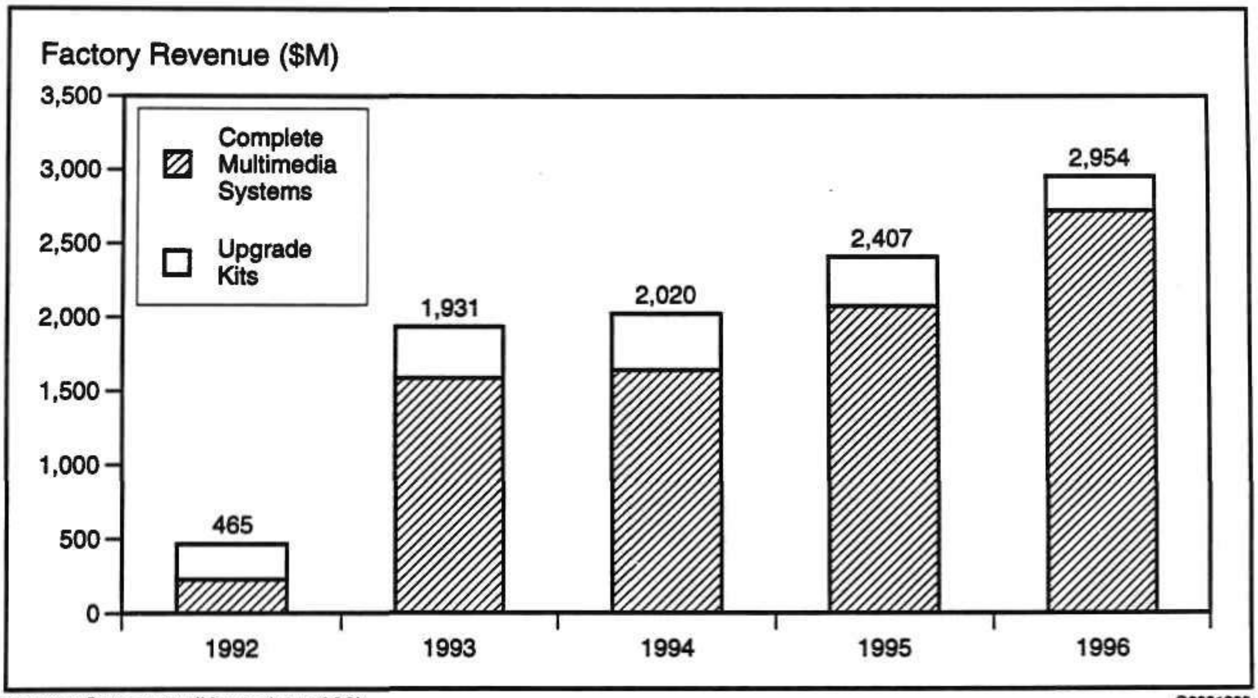
The CMS market for Macintoshes is expected to ship 112,500 units in 1992 and nearly 670,000 in 1996, posting a CAGR of 56 percent. Dataquest expects this market to record $191 million in revenue in 1992 and grow at a 46 percent CAGR while posting factory revenue of $870 million in 1996 (see Figures 5-5 and 5-6).

Figure 5-3
Worldwide Shipments of Intel-Based MEMs



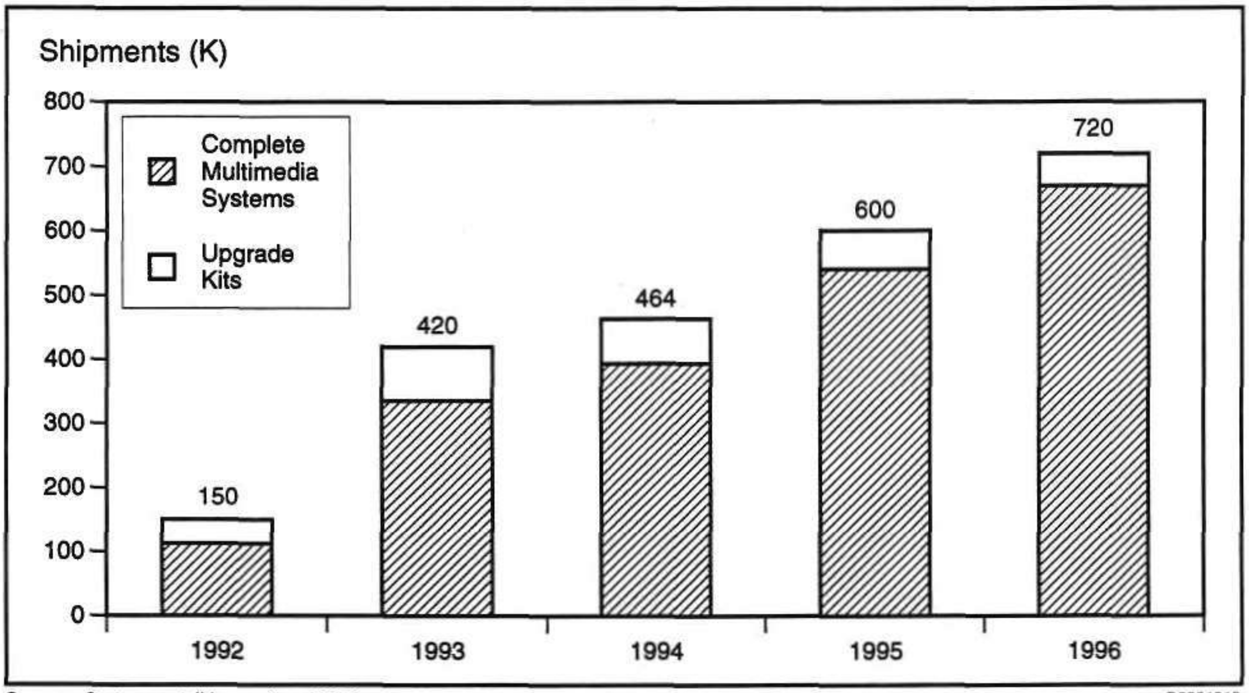
Source: Dataquest (November 1992)
G2001208

Figure 5-4
Worldwide Factory Revenue of Intel-Based MEMs



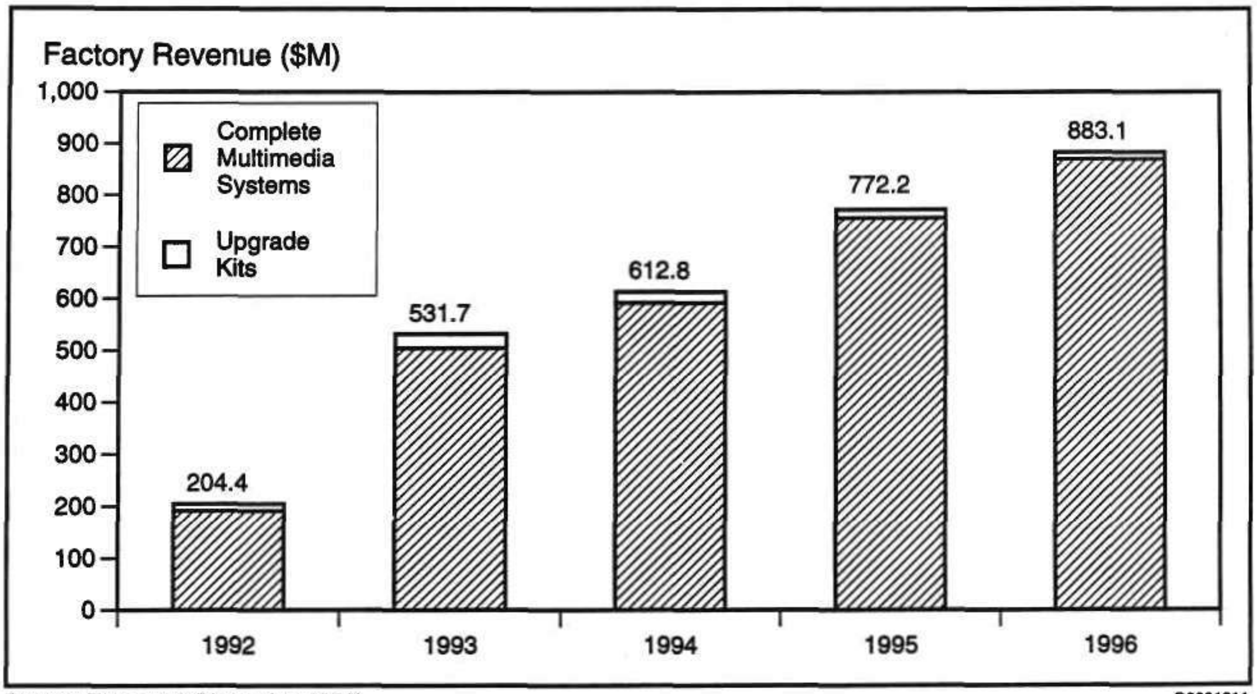
Source: Dataquest (November 1992)
G2001209

Figure 5-5
Worldwide Shipments of Macintosh/PowerPC MEMs



Source: Dataquest (November 1992)
G2001210

Figure 5-6
Worldwide Factory Revenue of Macintosh/PowerPC MEMs



Source: Dataquest (November 1992)
G2001211

The upgrade kit will find this market to be a fairly hostile environment. Dataquest expects shipments to post the lowest CAGR (7.7 percent) of all platforms, starting with 37,500 shipments in 1992 and culminating with 50,400 shipments in 1996. Because of the inherent multimedia qualities of the Macintosh, users will be hesitant to purchase an upgrade. In fact, many users think of their Macintosh as MEM already, even though they do not meet all the stated criteria. Dataquest expects factory revenue to show virtually zero growth over the forecast period, starting with $13.1 million in 1992 and ending with $13.1 million in 1996. Revenue will take a beating in this platform because of immense competition for a piece of a small pie. Dataquest estimates that 75 percent of Macintosh MEM shipments will be CMS in 1992, and expects this figure to increase to 93 percent by 1996. The parallels can be drawn between the Intel-based market and the Macintosh market. However, the effects will be more serious in the latter.

Workstations

Dataquest expects a total of 50,000 MEMs to ship in 1992, increasing to 384,000 in 1996, posting a CAGR of 66 percent. Factory revenue is expected to have a CAGR of 32 percent, growing from $620 million in 1992 to $1.9 billion in 1996.

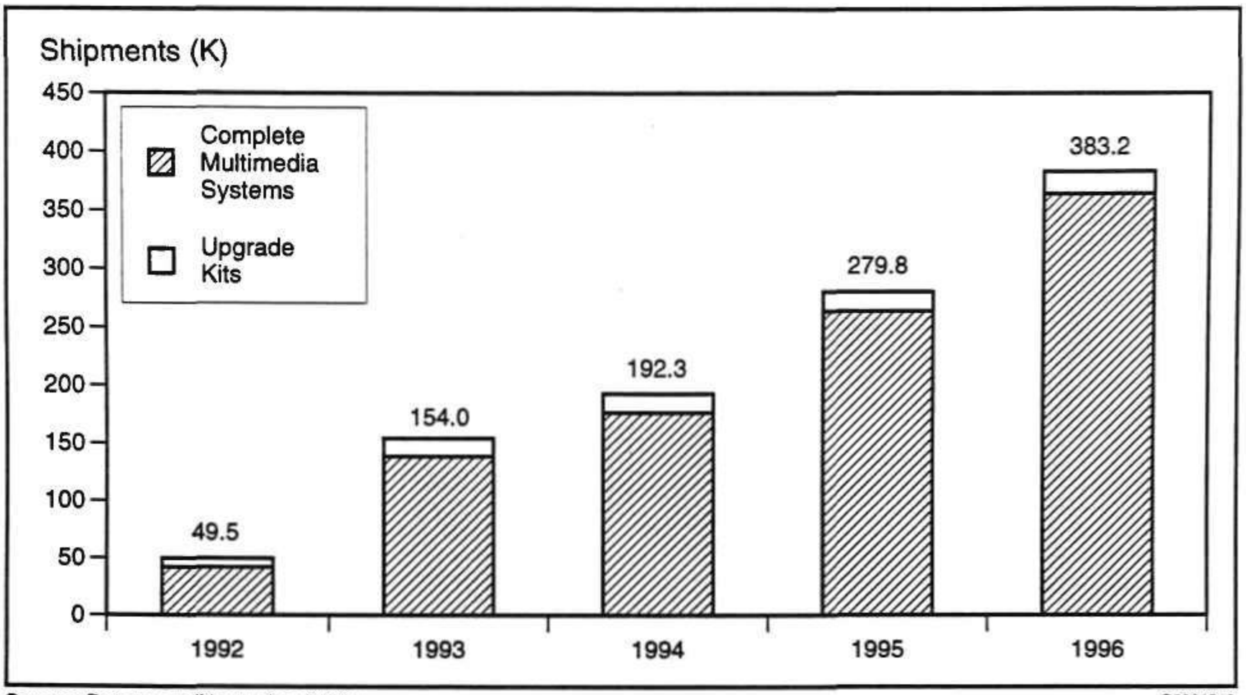
Because of the workstation's inherent capabilities, Dataquest expects the CMS portion of the workstation market to be 85 percent of the total MEMs shipped in 1992. This figures to be 42,500 units in 1992, growing to 364,000 in 1996 at a CAGR of 76 percent. In 1996, nearly 95 percent of the total MEMs shipped in this category will be CMS. Factory revenue is expected to grow from $616 million in 1992 to about $1.89 billion in 1996 at a CAGR of 33 percent (see Figures 5-7 and 5-8). Declining ASPs (negative 23 percent CAGR over the forecast period) are expected to force workstation vendors to differentiate their products to be competitive. With most multimedia components inherent in the workstation, adding the missing components is an easy and inexpensive way to differentiate.

The upgrade kit market for the workstation is more anemic than the same market for the Macintosh. Again, because of the inherent multimedia features found in most workstations, Dataquest believes that the upgrade market will be only 7,500 units in 1992, growing to 19,200 in 1996 at a CAGR of 26 percent. Factory revenue for this market is expected to be $3.8 million in 1992 and to approach $7.4 million in 1996, growing at a CAGR of 18 percent.

Other Platforms

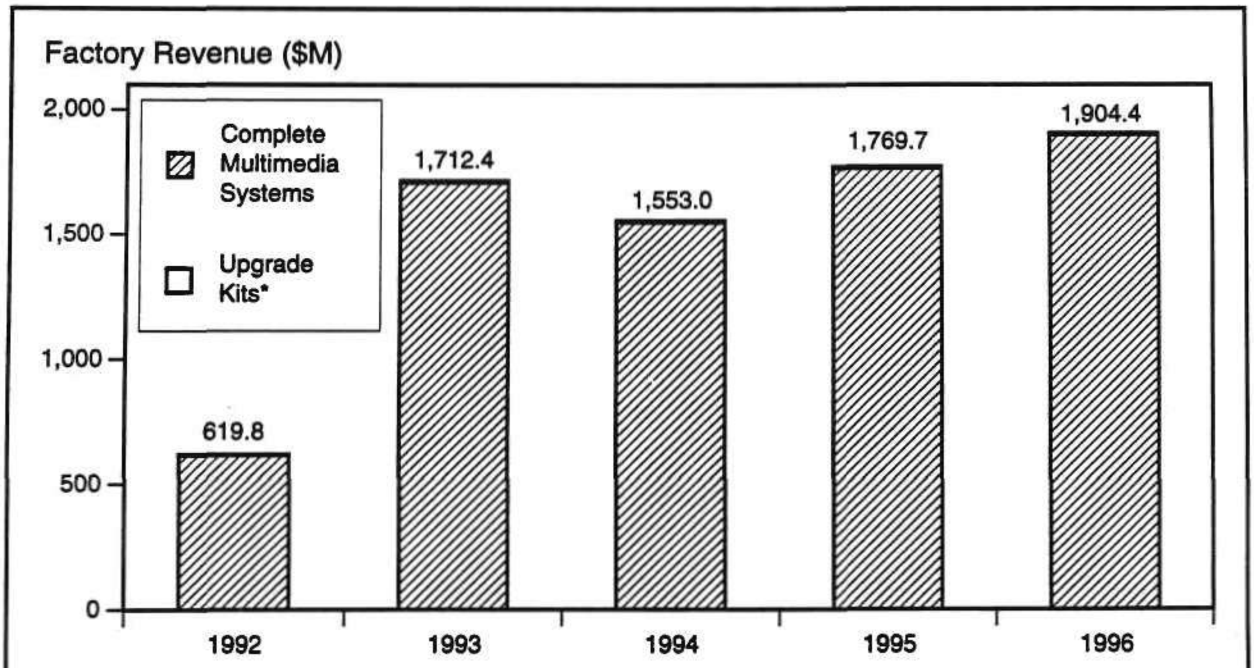
Other platforms include Commodore and Atari as well as other proprietary platforms. Dataquest believes that this market will sustain 50,000 MEM shipments in 1992, growing to 240,000 in 1996 at a CAGR of 48 percent. Factory revenue is expected to be $37 million in 1992 and to approach $177 million in 1996, while posting a 47 percent CAGR. Because these platforms have traditional strongholds in Europe, Dataquest believes that they will continue their focus on the European market.

Figure 5-7
Worldwide Shipments of Workstation MEMs



Source: Dataquest (November 1992) G2001212

Figure 5-8
Worldwide Factory Revenue of Workstation MEMs



*Note: Yearly revenue for "Upgrade Kits" is not large enough to display, relative to yearly revenue for "Complete Multimedia Systems."

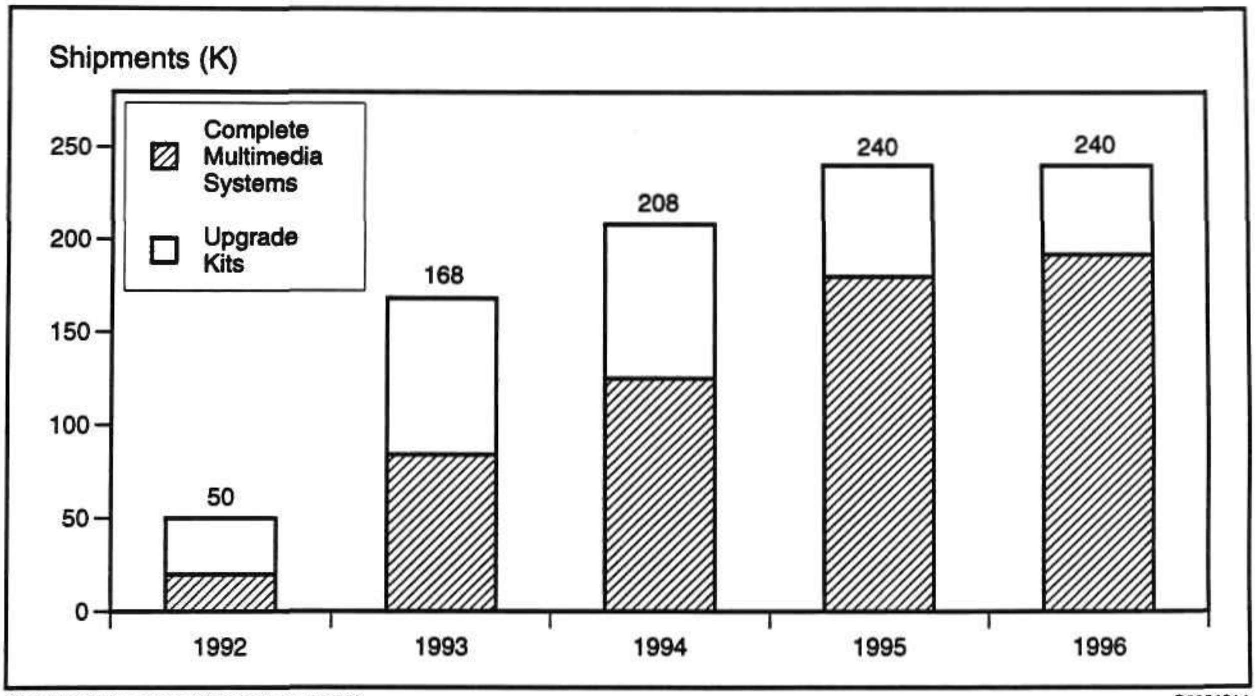
Source: Dataquest (November 1992) G2001213

Dataquest expects that 30,000 upgrade kits will be sold into this market in 1992. This figure will grow to 48,000 in 1996, posting a 13 percent CAGR over the forecast period. The upgrade kit for this market is expected to peak in 1993 (84,000), however. The upgrade kit market as a percentage of the MEM market (for this category) is expected to fall from 60 percent in 1992 to less than 20 percent in 1996. In order to stay competitive with the Intel-based market, these platforms will move at a faster pace to bring inherent multimedia features to their offerings. Factory revenue for this market is expected to be $11.3 million in 1992 and to grow to $14.2 million in 1996, down from a high of $30 million in 1993. Factory revenue is expected to grow at a CAGR of nearly 6 percent over the forecast period. Figures 5-9 and 5-10 show MEM forecasts for shipments and factory revenue for other platforms.

CMS versus Upgrade Kits

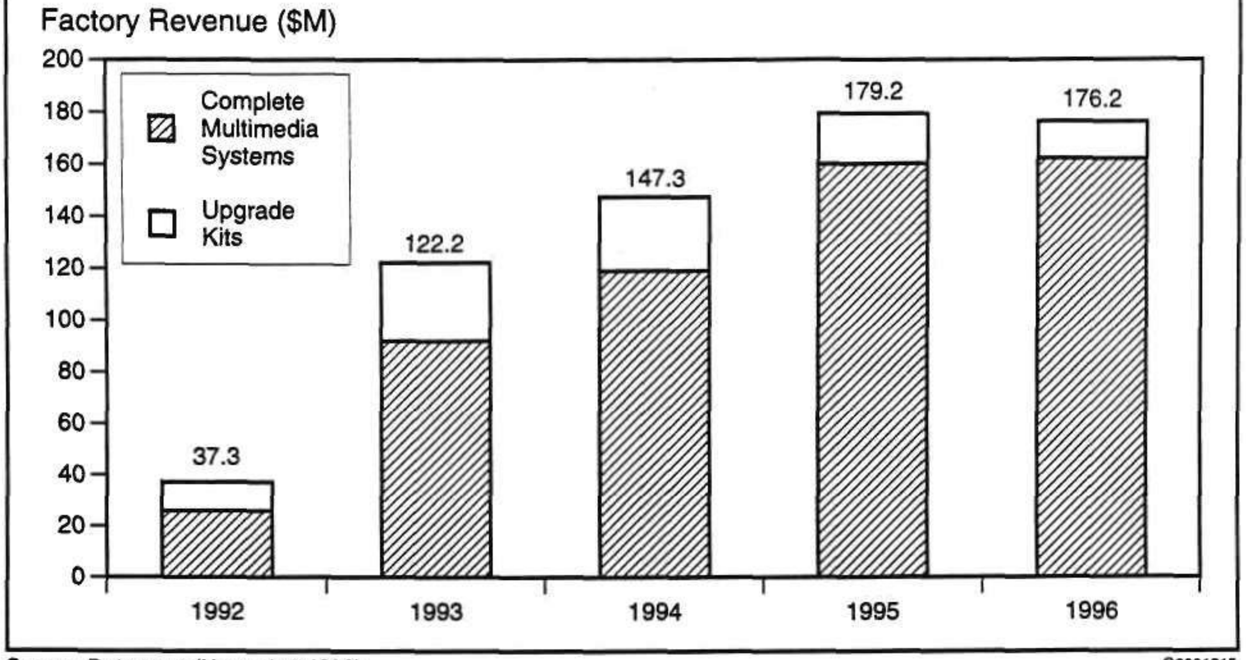
Dataquest expects competitive pressures to force vendors to bring multimedia features to their offerings. Because PCs largely are a commodity, vendors will be pressed to add value to their systems. Because of their inexpensive average selling prices, sound cards will infiltrate the PC market as a standard component. End users will no longer have to purchase these cards separately because PC vendors will include them in the overall package. Speakers and microphones will also allow PC vendors to maintain their price by claiming added value to the end user. This is a difficult thing to do in the middle of a price war, but it will initially give vendors a

Figure 5-9
Worldwide Shipments of Other MEMs



Source: Dataquest (November 1992)
G2001214

Figure 5-10
Worldwide Factory Revenue of Other MEMs



Source: Dataquest (November 1992)

G2001215

competitive edge. Will CD-ROMs follow? With declining ASPs, the only thing holding that market back is production capacity. Major PC vendors will be scrambling to sign OEM deals with CD-ROM vendors in the next two years.

With everything moving into the PC, where does this leave the upgrade kit market? The future in this market will lie in two areas, audio and video. Audio will most likely involve chip upgrades that lie resident on the motherboard. Digital video, however, is still in its infancy and will initially involve above-board add-ins. Digital video upgrade kits will sustain this market. Figure 5-11 shows the forecast of CMS versus upgrade kits.

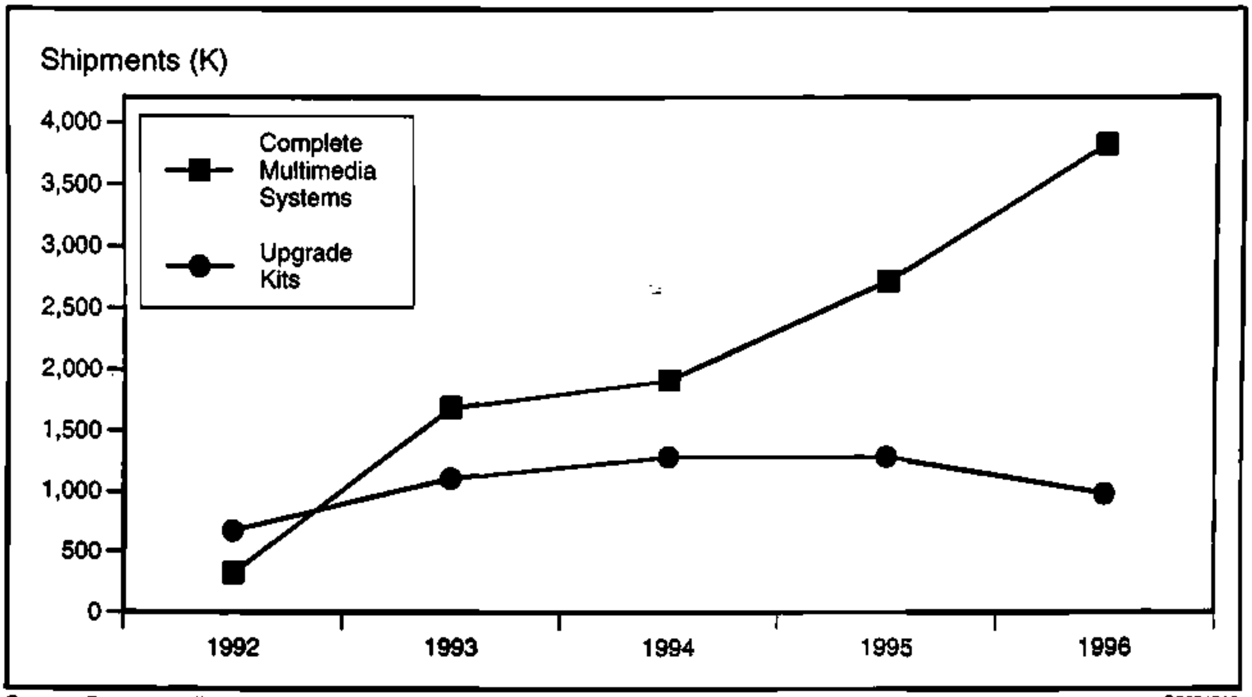
Issues and Trends

Publicity surrounding multimedia has been well documented and has generated excitement from both the developer and end-user communities. As is the case with any emerging technology, it is imperative that the players in the market understand what they hope to accomplish with this technology. We have identified specific issues and trends that will impact the development of the multimedia hardware computing industry, which are described in the following sections.

Standards

Conformance to standards is vital in the multimedia hardware arena. We have already seen the advantages of creating baseline multimedia hardware specifications in the PC industry. Independent

Figure 5-11
Worldwide Shipments of CMS versus Upgrade Kits



Source: Dataquest (November 1992) G2001218

software developers (ISVs) know that a multimedia software application they have created will work on any PC with the MPC logo. With the disparate technologies involved in multimedia, it is important that each so-called multimedia PC truly be capable of running multimedia applications. This can only be accomplished by certifying that the hardware is multimedia-capable. To its credit, the MPC Council has done an admirable job of promoting the MPC standard and bringing MPC vendors together to discuss issues regarding this burgeoning industry.

On the other hand, we have not seen the same cooperation among workstation vendors. No formal standards body governs multimedia workstation vendors. Therefore, no baseline multimedia hardware specification is in place, which means that although some vendors may promote their systems as "multimedia-ready," add-on components are required to maximize the systems' multimedia potential. We believe that workstation vendors must come together to create a council similar to the MPC Council whereby baseline multimedia workstation hardware specifications can be set.

We anticipate continued membership growth both domestically and internationally for the MPC Council, and believe that, in order to legitimize the workstation as a viable multimedia tool, the participating multimedia workstation vendors should cooperate toward creating a multimedia hardware standard.

Platforms

The three main platforms for multimedia hardware computing are PCs, Macintoshes, and workstations. The MPC Council has determined a minimum standard of an Intel-based PC running in an MS-DOS/Windows environment as the configuration. With the stability of the specification and addition of members to the council, the MPC standard should continue to grow in popularity.

IBM has developed its own UltiMedia platform as an alternative to the MPC standard. Whether IBM plans to join the MPC Council remains to be seen. For this to occur, the MPC Council would have to offer an alternative system software choice, OS/2 2.0, in its specifications. There has been speculation that the MPC Council would consider adding OS/2 to the specification, but IBM will continue to grow its installed base of UltiMedia supporters until that happens. IBM has intimated that it plans to implement the UltiMedia platform across its entire product line, in which case it would probably choose to remain independent of the MPC Council.

Although we include the Macintosh as a multimedia computing platform, it never met our definition of a multimedia-capable PC. We may have been swayed by the built-in sound and graphics capabilities of the original Mac and convinced that what we had before us was a multimedia machine. The first multimedia-ready Macintoshes actually were introduced in September 1992 and will include built-in CD-ROM drives. With the availability of the QuickTime multimedia tool set for System 7, Apple will be fully equipped to take on offerings from IBM and the MPC.

There is also an opportunity for Apple to compete with workstation players Sun and Silicon Graphics, with its Mac Quadra 950. The main obstacle lies in processing speed. Although both Sun and SGI use the faster RISC processor, the Quadra relies on the Motorola 68040 chip. Apple can greatly increase its multimedia presence and processing speed by incorporating RISC technology into its Quadra systems.

The workstation platform provides advantages over the PC platform in system performance and networking capabilities, as well as in inherent features such as graphics and video enhancements. This platform seems to be an ideal vehicle to exploit its various multimedia components (audio, video, graphics, animation, and text). The UNIX platforms offered by Sun, Silicon Graphics, and NeXT, the three predominant multimedia workstation manufacturers, offer a wide range of multimedia possibilities.

Sun believes that its networking capabilities differentiate itself from the other platforms, enabling workgroup multimedia applications to flourish on the desktop. Also, as the leading workstation manufacturer, it has the advantage of introducing multimedia applications to a substantial installed base. Multimedia software developers have clustered around the Sun platform and have provided a variety of sophisticated authoring and presentation tools for SPARCstation users.

Silicon Graphics provides a platform geared toward scientists and engineers requiring high-end visual computing. Multimedia is the perfect vehicle to present 3-D modeling, imaging, rendering, and animation. With the amount of multimedia applications development into these graphics-intensive areas, SGI has keenly carved a niche for itself. The SGI platform is superior to any other platform (PC or workstation), when it comes to visual computing.

Like the Apple Quadra 950, the systems from NeXT operate on the Motorola 68040 processor. NeXT will have to switch to the faster RISC processor to effectively compete with Sun and SGI, especially in the power-hungry world of multimedia. The lack of applications for NeXT systems in large part are because of the platform's small installed base. Although the company is focusing its efforts on increasing its installed base, it must retain its presence as a viable multimedia platform, because NeXT has designed a line of systems configured to work as multimedia machines.

Environment

The MPC Council's selection of Windows as its system software requirement was a triumph for Microsoft. Although the Level 1 specification is viewed as a baseline standard, users may be able to migrate to Windows NT, Microsoft's next-generation operating environment, when it becomes available. It would be a natural progression for those users already knowledgeable and comfortable with Windows. However, users looking for a preemptive multitasking operating system with multimedia capabilities will find that OS/2 2.0 more than fulfills their multimedia needs.

Both IBM and Apple have continued multimedia activities using their own respective operating systems. Ironically, a joint venture of the two companies, Taligent, was created in late 1991 to develop system software. Taligent plans to position the PowerOpen, when introduced, as a formidable operating system to run multimedia. An interesting possibility is the acceptance of PowerOpen at the expense of OS/2 2.0 and System 7 with QuickTime.

The difficulty in establishing multimedia standards in the workstation industry stems in part from the amount of proprietary operating systems available. It would be difficult for the workstation vendors to settle on one operating system, because each vendor has designed its respective operating system to maximize the potential of its own machine. To solve this issue, workstation vendors could develop a hybrid operating system that aggregates the features of the various proprietary environments and designate that as the workstation operating system standard.

Technology

The driving forces behind multimedia computing are and will continue to be advancements in technology. We have already seen this evolutionary process in the traditional PC and workstation arenas. The disparate technologies developed and implemented in these systems over the past decade were the building blocks for multimedia computing. If past events are any indication, the industry has only scratched the surface of multimedia. Indeed, multimedia computing is at the infant stage. As end users become more sophisticated in using their multimedia systems, vendors will have to keep pace by introducing new technologies to meet their needs. Thus, the evolutionary process continues, but on a higher level. In this section we discuss a few technologies that will have an impact on the future of multimedia computing.

Sharing of information in a networked environment has resulted in tremendous efficiencies in the workplace. From a multimedia standpoint, networking will further enhance the way we can communicate on the desktop. Though a percentage of multimedia PCs are standalone systems, anticipated penetration of multimedia PCs in the corporate environment will require that these systems be linked. It will take a robust PC network to handle the demands of multimedia applications. The MPC Council might consider setting minimum networking requirements for all MPC-compliant systems.

Recently, attention has been drawn to object-oriented programming (OOP). The growth of multimedia will depend on the availability of software applications. OOP represents the future of software development. OOP is designed to simplify the writing of complex computer software, which is accomplished by combining "objects" to create a fully written software application. Each object, with its specific instructions, can be thought of as a building block. Software programs would be "built" from these objects, which could be quickly upgraded by simply adding new objects. The advantage of OOP over conventional software programming is the speed at which software applications can be created. Multimedia software vendors could dramatically increase the number of available applications by implementing the OOP philosophy.

Multimedia affords the possibility of creating derivatives of existing technologies, such as electronic mail. We are all familiar with sending and receiving messages. An enhancement would be to have a window on the computer screen containing the image of the individual verbalizing the message. Though this scenario has not yet been perfected, work in the field of video compression holds promise. There are issues regarding the ability to send the information through Integrated Services Digital Network (ISDN) lines and networks. When these issues are resolved, video mail, as well as related technologies such as desktop video conferencing, will enhance the communications experience.

Vendor Profiles

This section contains vendor profiles on the following key vendors participating in the multimedia market:

- The Acer Group
- Apple Computer
- Commodore Business Machines
- Fujitsu Limited

- IBM Corporation
- Leading Edge Products Inc.
- NCR Corporation
- NeXT Computer Inc.
- Silicon Graphics Inc.
- Sun Microsystems Inc.
- Tandy Corporation

The Acer Group

Corporate Statistics

Headquarters Location	Taipei, Taiwan
President, The Acer Group	Stan Shih
Chairman and CEO, Acer America	Stan Shih
President and COO, Acer America	Ronald Chwang
Founded	1976
Fiscal 1991 Revenue	About $1 billion
Number of Employees	5,200

Overview

Founded in 1976, The Acer Group is recognized as one of the largest microcomputer manufacturers and a significant worldwide OEM supplier. Acer America Corporation, a subsidiary located in San Jose, California, is responsible for engineering, R&D, manufacturing, and marketing operations in the United States and Canada. The Acer Group acquired Altos Computer Systems in 1990 and now manufactures three computer brands: the Acer line of business PCs, the ACROS line of consumer PCs, and the Altos line of networked UNIX systems for the business environment. Acer's multimedia system, the Personal Activity Center (PAC), is targeted to both the business and home/education markets under the names the AcerPAC 150 and ACROS 380, respectively.

Financials and Market Position

The Acer Group's 1991 revenue approached $1 billion, distributed nearly equally among the North American, European, and Asian regions. Dataquest estimates that 1992 revenue for the PAC, introduced in May 1992, will be about $15 million.

Strategy

Acer has taken a bold approach in the distribution and marketing of its PAC. From a distribution standpoint, Acer has chosen a dual-channel approach, offering the identical product under both the Acer and ACROS product line channels. The AcerPAC 150, targeted toward the corporate market, will be sold through authorized

ACER dealers, distributors, and VARs such as ComputerLand and MicroAge. The ACROS 380, aimed at consumers in the home and education market, will be distributed through consumer electronics outlets, computer superstores, and office supply superstores including Circuit City, Best Buy, BizMart, ComputerLand Express, and Staples. The company believes that this dual-channel philosophy will demonstrate its belief in the versatility of the PAC in both the business and home/education environments.

In positioning the AcerPAC as a single, integrated system that comprises individual technology developments over the past few years, the company created a hybrid product that merges the features of a desktop PC and consumer electronics. Acer believes that the distinctive characteristics of the AcerPAC will meet the broad needs of the product's intended target markets.

In the medium-size- to large-business environment, Acer has targeted four main areas for the AcerPAC 150: telemarketing, sales, and customer service departments; executives; administrative assistants; and human resources. For small businesses, the integrated AcerPAC requires less desk space, while the online tutorials allow for the efficient use of resources. Finally, the home and education markets will benefit from the preloaded software that includes office applications and reference guides.

Acer has identified the retail, legal, medical, and manufacturing industries as vertical markets that may benefit from the graphic, audio, facsimile, and data storage capabilities of the PAC. Acer also plans to work with value-added resellers to develop applications into each of these industries that can best maximize the AcerPAC's varied functions.

Products

The Acer PAC is a 386SX-based, 20-MHz PC that comes with 4MB of RAM and a 130MB hard disk drive. It features a variety of consumer-electronic devices integrated into the system, including a CD-ROM drive, speaker phone, telephone answering device (TAD), fax/data modem, AM/FM receiver, audio mixer, and alarm clock. Software bundled with the AcerPAC includes MS-DOS 5.0, Microsoft Windows 3.0 with Multimedia Extensions (Acer will provide upgrades to 3.1 upon availability of the extensions), Microsoft Works for Windows (Multimedia Edition), Microsoft Bookshelf, Prodigy, and Delrina's WinFAX for sending and receiving facsimiles.

Acer plans to introduce an enhanced version of the original AcerPAC later this year, geared toward the business user, which will possess greater processing power and expandability. Beyond this year, next-generation PACs will also incorporate still imaging and full-motion video, as multimedia software becomes available.

Dataquest Perspective

With the introduction of the PAC, Acer has shown the viability of harnessing existing consumer-electronics features and integrating these disparate technologies into a cohesive PC package. The company has focused its attention on the system's ease of use and has downplayed issues concerning processing speed and upgradability. Though the system conforms to the MPC's hardware specification, Acer chose not to incorporate its "Chip-Up" technology in the AcerPAC. (Chip-Up refers to the ability of the customer to remove the existing processor and replace it with the next-generation chip. For the corporate environment, this may be an important point to consider before purchasing this system.)

From a multimedia perspective, the built-in audio functions, including a connector for an optional E-mu audio board that can enhance stereo sound to professional quality sound, are sufficient. Acer expects to incorporate digital sound in its next-generation AcerPACs. As mentioned earlier, Acer acknowledges that still imaging and full-motion video is not yet possible on the AcerPAC. In this regard, the system is not yet configured to perform complete multimedia presentations.

We expect the AcerPAC to thrive in the home and education environments. The cost of purchasing the individual components separately would far exceed the price of the AcerPAC. Again, the advantage of having these components and software integrated into a single system is quite appealing, and the current offerings on the AcerPAC more than exceed the needs of students, small business, and home users.

For the corporate environment, the limited multimedia capabilities, coupled with the inability to upgrade, may create nominal appeal in the marketplace. Though Dataquest views the AcerPAC as a desirable solution for telemarketing, sales, customer service, or training, the current system also has limited networking capabilities, other than its standard PC networking function. Networking is a prerequisite in the corporate arena, an advantage that multimedia workstation vendors can exploit in a client/server environment. If Acer can deliver on its promise of increased multimedia capabilities on its future PACs and if it can improve its networking capabilities, then we anticipate greater acceptance in the corporate market.

Apple Computer

Corporate Statistics

Headquarters Location	Cupertino, California
Chairman and CEO	John Sculley
President	Michael H. Spindler
Founded	1977
Fiscal 1991 Revenue	$6.3 billion
Number of Employees	14,432

Overview

Apple Computer offers a wide range of personal computing products including PCs, related software, and peripheral and communications products. Its premier product line, the Macintosh, includes a broad range of product offerings. This family includes the Macintosh Classic, Macintosh LC, Macintosh II line, and the Quadra line. Apple plans to bring the Macintosh II and the Quadra product lines into multimedia prominence.

Apple has long been a leader in the education market, both in the United States and elsewhere. Dataquest expects Apple to continue to inundate the educational market with its hardware and software.

Strategy

As mentioned earlier, Apple is pushing the Macintosh II and Quadra lines, coupled with System 7 and QuickTime, into multimedia forefront. The low-end Macintosh IIsi is configured with a 20-MHz 68030 CPU and 2MB of RAM, while the high-end Macintosh IIfx comes standard with a 40-MHz 68030 and 4MB of RAM. The various Macintosh II and Quadra product specifications are shown in Table 5-1.

None of these machines comes standard with a CD-ROM drive; however, one can be purchased as an option. The product strategy with these machines is to push the sound and graphic features of a multimedia machine. All Macintosh machines come with inherent sound capabilities as well as animation creation and playback capabilities with System 7 and QuickTime. These systems allow the end user to be "wowed" by the combination of sound and vision that can be easily created and manipulated.

Apple recently announced a special, promotional multimedia bundle offering for Kindergarten through 12th grade and higher education customers who purchase any hard disk-equipped Quadra 700 or 950 system. The bundle includes the following:

- SuperMac Tech VideoSpigot NuBus Card
- Adobe Systems' Adobe Premiere
- Aldus Corporation's Aldus Persuasion
- QuickTime Content Collection

Table 5-1
Apple Macintosh II, Quadra, and Performa Product Configurations

Product	CPU	RAM (MB)	Hard Drive* (MB)
Macintosh IIsi	68030-20 MHz	2 to 17	40 or 80
Macintosh IIci	68030-25 MHz	4 to 32	40 or 80
Macintosh IIfx	68030-40 MHz	4 to 32	80 or 160
Macintosh Performa 600 CD	68030-32 MHz	5 to 68	160
Macintosh IIvi	68030-16 MHz	4 to 68	40/80/160
Macintosh IIvx	68030-32 MHz	4 to 68	80/160/230/400
Quadra 700	68040-25 MHz	4 to 20	80/160/400
Quadra 900	68040-25 MHz	4 to 64	160/400
Quadra 950	68040-33 MHz	8 to 64	230/400

*All systems can be purchased without a hard drive.
Source: Apple Computer Inc.

It is certainly an impressive grouping of video graphics software, but nonetheless a hungry group in terms of system resources. The QuickTime Content Collection alone requires 40MB of disk space. Apple has never been one to follow traditional lines. Maybe the company would profit by offering the CD-ROM as standard equipment, as other multimedia vendors do. At least the end user would benefit.

Although CD-ROMs are not at the forefront of Apple's strategy, it is an important part of its multimedia strategy. Apple first embraced CD-ROM support in early 1988, announcing the AppleCD-SC. The AppleCD-SC stores more than 550MB with an access time of 500ms and a 150 KB/sec data transfer rate. Apple must succeed in this area if it is to take hold of the multimedia market. With the introductions of the Macintosh Performa 600 CD in September 1992 and the Macintosh IIvi and IIvx models the following month, the company has finally introduced systems incorporating a CD-ROM drive.

Dataquest Perspective

Dataquest believes that Apple, from a multimedia hardware standpoint, has the most to lose in the multimedia market. Although its products enjoy a renowned sense of multimedia-capable machines to many, Dataquest has identified issues of concern: the size of hard drives and application/platform dependency.

Although the Quadra 950 offers sizable hard drives, it also has a price tag to match. Because Apple does not offer a CD-ROM as standard equipment, the size of the hard drive becomes extremely important. For the high-volume Macintosh IIs, 160MB is the maximum storage capacity. If Apple really wants people to create animation and sound clips with its machines, two things must occur. Apple must supply larger hard drives as a purchase option or decrease the prices on the Quadra series. Secondly, multimedia applications ported to the Macintosh usually have no counterpart on the DOS/Windows side. It has taken nearly a decade for software vendors to port applications to various platforms. The industry cannot wait another 10 years for multimedia applications to become cross-platform. Apple is working on this issue by developing a QuickTime for Windows. Kaleida will undoubtedly address this issue in its development process. Corporate America, a large multimedia adopter, will focus on this issue as purchasing criteria. Applications must be independent of the platform they reside on and allow for seamless interoperability.

All in all, Apple has a large head start on the rest of the industry. Apple has been into sound and video integration for nearly eight years. The company's system software is multimedia aware and is simply an easier to use and more stable environment than Windows on DOS. Apple users have integrated these capabilities into their daily grind and, in essence, lead the formation and identification of the multimedia market.

Commodore Business Machines

Corporate Statistics

Headquarters Location	West Chester, Pennsylvania
President	James Dionne
Founded	1959
Fiscal 1991 Revenue	$797 million
Number of Employees	800

Overview

Commodore Business Machines Inc., based in West Chester, Pennsylvania, is the U.S. subsidiary of Commodore International. The company manufactures and markets a line of computers and peripherals for the business, education, government, and consumer markets. It entered the multimedia market when it designed the Amiga computer in 1985. Since then, Commodore has developed multimedia products including CDTV, Amiga 3000, and the AmigaVision authoring system.

Commodore defines multimedia as "a method of designing and integrating computer technologies on a single platform that enables the end user to input, create, manipulate and output text, graphics, and audio and video, utilizing a single user interface."

Strategy

In the past, Commodore competed on price, and its strategy for the Amiga multimedia series is based along these lines. In March 1992, Commodore announced special promotional pricing to its dealers. Because of the success of this strategy, Commodore elected to permanently adopt the lower prices by establishing new dealer and manufacturer's suggested retail pricing (MSRP).

Commodore's multimedia campaign is focused on the professional multimedia user involved in video graphics, dynamic presentations, interactive training, or point-of-information kiosks.

Commodore's Amiga product configurations are shown in Table 5-2.

Dataquest Perspective

If Commodore is competing on price, then the MSRPs do not show it. In fact, the prices are well above market MSRPs for similarly configured machines. Dataquest takes issue with two of Commodore's claims. The first issue involves the company's offerings in the multimedia market, and the second inivolves its pricing.

Although the Amiga 3000T series certainly offers the end user enough raw computing power, it does not offer a CD-ROM as standard equipment. According to Dataquest and the MPC Council, all multimedia-enabled machines must have a CD-ROM drive. The 200MB hard drive and 5MB of RAM coupled with the processor allow the user to create complex multimedia applications. But without a CD-ROM drive, the user has no way of storing vast amounts (640MB) of audio and video clips. Also, without a CD-ROM drive, the user cannot access the ever-growing amount of CD titles available.

The Amiga 2000 and 3000 25-50, on the other hand, do not give the user enough power to create and manipulate multimedia data types or applications, even though Commodore's target market is the professional user. As stated earlier, for all practical purposes, a system really requires 200MB storage, a CD-ROM drive, and at least 4MB of RAM.

Commodore's pricing strategy certainly is aimed at the professional market. The problem is that its products are not properly aligned. The professional video market requires greater processor power than the 2000 can furnish, as well as much greater storage capacity than any of the machines can deliver as standard equipment. Commodore simply has professional prices for low-end machines.

Table 5-2
Commodore Amiga Product Specifications

Product	Processor	Hard Drive (MB)	RAM (MB)	Monitor	Peripherals	MSRP Price ($)
Amiga 2000	68030	100	5	1084S	A3070 Tape drive (150MB)	2,699
Amiga 3000 25-50	68030	50	2	1950 or 1960 VGA	A2386SX BridgeBoard	3,399
Amiga 3000T 25/200	68030	200	5	1950 or 1960 VGA		4,499
Amiga 3000T 040/200	68040	200	5	1950 or 1960 VGA		5,998

Source: Commodore Business Machines

Fujitsu Limited

Dataquest includes in this discussion a company whose multimedia PC sells in Japan: Fujitsu's FM Towns. The following information on the FM Towns was provided by the FM Towns Support Center (FTSC), located in San Francisco, which serves as a liaison between Fujitsu Limited in Japan and ISVs from the United States and Europe that are creating software and applications specifically for FM Towns.

The original FM Towns was formally introduced at Microsoft's Fourth Annual CD-ROM Conference in March 1989. At the time, it was the first PC with a built-in CD-ROM drive. As of March 1992, sales of the FM Towns exceeded 200,000 units. One Fujitsu objective at the conference was to recruit third-party developers to create multimedia applications for the FM Towns. Shortly afterward, FTSC was formed to undertake those responsibilities.

Because FM Towns was introduced before the MPC standards were set, minor differences are apparent. Therefore, it is not MPC-compliant. There are issues regarding whether Fujitsu should convert its system to full MPC compliance, including the cost of conversion and the availability of MPC software in Japan. Currently, 95 percent of MPC software runs on FM Towns, so there seems to be no need to modify the hardware. As a member of the board of directors of the MPC Council, Fujitsu supports the concept of defining a base multimedia standard. In fact, Fujitsu has plans to introduce a similar product for the U.S. market, which it says will exceed the current Level 1-compliance measures.

In November 1991, Fujitsu introduced the FM Towns II product line, comprising six models under the UX and CX families. Each model comes standard with a 386SX 16-MHz processor, 2MB memory, and a built-in CD-ROM drive. The differences between the UX and CX models are the memory expansion capabilities and the hard disk drive availability on two of the CX models, as follows:

- FM Towns II Model UX/10—One 3.5-inch flexible disk drive (FDD)
- FM Towns II Model UX/20—Two 3.5-inch FDDs
- FM Towns II Model CX/10—One 3.5-inch FDD
- FM Towns II Model CX/20—Two 3.5-inch FDDs
- FM Towns II Model CX/40—Two 3.5-inch FDDs, 40MB hard disk drive (HDD)
- FM Towns II Model CX/100—Two 3.5-inch FDDs, 100MB HDD

Other notes about FM Towns include the following:

- As of March 1992, more than 500 FM Towns titles were available. Of that total, 60 percent were consumer titles, 30 percent were educational titles, and 10 percent were corporate titles.

- Microsoft Windows 3.0 with Multimedia Extensions runs on FM Towns. Fujitsu shipped MME for Towns in April 1992. More than 100 Windows 3.0 titles run on Towns.
- Video display is possible with the use of the Fujitsu Video Processor Card.
- The new FM Towns II models support Novell NetWare 386 v.3.1/J. A DSLink Network Card is required to become a Novell network client. The card is available from Fujitsu.

Dataquest Perspective

Dataquest believes that the new FM Towns II models will be as successful in the marketplace as their predecessor. The only suggestion for Fujitsu would be to increase the processing power in its new systems, which use the 386SX 16-MHz chip, because multimedia applications require robust processing capabilities.

The success of the original FM Towns shows the global desire for multimedia. As one of the few international members of the MPC Council, Fujitsu can promote the MPC standard to the other PC vendors in Japan, who may consider developing multimedia systems.

International Business Machines

Corporate Statistics

Headquarters Location	Armonk, New York
Chairman of the Board	John Akers
President	Jack Kuehler
Founded	1911
Fiscal 1991 Revenue (ended 12/31/91)	$64.8 billion
Number of Employees	About 330,000

Overview

The Computing-Tabulating-Recording Company was founded in 1911. After merging with International Business Machines Corporation in 1924, the company chose to retain the IBM name. The company is acknowledged as the world's largest computer systems vendor. IBM formally entered the multimedia market in June 1990 with creation of the Multimedia and Education Division, naming Lucie Fjeldstad as vice president and general manager of the Multimedia Division, and Michael Braun as assistant general manager. The division introduced the PS/2 UltiMedia M57 SLC, its first desktop multimedia system, in October 1991 and began shipping in March 1992.

Financials and Market Position

IBM ended 1991 with an estimated $64.8 billion in revenue. Dataquest estimates 1992 sales of its PS/2 UltiMedia M57 SLC and multimedia hardware options to exceed $150 million.

Strategy

Though IBM did not formally launch its multimedia division until 1990, its pioneering efforts in the field of multimedia technology indicated desire to search for ways to allow individuals to learn more effectively. People retain about 20 percent of what they see *or* hear; 40 percent of what they see *and* hear, and 75 percent of what they *see, hear, and do.* IBM recognized a need to develop a system to satisfy these senses. An experimental version of an interactive system, comprising a desktop computer (the predecessor to the IBM PC), a videotape player, and OEM touch-technology equipment was developed in 1980 and demonstrated as a tool for sales training and educational instruction.

Over the next few years, IBM's commitment to streamlining sales training and education costs resulted in discovery of new technologies as next-generation interactive developmental projects were undertaken. Projects such as "Vision" introduced the videodisk as a superior alternative to the videotape player, and the InfoWindow Touch Display incorporated stereo sound, touch, motion video, graphics, and text.

The progressive advances that IBM made with its various developmental projects led to what IBM calls "UltiMedia," the "ultimate in media," because it blends the traditional mediums of sound, motion video, photo-like imaging, graphics, text, and sound into a unified system. IBM's UltiMedia vision centers around the ability to deliver all forms of information to individuals by what the user requires, anytime and anywhere. To accomplish this, IBM outlined three provisions for the UltiMedia platform: the most natural user interface, the integration of hardware and software products into existing infrastructures, and the highest possible product quality.

IBM's vision of multimedia indicates its desire to provide UltiMedia solutions to its entire installed base, ranging from its desktop PS/2 users to its mainframe ES/9000 customers. The company's plan to implement multimedia solutions across all product segments is a long-term undertaking, although IBM has already demonstrated through history its commitment to provide integrated solutions to various environments, including education and business.

Products

The PS/2 UltiMedia Model M57 SLC is IBM's first integrated multimedia-hardware offering. The company set minimum hardware specifications not only for its maiden product, but also for its future UltiMedia systems. These specifications include a 386SLC 20-MHz microprocessor, 4MB memory, a CD-ROM/XA drive, a 160MB hard disk drive, a 3.5-inch 2.88MB floppy disk drive, XGA graphics capability, a CD-quality audio subsystem, and microphone. The company's most recent operating system, OS/2 2.0 with Multimedia Presentation Manager/2, is also required, which supports both DOS and Windows applications. The operating system is preloaded on the CD-ROM.

Prepackaged multimedia applications from both IBM and a variety of ISVs, along with multimedia authoring tools, allow the user to build custom multimedia applications. IBM has also made available a team of UltiMedia Business Partners to work with end users in developing custom multimedia applications for their company.

A variety of UltiMedia options for the PS/2 M57 SLC from IBM include the following:

- Touch display (Model 8516): Touch screen that does not use overlays.
- M-Motion Video Adapter/A: Allows for full-motion video adapting.
- PS/2 TV: Television tuner that allows for monitoring audio/video from a variety of sources, including cable TV, videodisk, VCR, or closed-circuit camera.
- ActionMedia II adapters: Compression of full-motion video and stored in a digital format.
- PS/2 3.5-inch rewritable optical drive: Available in both internal or external versions.

In late September, IBM introduced four new UltiMedia models:

- PS/2 UltiMedia M57 486 SLC2
- PS/2 UltiMedia DV M57 486SLC2
- PS/2 UltiMedia M77 486
- PS/2 UltiMedia M77 486 DX2

These models come standard with 8MB RAM and 212MB hard drives, and will be available by the end of the year.

Dataquest Perspective

In early September 1992, the IBM Personal Computer Company was created in order to reverse IBM's market share slide. This has resulted in a slew of new product introductions, including the four new UltiMedia systems. More importantly, the price of the original UltiMedia M57SLC was reduced from $5,995 to $3,355. The new independent subsidiary can now be price-competitive with its multimedia systems.

IBM has chosen to create its own multimedia hardware and software specifications, instead of those set by the MPC Council, and the reason is simple: OS/2 2.0 versus Windows 3.1. At this point, there is no indication that the MPC Council would consider adding an alternative operating environment to its specification. The significant installed base of Windows 3.0 and 3.1 users, coupled with the increasing number of vendors creating MPC-compliant systems, indicates the popularity of Windows. Though it was a bold move for IBM to set its own multimedia standards, it was predictable. It had no choice but to support its proprietary operating system.

The success of the PS/2 UltiMedia M57 SLC will depend on whether the end user views the UltiMedia PC as a viable alternative to any of the multimedia PCs available. The differentiation lies in the operating environments. There will always be OS/2 and Windows loyalists, and IBM certainly anticipates a percentage of UltiMedia PC sales because of the loyalty factor. The question is whether IBM can persuade nonloyalists to forgo purchasing an MPC in favor of an UltiMedia PC.

Leading Edge Products Inc.

Corporate Statistics

Headquarters Location	Westborough, Massachusetts
President and CEO	Albert J. Agbay
Founded	1980
Fiscal 1991 Revenue	$109.3 million
Number of Employees	75

Overview

Founded in 1980, Leading Edge is a wholly owned subsidiary of Daewoo Telecom Company Ltd., part of Korea's $22 billion Daewoo Group. Leading Edge helped establish the PC "clone" market for IBM PCs with the introduction of the Model D PC in 1984. Since then, the company has installed nearly 1 million systems worldwide. Leading Edge sells desktop, laptop, and notebook computers as well as monitors.

Strategy

Leading Edge's product strategy focuses on competitive pricing while supplying channel members with respectable margins. Its direction will focus on strengthening both its portable and desktop product lines through feature enhancements to existing products, and introduction of evolutionary new products, such as color notebooks and multimedia systems. Leading Edge will continue to focus on developing high-end products, including fully modular and upgradable systems. It will also continue to offer a complete line of peripheral products, including monitors, mice, and modems.

Leading Edge employs a controlled-distribution system to reach its customers. It controls and monitors the number of distributors, thus allowing the distributors to sustain proper margins and territories for each distributor. By using distributors as its primary distribution vehicle, Leading Edge takes advantage of the distributors' inherent efficiencies, which include timely product shipments, variety of products offerings, technical assistance, financing, and competitive prices to resellers. Leading Edge authorized resellers then add value-added benefits of software, customization, service, training, and proximity.

Through its controlled distribution plan, Leading Edge has forged alliances with the following distributors, as well as others:

- Almo Distributing Company
- CAM/PRC
- Daistek
- Distribution Plus
- Futureware Distribution
- Ingram Micro
- Tech Data Corporation

Leading Edge also provides extensive support and service both directly to the end user and through the channel. The program is designed to support Leading Edge's distribution strategy, by instituting a series of service programs for the channel as well as for end users. The company's program for distributors/resellers includes unlimited toll-free technical support, technical product training, warranty reimbursement, and 24-hour warranty exchange for parts. In addition, Leading Edge has made investment in reseller certification programs and training seminars.

The end user can call upon the resellers for service and support or the company itself for product support and service. It also offers an innovative warranty program that allows the end user to choose among various programs ranging from simple parts and labor to on-site contracts.

Products

Leading Edge has nine multimedia systems powered by the Intel 386SX microprocessor (16 or 20 MHz), 386DX 33-MHz, and 486SX 20-MHz processors. The models include the Multimedia SX-20 Plus series, the Multimedia SX-20c series, the Multimedia-Mini Tower DX/33 series, and the Multimedia 486/SX-20 series. Prices range from $1,799 to $3,300, depending on the configuration. The possible configurations are listed in Table 5-3.

Dataquest Perspective

Leading Edge is a company that is well suited for the clone market; its distribution system is well established and responsive, its service and support functions properly, and its products are priced to compete in this commodity market. However, the multimedia hardware market is far from a commodity at this time. Dataquest takes two important issues with Leading Edge's offerings in the multimedia market: sheer computer power and unsuitable configurations.

Multimedia applications performed on a 386SX 16- or 20-MHz machine are impractical and a bit uncomfortable. Applications run at a dogged pace, providing for inconsistent audio and video. Even the 386DX 33-MHz option will still feel a bit awkward when running graphics-intensive operating environments and multimedia applications. Shipping a "multimedia" machine with only 2MB of RAM standard should be a crime with a mandatory jail sentence.

Table 5-3
Leading Edge Product Configurations

Feature	Specification
CPU	Intel 386SX 16- or 20-MHz Intel 386DX 33-MHz Intel 486SX 20-MHz
RAM	1MB, total of 16MB
Floppy Drive(s)	1.2MB and/or 1.44MB
Hard Drive(s)	44/84/130MB, 213MB
Video	800 x 600/16 colors, 256KB video memory
Storage Bays	Four bays
Slots	Four 16-bit slots
Ports	One parallel, two serial, and one MS-BUS mouse
CD-ROM	Internal CD-ROM drive
Software	MS-DOS 5.0, Viruscan
Peripherals (Optional)	Mouse, headphones, stereo speakers, and sound card
CD Titles (Optional)	Illustrated Encyclopedia, Interactive Storytime, Microsoft Works for Windows and Bookshelf for Windows, Time Table of History, Family Education Collection
Warranty	6-month on-site or 20-month carry-in

Source: Leading Edge Products Inc.

In fact, most applications will not even load unless there is 4MB of RAM. For all practical purposes, Windows will not run with less than 4MB.

If the end user is using the machine for everyday work such as word processing, spreadsheet, and database work, as well as creating multimedia presentations (not an unlikely scenario), a 130MB hard drive will not be suitable. With a 213MB hard drive in its repertoire, Leading Edge has chosen to configure it to one of the Mini-Tower DX/33 series. Video (moving or still pictures) off a CD-ROM library can be edited, but it cannot be loaded back onto the CD. These video files have massive storage requirements, even for the smallest still picture. In all likelihood, users will need a minimum of 200MB or more simply to load the programs, data files, video files, and audio files.

Although it is true that the early bird gets the worm, it is also true that sometimes the early worm gets eaten. In this case, Leading Edge may be the early worm. Although it was one of the first to market multimedia PCs, it has little in the way of standard equipment configurations to offer the end user. Dataquest believes that Leading Edge should bite the bullet on some of its options and offer a true multimedia system, one with enough disk space, RAM, and CPU power to execute the snappy multimedia applications now available. In the near future, multimedia applications will require 8MB of RAM and 20MB or more of disk space, and with Leading Edge's current configurations, the end user is left in the cold.

NCR

Corporate Statistics

Headquarters Location	Dayton, Ohio
Chairman and CEO	Gilbert P. Williamson
President	R. Elton White
Founded	1884
Fiscal 1991 Revenue	$6.3 Billion
Number of Employees	55,000

Overview

NCR, the Networked Computing Resource of AT&T, was founded in 1884 by John H. Patterson as National Cash Register. The company was acquired by AT&T in 1991. NCR develops, manufactures, markets, supports, and services enterprisewide information systems for worldwide markets.

NCR has long been a supplier to large enterprises and now is throwing its hat in the ring as a supplier of multimedia systems to large businesses. In fact, the company largely is ignoring the home multimedia market and focusing on its core business. According to Assistant Vice President Neil Whittington, "For business users today, we are delivering a combination of crisp graphics, stereo audio, and full-motion, digital-video capabilities that will capture the interest of business trainees in an interactive way."

Strategy

NCR's System 3000 Model 3331 Multimedia Learning Station is the company's first offering to the multimedia market. The NCR learning station will be used as an online business training and education system for large NCR customers that train new employees frequently. The company is placing heavy emphasis on computer-based training (CBT) and is positioning its product to take advantage of this growing market.

Mr. Whittington says that NCR's intent was "to create a business tool that is more economical than traditional classroom-based training, and can be used at any time and in almost any location. By creating an interactive course, a trainer can replicate a training course throughout many branch offices, and it will be useful for a long time to come."

Key features include the following:

- Intel's 486SX and 486DX microprocessors
- Full-motion digital video

- CD-quality audio provided by MediaVision's integrated 16-bit digital audio technology, which allows users to create and alter sounds using industry standard MIDI or wave form audio, or play consumer musical compact discs through the system
- 256-color graphics chip with 1024 x 768 resolution

Other key features include Fluent Inc.'s software digital video playback, AimTech's IconAuthor runtime module, DVI software playback, CD-ROM (with SCSI adapter) drive with MS-DOS 5.0 and Windows 3.1, one serial and one parallel port, and a Yamaha 20-voice stereo synthesizer.

NCR expects to deliver this product starting in August 1992 with a price of $5,300. The NCR 3331 Multimedia Learning Station will be marketed through NCR's direct and indirect sales channels, including VARs, distributors, OEMs, dealers, and systems integrators.

Dataquest Perspective

NCR has coupled a concise marketing strategy with proper product positioning to take full advantage of an emerging market. The Multimedia Learning Station is packed with multimedia features and the needed processing power to really make a splash in the pool of multimedia. Dataquest expects the NCR 3331 Multimedia Learning Station to be successful for two reasons: The company has a focused product strategy for the 3331, and the 3331 comes with the necessary hardware.

NCR has successfully identified an area in which it can use its strength to provide enterprising hardware and software solutions, while simultaneously employing multimedia technologies to enter the CBT market. NCR is not pursuing the home market because it does not know anything about the home market. The company chose to focus its efforts in an area in which it can make a difference—a sound business strategy. The 3331 is priced accordingly for its target market and will be sold through already existing and proven channels. The 3331 was originally designed as a CBT machine for large corporations.

Hardware requirements for CBT are demanding because of video and audio requirements. NCR is using the most current technologies to provide its users with the best possible product. The company has aligned itself with Fluent Inc. and AimTech to strategically take advantage of these companies' expertise in the multimedia-software solutions market. Fluent provides the 3331 with the ability to play back digital video. AimTech's IconAuthor allows end users to develop in-house multimedia applications.

Dataquest expects NCR to do quite well in the CBT market by exploiting its expertise and technology. The concise marketing strategy combined with a product specifically designed for that market will allow NCR to build an early reputation as a corporate multimedia supplier for the CBT market.

NeXT Computer Inc.

Corporate Statistics

Headquarters Location	Redwood City, California
Chairman and CEO	Steven P. Jobs
President and COO	Peter Van Cuylenburg
Founded	1985
Fiscal 1991 Revenue	$108 million
Number of Employees	570

Overview

NeXT Computer Inc. designs, manufactures, and markets workstations based upon the proprietary NeXTstep object-oriented operating system. NeXT markets its computers to medium-size and large organizations to develop mission-critical custom applications as well as to run a suite of productivity applications. More than 80 percent of customers that purchase NeXT systems are from the business and government sectors, with the balance of sales going into higher-education institutions. Customers in the business arena may obtain NeXT systems from independent dealers, VARs, or directly from the company, while government customers may utilize federal systems integrators, the General Services Administration (GSA) list, or NeXT to purchase a system. Finally, NeXT uses a campus reseller network comprising on-campus computer dealers and university bookstores to target the higher-education environment.

Products

NeXT offers five object-oriented workstations for the corporate, government, and higher-education environments: the original NeXTcube, NeXTcube Turbo, NeXTstation Turbo, NeXTstation Turbo Color, and NeXTdimension, a board that is available separately or can be preinstalled on a NeXTcube. A comparison of the various workstations is shown in Table 5-4.

From a hardware perspective, NeXT has created systems with inherent multimedia capabilities. Motorola's 56001 digital signal processing (DSP) chip, built-in microphone, and audio circuitry are standard features in every NeXT computer. Developers can take advantage of these built-in features to incorporate voice, CD-quality sound, and music into their multimedia applications.

Video capabilities are greatly enhanced with the introduction of NeXTdimension, a board that goes into a NeXTcube. Though the NeXTstep operating system supports video objects, the addition of the NeXTdimension board, which utilizes an Intel i860 33-MHz RISC processor, provides the versatility to create full-fledged multimedia programs. The robust RISC processor allows for accelerated graphics and full-color imaging, while the video input and output capabilities allow the user to connect the board to a choice of video sources, such as a laser disk player, video camera, or

Table 5-4
NeXT Product Configurations

	NeXTcube Turbo	NeXTstation Turbo
Processor	33-MHz Motorola 68040	33-MHz Motorola 68040
Sound Chip	Motorola 56001 DSP	Motorola 56001 DSP
Sound I/O	Built-in sound I/O	Built-in sound I/O
RAM (MB)	16	8
Display	17 b/w MegaPixel	17 b/w MegaPixel
Slots	3 NeXTbus slots	-
Ports	SCSI, RS-423 serial (2), DSP I/O, display, laser printer, twisted and twin	SCSI, RS-423 serial (2), DSP I/O, display, laser printer, twisted and twin
	Ethernet	Ethernet
Floppy Drive (MB)	NeXT 2.88	NeXT 2.88
Hard Drive (MB)	400	250
Color	Monochrome	Monochrome
	NeXTstation Turbo Color	NeXTdimension
Processor	33-MHz Motorola 68040	33-MHz Motorola 68040
Sound Chip	Motorola 56001 DSP	Motorola 56001 DSP
Sound I/O	External sound box	External sound box
RAM (MB)	16	32
Display	17 MegaPixel Color	17 MegaPixel Color
Slots	-	3 NeXTbus slots
Ports	SCSI, RS-423 serial (2), DSP I/O, display, laser printer, twisted and twin	SCSI, RS-423 serial (2), DSP I/O, display, laser printer, twisted and twin
	Ethernet	Ethernet
Floppy Drive (MB)	NeXT 2.88	NeXT 2.88
Hard Drive (MB)	250	400
Color	16-bit color	32-bit color

Source: NeXT Computer Inc., New Media

videocassette recorder (VCR). Concurrently, incoming video images can be displayed in a window to provide the user with a complete visual experience.

The object-oriented capabilities of NeXT's workstations differentiate these systems from other multimedia systems available. The NeXT-step object-oriented operating environment allows for custom applications to be developed much faster than traditional software applications. Features of the recently released NeXTstep 3.0 include the following bundling of various object kits:

- Database Kit (DBKit): Applies object-oriented capabilities to database application development, and provides a single interface to SQL databases from multiple vendors.
- 3-D Graphics Kit (3DKit): Allows for integration of 3-D graphics into existing NeXTstep applications, based on Pixar's RenderMan standard for 3-D graphics.
- Distributed Objects: Enables messaging between objects within a NeXTstep application to messaging between different applications and across networks.
- Object Links: Based on Distributed Objects, a multimedia hyperlinking system that allows documents to share dynamic information.

Strategy

NeXT underwent a company reorganization during March 1992 that resulted in a commitment toward strengthening its position in the business and financial communities. In contrast to other workstation vendors whose products are designed for the technical environment such as science and engineering, NeXT states that its workstations are structured for mainstream business and professional environment, yet have the same capabilities of similar technical workstations.

The company plans to utilize the flexibility of its NeXTstep operating system to quickly develop custom applications for these two environments. The ability to leverage objects created for one application for reuse in other applications will allow software developers to bring products to market quicker. NeXT is also hopeful that its own customers will continue developing custom applications for their own organizations.

In concert with its business/professional focus, NeXT is promoting its systems as tools to create mission-critical applications. The company believes that these applications are vital in the corporate arena, especially in the financial market. Mission-critical applications include online transaction processing (OLTP) applications used by financial brokers. (OLTP is a message- or transaction-driven process that includes predefined structured changes, including updates, additions, and deletions to common databases shared by multiple users.) Similarly, the banking industry would benefit from a system that would provide quick retrieval of customer account information. By further penetrating these industries, NeXT is boldly encroaching an area once reserved only for midrange- and mainframe-computing environments.

Dataquest Perspective

Ever since Steve Jobs launched NeXT in 1985, the industry has waited to see whether he can replicate the success he had with

Apple Computer. Though it would be unfair to judge NeXT based on the phenomenal growth at Apple during its first few years, it is fair to say that the company's inability to substantially grow its installed base forced NeXT to rethink its business plan. Although it is commendable that NeXT is now focusing its efforts in the business and professional environments, it may be doing so at the expense of promoting its multimedia efforts.

As is the case with the entire multimedia market, there is a lack of multimedia applications for NeXT's proprietary platform. Coupled with management's decision to alter its business strategy, multimedia developers may not be inclined to create applications for NeXT systems. This would be unfortunate, because the NeXT platform is as close to multimedia-capable as any machine on the market. NeXT must continue forging relationships with these developers. If NeXT does not have the variety and amount of applications to compete with other workstation manufacturers, it will squander an excellent opportunity to exploit its inherent multimedia features.

There is nothing wrong with marketing the NeXT systems as corporate solutions. The concern is whether the company will have the resources and/or commitment in the near term to furthering its multimedia efforts. NeXT must be wary of alienating itself from the multimedia market during its transition. If it can avoid this, it can effectively position itself as a viable multimedia computing platform in the corporate environment.

Silicon Graphics Inc.

Corporate Statistics

Headquarters Location	Mountain View, California
Chairman of the Board	James H. Clark
President and CEO	Edward McCracken
Founded	1982
Fiscal 1991 Revenue (ended 6/30/91)	$550 million
Fiscal 1992 Revenue (ended 6/30/92)	$867 million
Number of Employees	3,500

Overview

Formed in 1982, Silicon Graphics Inc. (SGI) is a pioneer in visual computing systems. The company designs and manufactures workstations targeted to scientists, engineers, and other professionals who require the development, analysis, and simulation of objects in a three-dimensional (3-D) environment. The primary industries that Silicon Graphics targets include visual simulation, manufacturing, science and research, and graphic arts and animation. In 1991, Silicon Graphics introduced the IRIS Indigo workstation, which the company is positioning as its multimedia-capable hardware product.

The Indigo product line comprises four models, ranging from an entry-level system to an advanced desktop graphics offering.

Financials and Market Position

Silicon Graphics' fiscal 1992 revenue totaled about $867 million. Sales of its IRIS Indigo workstation, introduced during the third quarter of 1991, were about $30 million.

Strategy

Silicon Graphics realizes that its customers are searching for new and more expressive methods to communicate their ideas, and understands that multimedia is the vehicle to provide these next-generation communications solutions. Further, the company acknowledges that multimedia technology is a natural progression for its workstations.

Digital media, described as a core technology available on SGI systems, is the term that SGI gave to what it believes is an evolutionary advance in computers. Digital media-capable workstations allow users the simultaneous access to 3-D graphics, audio, video, still images, animation, and text. SGI hopes to refine its digital media process over the next few years, and to replicate the success it has had in developing workstations capable of advanced 3-D graphics. To that end, SGI recently announced a digital media solutions environment, comprising SGI audio/video hardware, programming libraries, end-user tools, and third-party hardware/software products.

Silicon Graphics differentiated itself from other workstation vendors in its approach to multimedia system design. Whereas conventional workstations must be supplemented with add-on components to achieve true multimedia capability, SGI took a total integration approach. This means that the ability to utilize all forms of digital media is already built into the machine, making the system multimedia-ready out of the box.

Regarding the distribution strategy for the IRIS Indigo, SGI plans to use the same channels as it has for its other IRIS workstations, including a direct sales force, VARs, authorized dealers, and OEMs. Additionally, the Indigo may be purchased through SGI's new direct marketing division, SGI Express.

Products

The introduction of the IRIS Indigo workstation signals Silicon Graphics' entry into the multimedia market and serves as a model, because SGI plans to eventually implement digital media in a total-integration approach across its entire product line. Targeted toward professionals in the fields of molecular modeling, architecture, computer-generated special effects and animation, computational fluid dynamics, medicine, mechanical engineering, and digital media software development, the IRIS Indigo's 3-D graphics, video, still imaging, animation, and audio capabilities make it possible for these individuals to have their work presented in an innovative fashion.

Powered by a 33-MHz RISC CPU, the IRIS Indigo incorporates 2-D and 3-D graphics with real-time audio and video capabilities. The digital audio tape (DAT) quality audio is integrated on the motherboard, while the graphics subsystem supports a video bus. An optional full-motion video board, IndigoVideo, allows the user to capture, store, and manipulate images from either a videotape, video camera, 24-bit still frame image, or laser disk player. The board plugs into the Indigo's graphics board via the system bus.

More than 20 third-party hardware and software applications are available for the IRIS Indigo, with a majority of the applications designed to take advantage of the Indigo's digital media capabilities. Examples of multimedia applications include the following:

- Showcase: A drawing and presentation package that integrates audio, video, text, 3-D objects, images, and patterns.
- Media Mosaic: Allows for full-motion performance with the ability to grab video frames, create movies, and save to disk.
- Media Mosaic-Audio: Accomplishes push-button capture, creation, and sound editing; takes advantage of built-in microphone and five audio ports.
- Digital Media Developers Kit: Allows the user to develop custom applications and includes sample source code; contains seven library modules (Audio Library, Audio File Library, CD-ROM Audio Library, DAT Library, MIDI Library, IndigoVideo Library, and Compression).

Dataquest Perspective

Silicon Graphics should be acknowledged for adopting the total-integration concept into the IRIS Indigo. Again, though no minimum multimedia standards are in place for workstation manufacturers, SGI has taken the end user into consideration by creating a multimedia-capable system directly from the factory. The IndigoVideo board is the only significant option not included with the system. SGI might consider offering the board standard with the other IRIS workstations that the company plans to make digital media-capable.

We believe that Silicon Graphics can take a more active role in working with multimedia standards organizations in creating a multimedia platform for workstation vendors. The IRIS Indigo shows SGI's innovative approach to multimedia, and Dataquest believes that the workstation industry would benefit tremendously from the thoughts, insights, and suggestions from Silicon Graphics. With its reputation as a technology leader, SGI can take a leadership position in working with the standards organizations to forge an effective multimedia platform.

Sun Microsystems Inc.

Corporate Statistics

Headquarters Location	Mountain View, California
Chairman, President, and CEO	Scott McNealy
Founded	1982
Fiscal 1991 Revenue (ended 6/30/91)	$3.2 billion
Fiscal 1992 Revenue (ended 6/30/92)	$3.6 billion
Number of Employees	12,800

Overview

Sun Microsystems, formed in 1982, has established itself as a leading client/server computing systems vendor. Its products include workstations, servers, networking products, system software, and other products utilizing the UNIX operating system. Subsidiaries have been developed to handle specific areas of product development. For example, Sun Microsystems Computer Corporation is responsible for hardware design, development, and manufacturing. Sun's SPARCstation line of workstations are multimedia-ready, and its newest product, the SPARCstation 10, is the first workstation with built-in ISDN capabilities, which allows for the merging of computer and telephone functions.

Financials and Market Position

Sun's fiscal 1992 revenue totaled about $3.6 billion. We estimate that about 10 percent of Sun's total 1991 shipments of workstations were configured to run multimedia applications. We expect that percentage to increase in 1992 because of the SPARCstation 10 introduction.

Strategy

Sun's vision of multimedia revolves around the concept of collaborative multimedia, defined by Sun as the combination of multimedia with desktop systems and networking to enable powerful communication systems for groups of people working in teams. This concept further reinforces its commitment to client/server computing. Sun acknowledges that multimedia may be perceived by many as a method for individual productivity gains on a PC, but it strongly believes that, through collaborative computing, far greater productivity gains may be realized through distributed multimedia applications in a client/server environment.

The company outlines the following four advantages that it believes differentiate the client/server environment from the PC platform when running multimedia applications:

- High-speed networking for quick data transfer within and among networks is possible.
- High performance is provided to attack compute-intensive applications.

- When necessary to access information simultaneously, the client/server's multitasking capabilities allow for convenient and timely access.
- The open systems approach allows for workgroup flexibility, giving users the ability to utilize a range of hardware and software products as needed.

Sun has established a three-point multimedia strategy that involves delivering multimedia-ready workstations, providing an open development environment, and forming key strategic partnerships.

The entire line of Sun SPARCstations are multimedia-ready systems. They have incorporated voice-quality audio since their introduction in 1989, and they also support high-resolution color graphics, large-screen displays, and a CD-ROM interface. Sun plans to increase the level of bundled multimedia support it offers in its future systems. There are more than 100 current multimedia-related third-party applications, encompassing products in the following areas: image manipulation and animation, audio and speech recognition, ISDN and fax, multimedia presentations, and video hardware/software.

Sun has made an effort to create a multimedia platform, based on industry standards, that will provide a unified multimedia programming interface for open systems developers. To that end, Sun is active in organizations including the Interactive Multimedia Association (IMA), which focuses on cross-platform multimedia standards. Areas that Sun is tracking for cross-platform interoperability include video, video and audio compression, communication, fax, CD-ROM, and graphics/imaging.

The company's belief in an open development environment for multimedia is an extension of its corporate philosophy toward open systems.

Cooperation among industry players is vital to the growth of multimedia, and Sun recognizes the need to cultivate various key strategic partnerships between hardware/software developers to formulate complete multimedia solutions and customers that can provide feedback by identifying requirements for a multimedia solutions package. Again, technology partnerships are critical, as Sun and its partners work on cross-platform development and standards efforts.

Products

Sun's entire line of SPARCstation workstations are considered multimedia-ready systems. To make Sun fully equipped for multimedia, end users can choose from more than 100 Sun and third-party multimedia hardware and software applications. For our report, we focus on the SPARCstation 10, the first workstation with built-in ISDN capabilities. ISDN availability is especially important in a networked, multimedia environment.

ISDN allows for the ability to send high-quality data, audio, still images, and full-motion video over digital phone lines. When ISDN becomes available worldwide (it is widely available in Europe and Japan), the implications will be tremendous, because a global wide-area network will be created in which multimedia communication may be shared over existing telephone lines. To enhance the audio capability of ISDN technology, Sun has provided CD-quality (16-bit) audio and a microphone as standard features on its SPARCstation 10 product family.

The SPARCstation 10 product family is Sun's high-end version of the SPARCstation desktop product line, which includes the entry-level SPARCstation ELC, SPARCstation IPC, SPARCstation IPX, and SPARCstation 2. It is the first workstation to include multiprocessing capabilities, and its modular design allows for customer-installable CPU upgradability. The end user can pull the SPARC module out of the motherboard and replace it with faster, next-generation CPUs. Multiprocessing systems allow for higher performance because more than one processor is used to execute multiple applications simultaneously, which is an advantage when running power-hungry applications such as multimedia.

All SPARCstation 10 models come bundled with OpenWindows V3 multimedia mail tool software, applications geared toward addressing collaborative work and multimedia communication. Multimedia applications include: XIL, an API that provides software and hardware developers with an interface to develop imaging and full-motion video products; VideoPix, a still-frame video capture board that allows users to capture and share video images across a network; and ShowMe, a computer conferencing software product that allows for graphics, images, and text to be shared on the network.

Sun has targeted the SPARCstation 10 toward "power users" in the commercial and technical markets, including computer-aided software engineering (CASE), electronic design automation (EDA), and mechanical computer-aided design (MCAD). Service workers in the financial services and insurance industries may also use the multimedia aspects of the SPARCstation 10.

Sun recently announced a multimedia training course entitled SunTutor: OpenWindows Environment for Users. Designed for new users of Sun workstations, SunTutor combines audio, video, text, graphics, and simulation to create an interactive training environment in which first-time Sun users can become familiar with their system. The self-paced course is an alternative to traditional classroom training and affords the user an opportunity to experience multimedia firsthand.

Dataquest Perspective

Unlike with PCs, there are no explicitly stated multimedia workstation specification standards. Until similar standards are set, workstation vendors can market their systems as "multimedia-ready," as Sun has done with its SPARCstations, which implies that third-party options such as a CD-ROM drive are necessary to make these systems multimedia-capable. By Dataquest's definition, we do not consider Sun's SPARCstation product line to be true multimedia machines. Instead, we refer to the systems as multimedia-ready, which means that additional features are necessary to achieve what we consider to be a *multimedia configuration*.

For its part, Sun is attempting through its involvement with IMA to forge an industry-standard multimedia workstation platform based on its philosophy of client/server computing in an open systems environment. Dataquest believes that the market will define the standards for a multimedia platform, and Sun to its credit has created strategic partnerships with its customers to identify platform and standards requirements.

Sun should also be commended for including built-in ISDN capabilities with its SPARCstation 10. ISDN's ability to digitally transmit audio, video, data, and text over existing telephone networks will soon make it the vehicle for multimedia communication. Coupled with the multiprocessing and upgradability features of the SPARCstation 10, Sun has created a desirable multimedia workstation.

Sun's concept of collaborative multimedia is consistent with its client/server computing philosophy. The collaborative tools available to employees have changed the way they work and, more importantly, they now work more efficiently. Because of Sun's success in providing networked computing solutions in the corporate environment, we believe that it can integrate its collaborative multimedia platform into the client/server computing arena.

Tandy Corporation

Corporate Statistics

Headquarters Location	Fort Worth, Texas
Chairman and CEO	John V. Roach
Founded	1919
Fiscal 1991 Revenue (ended 6/30/91)	$4.56 billion
Fiscal 1992 Revenue (ended 6/30/92)	$4.68 billion
Number of Employees	40,000

Overview

Tandy Corporation, founded in 1919, is a leading manufacturer of various consumer electronics items, including audio, video, telephony, and magnetic media products, as well as PCs. The company is also the largest consumer electronics and PC retailer in the United States, operating more than 7,400 stores and dealer/franchise outlets under the names Radio Shack, McDuff Electronics, VideoConcepts, The Edge in Electronics, and Computer City SuperCenter.

Tandy is considered one of the pioneers in multimedia computing. In 1988, it held initial discussions with Microsoft to chart the path for multimedia technology in PCs. Over the next two years, engineers from both companies were assigned the task of developing the minimum multimedia hardware specifications, which evolved to become the MPC hardware specification, announced in November 1990. As a founding member of the MPC Council, Tandy is acknowledged as the first company to introduce a fully integrated line of multimedia PCs.

Financials and Market Position

Tandy's overall revenue for 1991 totaled about $4.6 billion. Of this total, Dataquest estimates that 1991 sales of its first-generation multimedia PCs totaled about $28.2 million, based on about 9,100 unit shipments worldwide.

Strategy

Tandy believes that multimedia personal computing is a natural evolution of the PC and that end users are justified in demanding more features from their systems, including stereo sound, photorealistic images, and CD-ROM mass storage. Before the term "multimedia computing" became an industry buzzword, Tandy was already at work incorporating multimedia-type features into its PCs. For instance, it introduced the Tandy 1000 TL in 1987, the industry's first PC with built-in digital sound and playback capabilities. This example shows Tandy's ability to anticipate end-user needs and fulfill their demands. Also, with its expertise in the consumer electronics industry, Tandy recognized early on the potential of incorporating audio and video capabilities into its systems.

By opening a technology center dedicated to multimedia shortly before announcing its first line of multimedia PCs, Tandy reiterated its commitment to providing the resources necessary to support this new industry. The center, comprising multimedia training, application development, and the evaluation of new multimedia technologies and products, provides a solid foundation for ISVs to create a variety of multimedia applications while experimenting with the latest in multimedia hardware.

Extending this philosophy, Tandy distributed its first multimedia PCs to ISVs, as well as to publishers and selected Radio Shack business and education customers, before shipping in volume to its more than 7,000 Radio Shack Computer Centers and Radio Shack technology stores and dealers. Tandy understands the importance of software development to multimedia and will continue to work closely with the ISVs.

Products

Tandy's first line of fully configured multimedia PCs, introduced in May 1991, comprises five systems, each standard with a 3.5-inch floppy disk drive, 512K video memory for VGA Plus graphics, CD-ROM, and a multimedia expansion adapter with audio circuitry and CD-ROM interface. Preinstalled on the systems' hard drive are

MS-DOS 5.0 and Microsoft Windows' 3.0 graphical environment plus Multimedia Extensions 1.0. System models and configurations are as follows:

- 2500 SX Multimedia: 386SX/16-MHz, 2MB memory, 40MB HDD
- 2500 SX/20 Multimedia: 386SX/20-MHz, 4MB memory, 52MB HDD
- 4016 DX Multimedia: 386/16-MHz, 4MB memory, 52MB HDD
- 4025 LX Multimedia: 386/25-MHz, 4MB memory, 105MB HDD
- 4033 LX Multimedia: 386/33-MHz, 4MB memory, 105MB HDD

Tandy also introduced two upgrade kit versions, one with an internal CD-ROM and one with external. Each kit contains a CD-ROM drive, multimedia expansion adapter with audio circuitry and CD-ROM interface, and Microsoft Windows 3.0 plus Multimedia Extensions. Radio Shack also has made the internal CD-ROM drive available separately. The data transferability of the CD-ROM enables the ability to run multimedia graphics and high-fidelity audio.

The company's next generation of multimedia systems, introduced at COMDEX/Spring '92, reflects the natural progression of multimedia technology. The four additional models feature an enhanced video chip, designed by Tandy, with the ability to display up to 16 million colors on standard VGA monitors, and an audio board that provides true 16-bit digital stereo sound and allows for the mixing of various audio sources. Because the audio board includes the CD-ROM interface, only one expansion slot is required. These models come standard with 4MB system memory, 512K video memory, a CD-ROM drive, and both MS-DOS 5.0 and Windows 3.0 plus Multimedia Extensions. System models and configurations are as follows:

- 2500 SX/25 Multimedia: 386SX/25-MHz, 85MB HDD
- 4825 SX Multimedia: 486SX/25-MHz, 120MB HDD
- 4850 EP Multimedia: 486DX2/50-MHz, 120MB HDD
- 4833 LX/T Multimedia: 486DX/33-MHz, 120MB HDD

Tandy refers to these four systems as its Version 1.1 multimedia PCs. As with the original systems, upgrade kits are available. These newer kits are compatible with Version 1.1 specifications. We should note that these specifications are set by Tandy and are independent of the specifications set by the MPC Council.

The latest system offered by Tandy, the Sensation, is targeted at home, education, home-office, and small business environments. It offers a 486SX/25-MHz processor, 4MB system memory, a 107MB hard disk drive, a 3.5-inch floppy disk drive, a CD-ROM drive, a built-in modem (2400-bps with voice-mail capabilities, 4800 baud fax transmission), MPC sound on the main logic board with FM synthesizer, MS-DOS 5.0, Microsoft Windows 3.1, Microsoft Works for

Windows, and Microsoft Bookshelf for Windows. The system also comes standard with three online services, including Prodigy, America Online, and The Sierra Network. An optional feature is the PC/TV add-in board, which transforms the Sensation into a 122-channel, cable-ready tuner. Setting this system apart from other Tandy multimedia systems is incorporation of new WinMate organizer for Windows, comprising the following eight categories that may be opened by direct selection or by having a digitized voice describe the contents:

- In the Know: Accesses Microsoft Bookshelf for Windows.
- In Touch: Features Teleminder (telephone answering system) and Message Center (plays back messages in text or voice format).
- In the Bank: Accesses Microsoft Works for Windows tools, including financial
- In Control: Home inventory application for personal property.
- In Charge: Performs personal management functions (for example, scheduler and calendar).
- In Play: Learning games for children (teaching the alphabet, typing, math).
- In Print: Accommodates printing of banners, cards, signs, and name tags.
- Inside: Accesses standard Windows tools such as Control Panel, Paintbrush, and File Manager.

Dataquest Perspective

It is natural that Tandy would have a strong interest in multimedia. As both a leading consumer electronics and PC manufacturer, the company realized that it can leverage its technology expertise from its consumer electronics divisions and incorporate those features into its PCs. Furthermore, it can take advantage of its tremendous retail presence to distribute its multimedia systems. Besides its flagship Radio Shack chain, the recent launching of both the Computer City SuperCenters and Incredible Universe stores will aid in promoting its multimedia systems.

With a multimedia PC "infrastructure" in place, Tandy took the initiative by working with Microsoft to set the groundwork for multimedia hardware standards, while continuing to enhance its PCs with multimedia-type features. As an active, founding member of the MPC Council, Tandy has taken a leadership role in promoting multimedia computing. More importantly, it has the capital, technology, and distribution structure to effectively market its multimedia systems. Tandy has made tremendous contributions to multimedia, and its pioneering efforts should not be overlooked. Dataquest looks for Tandy to continue furthering its multimedia activities from both a company and industrywide point of view.

Dataquest Perspective

Opportunities for Success

Dataquest views the multimedia hardware market as the next great frontier for the PC and for upgrade kit vendors. Dataquest has identified the following areas as opportunities for success in the multimedia market:

- Digital video
- Networking
- Multimedia-specific distributors/need-specific design

Digital Video

Digital video capabilities will be the next sound board. Multimedia computing encompasses sound and video. Audio is only one of the two most compelling elements of multimedia. Video, the second element, is a bit more complex than sound for two main reasons: a video clip requires an extreme amount of space to store, and the nature of the data is much more complex than that of the most complex audio clip. Herein lies the opportunity: produce a digital video chip/board that allows the user to compress the image or video into a format easily stored and retrievable. However, the chip/board must not lose the robustness of the image in the compression process.

MPEG and JPEG compression are two proposed standards that the industry is inspecting. The sooner a standard can be established, the sooner more board manufacturers can enter the business. The size of the market is so small that vendors are specialized to the markets they want to target. The overall market needs an inexpensive general board that permits the end user the ability to integrate video into everyday applications. Once the digital video market is expanded, the multimedia market will have another leg to stand on.

Networking

The ability to network computers and, in a sense, people, is integral in today's business environment. Systems with multimedia capabilities are no exception. The ability to transfer rich data types (audio and video integrated with text) will be in high demand.

One of the most anticipated uses of multimedia computing is video mail, which initially will be used much the same as e-mail, except that a digital video/audiotaped message will be sent to the address chosen. Today's networking systems are not set up to receive such massive files, nor can they transport them in a timely fashion. The ability to communicate through the computer has been an end-user demand from the beginning.

Another application on the horizon is video teleconferencing through the desktop, which would enable the ability to communicate between work groups in two different locations and the ability to view and interactively change an IC circuit designed between these two work groups. Dataquest views multimedia networking as an opportunity (see Chapter 7 of this report, "Multimedia Telecommunications").

Multimedia Distributors/Need-Specific Design

As with any new product or market segment, the problem of getting the product to the people who want it must be faced. Dataquest believes that there is an opportunity for multimedia distributors or integrators. Today's MEM, for the most part, are kluge machines. That is, they have been taken off an existing assembly line and given multimedia capabilities. They have not been designed from the ground up for a specific task. An exception would be NCR's Model 3331, which is designed for the CBT market.

Dataquest believes that there is a need for systems integration in the multimedia arena. For the most part, systems today are simply generic multimedia machines built for a market that has not really been defined or segmented. The multimedia needs for schools are certainly different from those of a Fortune 500 company looking for a CBT system. Why should either have to sacrifice for the other? Systems integrators will determine the needs of a client and piece together a system that will meet those specific needs. In essence, the systems integrators will be able to segment the marketplace by specific needs and address those needs.

Vendors hoping to compete in the multimedia market will soon realize that there is no such thing as generic multimedia needs. Vendors will either profit from selling on an OEM basis to systems integrators or they will follow the path of NCR, by designing a systems to meet the needs of various segments of the market. IBM would not try to sell one of its Olympic Kiosks to a Fortune 500 company, so end users should not be forced to buy something that does not meet their needs. Dataquest expects operation-specific systems to be developed over the next 12 months to meet the needs of the various segments of the multimedia market.

Barriers to Success

Despite advancement in multimedia technologies, there are roadblocks that may inhibit acceptance of multimedia as a viable computing environment. Dataquest has identified a few of these barriers to success in multimedia computing, as follows:

- Acceptance of new technology
- Lack of multimedia applications
- Production capacity of CD-ROM drives
- Lack of perceived need
- Cost
- Budget cuts in education

Acceptance of New Technology

Human nature makes us reluctant to change. Multimedia hardware vendors will have to take into consideration the reluctance to accept multimedia as a viable computing environment when marketing their products. As with any new technology, it will take time for the market to accept and become comfortable with multimedia computing. The multitude of features can be intimidating to new multimedia systems users. Most hardware vendors provide online tutorials to familiarize these users, but as the market grows and corporations begin implementing these systems, formal classroom training sessions may be necessary to speed the learning curve. The success of multimedia will in part depend on how quickly the market can adapt to multimedia computing.

Lack of Multimedia Applications

A major factor in the relative success or failure of a hardware product historically is in availability of software. Multimedia hardware vendors are aware of this and have been working with ISVs to ensure that a variety of multimedia solutions will be developed. But despite their efforts, there are a lack of multimedia applications at present, especially for business use. Though Dataquest expects the growth of multimedia applications for business to occur within the next 12 to 18 months, the lack of applications prevents corporations from investing in multimedia hardware. This lag in software availability represents lost revenue opportunities for hardware vendors that have already invested substantial time and effort in getting their products to market.

Production Capacity of CD-ROM Drives

Just as the lack of multimedia applications has tempered market growth, availability of CD-ROM drives will play a major role in determining multimedia's market potential. Demand for CD-ROM drives has increased tremendously, and CD-ROM manufacturers have been hard-pressed to meet these demand requirements. And, with the multimedia market poised to take off as more applications become available, even more pressure will be placed on these manufacturers. Unmet demand requirements will be detrimental to both the multimedia hardware and upgrade kit manufacturers. Though designated production capacity is a barrier, it may be an opportunity for new CD-ROM drive manufacturers to enter the market. The fear is that these "clone" drive manufacturers may flood the market with low-cost, though inferior products, much as clone PC manufacturers did during their initial shipments in the early and mid-1980s. It is hoped that the current drive manufacturers will be able to maintain production schedules while producing top-quality CD-ROM drives.

Lack of Perceived Need

Dramatic new technologies offered through multimedia should appeal to a majority of the market, though a certain percentage will question the need for such an environment. Some will argue that the business environment has gotten along fine without multimedia. The features are exotic, but are they necessary? And why invest in a technology that exceeds the computing requirements of a given company? The only way to combat these issues is to demonstrate the value-added features that multimedia can bring to the desktop. This lack of perceived need relates to the acceptance of new technology. Once users are properly trained and have reached a comfort level with multimedia, the system may be perceived as a need.

Cost

Much attention has been focused on the cost of multimedia systems because of the price wars in the PC industry. While traditional PC and workstation vendors have engaged in price cutting, some anticipate the same to occur with multimedia systems. This simply will not happen at present. From a basic economic standpoint, the multimedia vendors are bound by the component vendors' costs, especially CD-ROM drive manufacturers. It would be impossible for them to lower their system prices unless their component costs are reduced. Unlike traditional systems vendors, multimedia hardware vendors are bound by a rigid cost structure and at the same time attempt to establish a price that will attract a market for this new technology. The price premium that multimedia systems vendors must charge may be an initial barrier. But if they can communicate the value-added message to the corporate, home, and education environments, they can effectively differentiate their products from traditional PCs, which essentially have become commodity items.

Budget Cuts in Education

We have already witnessed the benefits of traditional computers in education over the past decade, especially in the K-12 grade levels. Interactive, multisensory multimedia computers could have substantial impact in the classroom. This vision, however, may never be fully realized because budget cuts have plagued the educational system for the past few years.

A greater effort must be made toward integrating computers into the national curriculum. Education officials and teachers can work with software developers to create a greater variety of education-specific applications. Also, multimedia systems vendors can take a bottom-up approach to system design by creating systems specifically for the classroom. The systems vendors and software developers will work from their end to design products for this market, but they will need assistance from the market itself. It is vital that education officials do what they can, in light of this difficult situation, to continue allocating resources for computers, specifically to multimedia systems. These systems will not only enhance the education experience, but more importantly will prepare students for occupations that are increasingly becoming computer-dependent.

Upgrade Kits and Boards

This section is a self-contained discussion of the markets for computer digital video and sound boards, as well as an overview of multimedia upgrade kits.

Definitions

Multimedia enhancement products for PC and workstation platforms can come in a variety of forms. In this section we will examine add-in boards and upgrade kits. CD-ROMs, a major element of multimedia upgrading, are covered in Chapter 6 of this report, "Multimedia Storage Requirements."

Sound and Video Boards

Sound and video boards are add-in boards for PCs and workstations that expand the platform's sensory capabilities. Sound boards provide the input, output, and processing capability for voice, sounds, music, and MIDI (encoded music). They also provide the necessary interfaces to microphones, speakers, and recording and playback devices such as CD-ROM or CD-audio, and musical instruments (via the MIDI connection).

Video boards allow platforms to process motion video and still images, and provide the necessary interfaces to video sources and storage (for example, VCR tape, TV signals, camcorders, and CD-ROM) and to the platform's display subsystem.

These boards can be marketed as part of upgrade kits, and sold to platform OEMs for incorporation into multimedia systems, VARs, or directly to the public.

Upgrade Kits

Upgrade kits represent bundled elements used to upgrade platforms to perform multimedia tasks including the boards mentioned earlier, multimedia software, and CD-ROM drives. In this analysis, Dataquest only counts upgrade kits that have a CD-ROM and a sound board as a minimum configuration. These upgrade kits are packaged by OEMs and VARs, and are sold principally through the various retail channels.

Market Drivers and Dynamics

Aftermarket and point-of-sale purchases are the volume channel of upgrade kits and add-in boards. The fierce battle to cut prices to secure market share is keeping most computer vendors busy watching margins and away from immediate incorporation of multimedia features in their products. As a direct effect of systems being cheaper, there is an opportunity to sell upgrade kits or their elements. This is expected to continue to be the case for the next two to three years, until multimedia features become embedded in more platforms and as standards settle out.

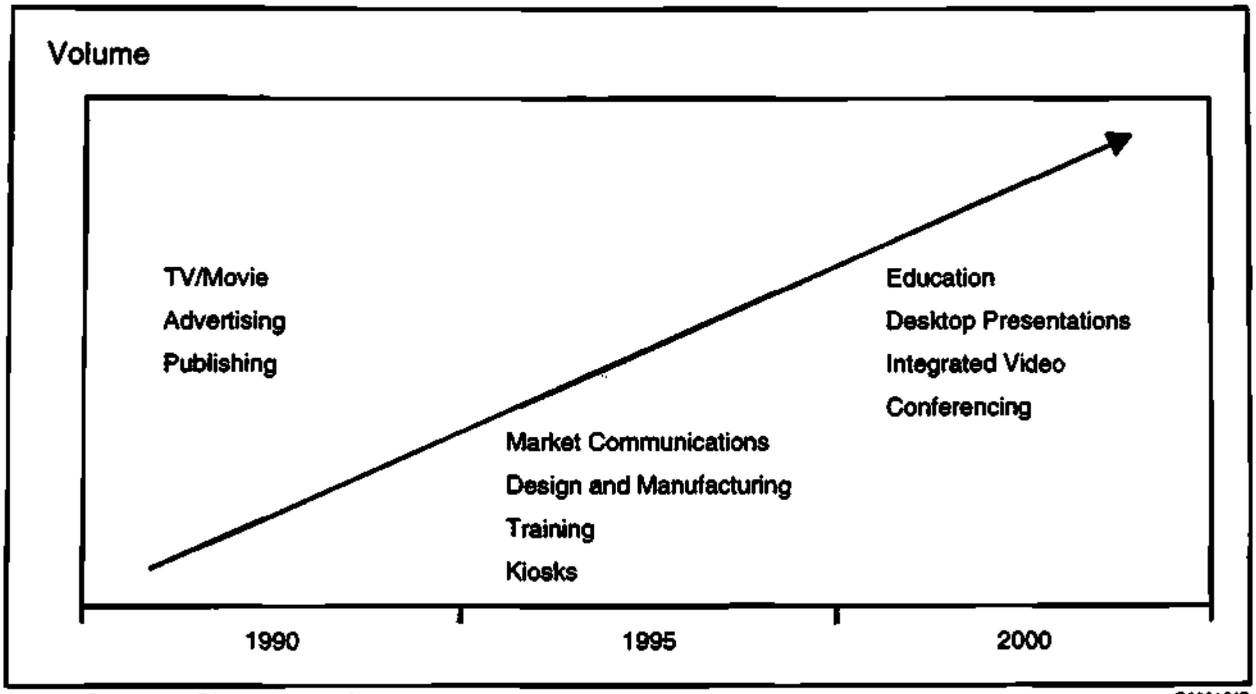
Digital Video: Can Be Seen

Digital video and with video conferencing are the most challenging aspects of computer multimedia. The challenge comes from the combined criteria of achieving acceptable quality at a reasonable price. There is little doubt that the hardware designers will hit these targets in the near future. The only question is when and how users will employ video capability in computing applications.

Figure 5-12 presents one scenario as to how and when digital video will be applied in various markets. Early adopters of computer-based image and video manipulation include TV and movie studios, advertising agencies/service bureaus, and publishers, all of whom have immediate need to convert video to a digital form for editing. The next wave of users includes the more sophisticated corporate users such as market communications specialists and training departments. We also expect scientific, engineering, and design teams to expand graphic-based visualization into video-based. Kiosks, or interactive computer platform-based booths, used for consumer information are also evolving into big users of digital video.

The third wave of digital video deployment comprises those applications that are the most cost-sensitive and require the longest time to develop compelling application and title software for. In this category fall mainstream office desktop and education markets.

Figure 5-12
Computer Digital Video Application Trend



Source: Dataquest (November 1992)
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Video Technology Migration

Digital video technology is changing dramatically. It has to in order to be employed in out-year applications noted in Figure 5-12. Digital video add-in boards come in a spectrum of prices and varieties ranging from frame grabbers to full motion with compression capability. Many features can also be achieved through interconnected daughter cards. Key features of digital video boards include the following:

- TV tuner: NTSC (United States and Japan), PAL (Europe), and SECAM (Europe), cable-compatible versions.
- Video I/O formats: Composite (standard video signal with chromiance and luminance signals combined), S-video (for example, laser disk and Hi8), broadcast, and VHS.
- Digitization: Conversion of standard analog video signals such as NTSC to YUV color space for computerized manipulation and subsequently conversion to RGB for display on the computer monitor (a basic requirement of digital video).
- Resolution and color: Usually traded off against each other, with VGA modes the most supported for IBM compatibles; scalability to different resolutions or window sizes; ultimate capability is full-screen, 24-bit color, at full motion (30 frames per second).
- Capture: Concerns buffering and storage of an image or a series of images that comprise a motion video; genlock is a feature that concerns the synchronization of disparate video sources.
- Special effects: Features such as hardware-based panning, cropping, scaling, chromakeying, filtering, color-brightness control, and zooming.
- Editing: Usually a multicard set with high-end features such as A/B roll (for transitions), edit decision list (EDL) management, and SMPTE time-code management; these systems run specialized software and run $2,000 to $15,000; companies such as Digital F/X (Apple), Matrox (IBM), and Paltex (IBM) provide desktop editing systems.
- File formats: Ability to work with different industry standard image file formats such as PICT, TIFF, or TARGA.
- Software support: Ability to work under popular operating environments such as Apple's QuickTime, Microsoft's AVI, or IBM's OS/2 2.0 Multimedia Presentation Manager, and with authoring packages.
- Sound support: On-board mono or stereo sound input/output, DSP, amplification, and synchronization with video.
- Compression: Hardware acceleration of standards such as JPEG, MPEG, QuickTime, and AVI compression and decompression.
- Graphics support: Overlay (text and graphics) and windowing operation.
- Other features: SCSI host adapter for CD-ROM interface.

The Video Future

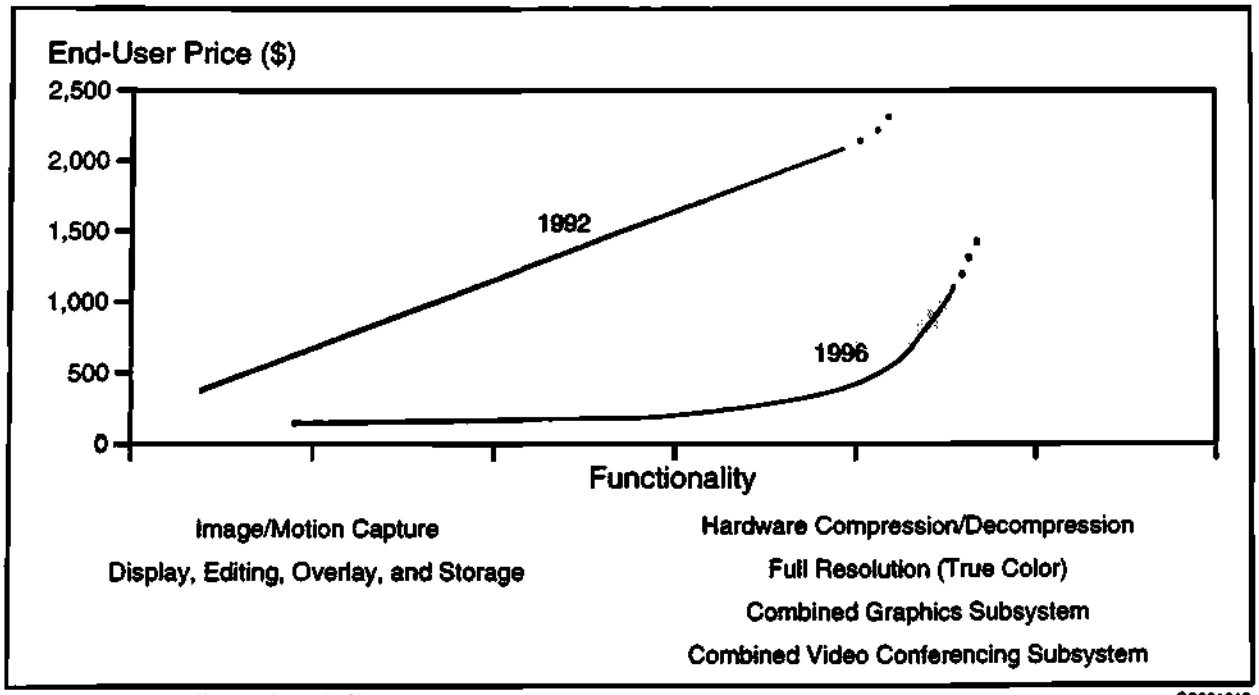
Figure 5-13 shows an evolutionary scenario of performance and price. Basic capture, display, overlay, editing, and storage are available today in products such as SuperMac's Video Spigot and Creative Labs' Video Blaster for a street price of about $400. High-end functionality including hardware compression acceleration is available for about $2,500 from companies such as Intel/IBM with their Action Media II. As for compression only, Storm Technologies' StormCard provides QuickTime (works with Video Spigot) compression functionality ($999).

The future will witness current low-end functionality moving into an even more affordable price range for mass appeal with prices reaching as low as $200 per board by 1996. We predict by that time frame boards with hardware compression could be about $300 by then as mass-produced compression accelerator chips enable a larger market. For a discussion of the involved digitization and compression technology, refer to Chapter 3, "Semiconductor Technologies and Opportunities in Multimedia."

Video OEMs

The list of companies providing digital video boards is long and the market fragmented. In many cases the companies already participate in the graphics board business and have extended their offerings into video and imaging as well. Some alliances are beginning to happen: RasterOps plans to acquire Truevision, IBM works with

Figure 5-13
Computer Digital Video Technology Trend



Source: Dataquest (November 1992)

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Intel (DVI, Action Media) and Video Logic, and Cardinal Technologies works with Fuji. Truevision is estimated to have about 20 percent of the 1992 market in revenue, and SuperMac about 8 percent. Video Logic, New Media Graphics, IBM/Intel, and Creative Labs each have 5 percent. The rest of the OEMs are expected to have less than $10 million in revenue. Table 5-5 lists leading OEMs and their offerings.

Many other companies are involved in digital video, including a growing contingent from the Asia/Pacific region, as follows:

- A.W. & Associates: Long Beach, California
- Avid: Burlington, Massachusetts
- Canon: Tokyo, Japan
- DesignTech: San Jose, California
- Digital F/X: Mountain View, California
- E-Machines: Beaverton, Oregon
- IEV International: Salt Lake City, Utah
- Genoa Systems: San Jose, California
- Kingston Technology: Taipei, Taiwan
- Magni Systems: Beaverton, Oregon
- New Media Graphics: Billerica, Massachusetts
- NewTek: Topeka, Kansas
- Newer Technology: Wichita, Kansas
- Optibase: Canoga Park, California
- Radius: San Jose, California
- Rapid Technology: Amherst, New York
- Visionetics: Taipei, Taiwan
- 50/50 Micro Electronics: Sunnyvale, California

Computer Digital Video Forecast

Figures 5-14 and 5-15 present Dataquest's forecast for digital video boards of all varieties. As usage expands into the broader markets, volume economics will develop and prices will come down substantially. We expect worldwide shipments to reach 1 million units during 1994. The outer years will see a blending of a growing percentage of compression-enabled boards, accounting for half of all boards by 1994. We further estimate that 20 percent of the computer digital video market will be a subsystem on the motherboard by 1996.

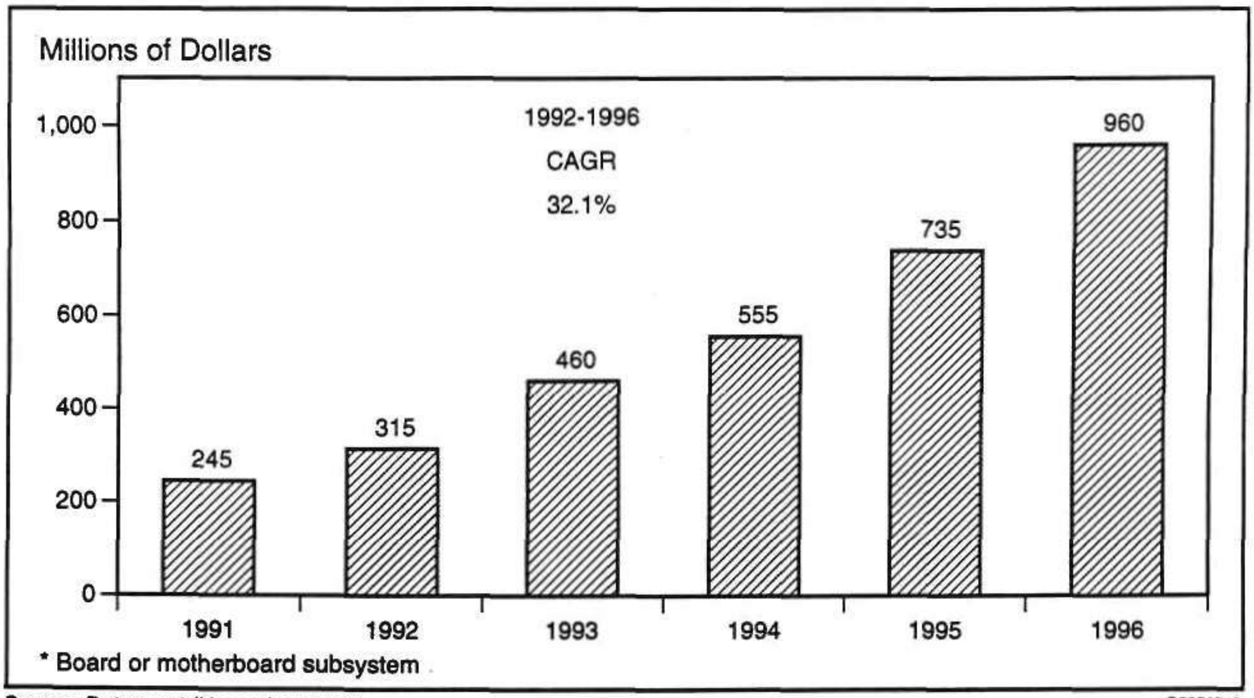
North America accounts for 75 percent of the market; that figure should drop to 55 percent by 1996 as Europe grows to 30 percent

Table 5-5
Examples of Computer Digital Video Offerings

Company	Location	Key Products
Cardinal Technologies	Lancaster, PA	SNAPplus, COMPIX, SOUNDvision (IBM)
CompuAdd	Austin, TX	TV/Video Board (IBM)
Creative Labs	Milpitas, CA	Video Blaster ($499 list)
	Singapore	(IBM)
Digital Vision	Dedham, MA	TelevEyes, ComputerEyes
Dolch Computer Systems	Milpitas, CA	JPEG-VIPER
Fluent Machines	Framingham, MA	Fluency (IBM)
Hauppauge Computer Works	Hauppauge, NY	Win/TV Series ($495 list) (IBM)
IBM	Atlanta, GA	M-Motion/Action Media II/PS/2 TV
Intel	Princeton, NJ	Action Media II (IBM)
Mass Microsystems	Sunnyvale, CA	QuickImage 24 (Apple)
Matrox Video Products	Quebec, Canada	Marvel (IBM)
New Video	Santa Monica, CA	EyeQ (Apple)
NeXT	Redwood City, CA	NeXTDimension (NeXT)
RasterOps	Santa Clara, CA	24XLT(S)V (Apple)
Storm Technologies	Mountain View, CA	StormCard ($999) (Apple)
Sun Microsystems	Mountain View, CA	VideoPix (SPARCstation)
SuperMac Technology	Sunnyvale, CA	VideoSpigot ($349 retail) (Apple)
Truevision	Indianapolis, IN	Bravado ($1,295), TARGA+ MCA (IBM)
Video Logic	Cambridge, MA,	DVA-4000, Mediator,
	London, United Kingdom	Rapier-24, MediaSpace (IBM, Apple)

Source: Dataquest (November 1992)

Figure 5-14
Worldwide Computer Digital Video* Market Forecast (Factory Revenue)



Source: Dataquest (November 1992)

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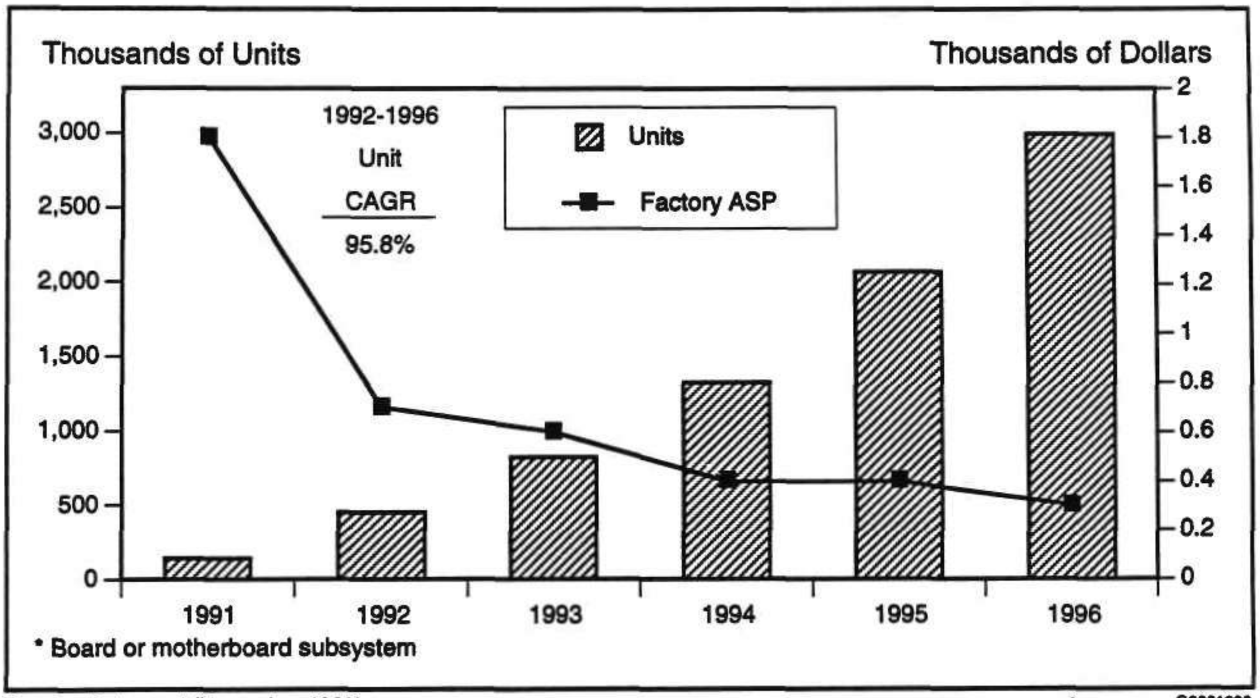
Figure 5-15
Worldwide Computer Digital Video* Market Forecast (Units and Factory ASP)



Source: Dataquest (November 1992)

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and Japan to 10 percent. Sales channels for digital video boards are expected be split among distribution, retail (stores and catalogs), and OEM.

Dataquest Perspective on Digital Video

We are optimistically realistic about the prospects for the use of digital video on computer platforms. The twin factors of software availability and dropping hardware prices will help stimulate demand. The early adopters such as publishers are indoctrinated already; next come the training and design visualization markets. The vast bulk of the market will not be available until later in the decade, when desktop use develops.

Software-driven decompression standards as supported by the major OS vendors will help jump-start usage as the magnetic disk drive becomes a convenient storage mechanism for content creators. Hardware compression acceleration is expected have a bigger presence during the next year, following a market scenario much as floating point and graphics controllers did. We expect board vendors to start consolidating with those with better alliances in order to survive. Existing graphics board houses stand a good chance of being among the chosen as graphics functions merge with video functionality.

Sound Boards: Boom

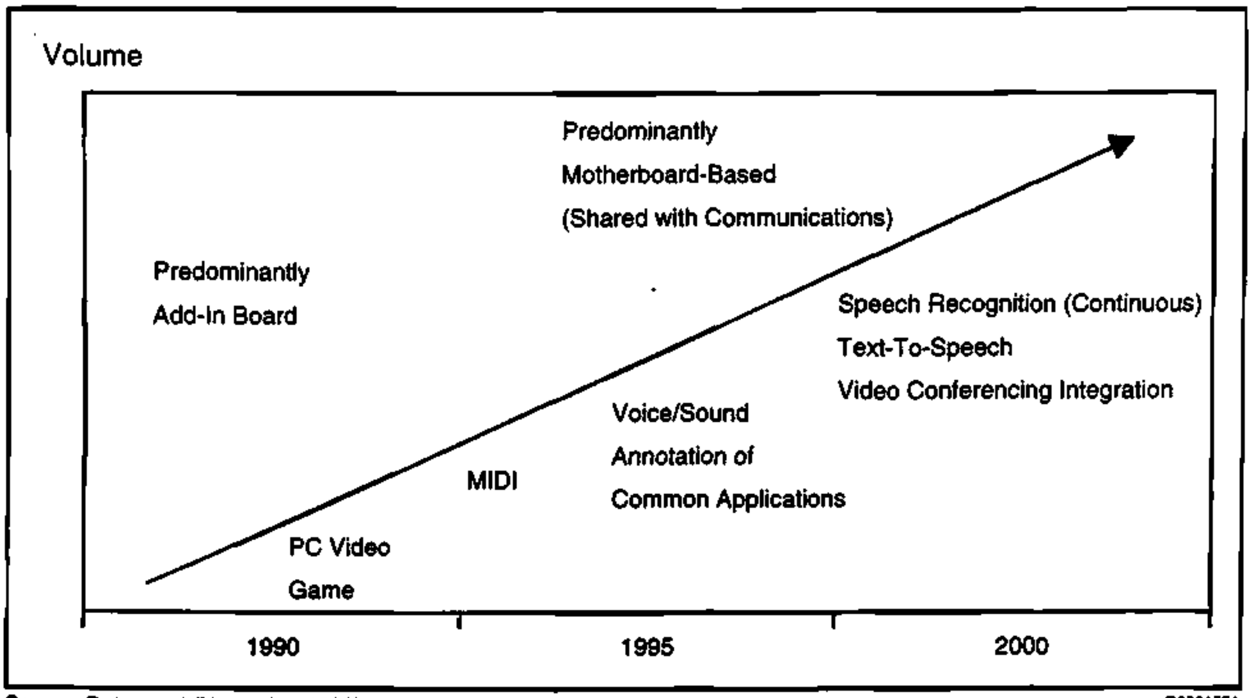
In the quest to upgrade computer platforms, sound is proving to be the most desirable sensory feature. Sound boards' first big draw over the past year was to enhance the home PC-based for entertainment and musical composition. Now mainstream desktop applications are tapping into the wave as well (see Figure 5-16).

Software such as Lotus 1-2-3 is turning to sound to help users learn. With software such as Windows' object linking and embedding (OLE), sound can be embedded in applications and files and played with a click of an icon. Designers are even talking about the concept of a sound user interface to complement the successful graphical user interface. Our surveys indicate that the demand for sound is so pervasive, functionality is rapidly heading for motherboard incorporation.

Sound Technology Migration

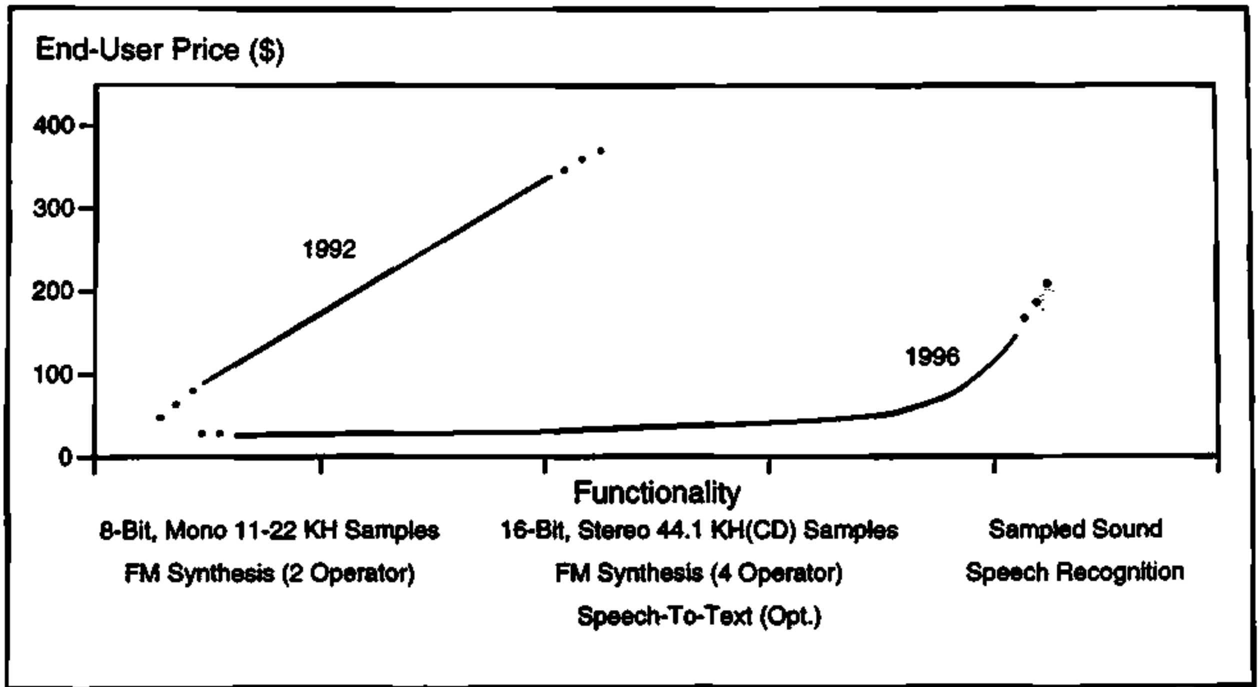
Chapter 3 discusses most of the technology trends with sound. Figure 5-17 summarizes some of them. Eight-bit technology today is represented by the original Sound Blaster from Creative Labs, or what is found in a Macintosh computer. In two to three years, CD-quality 16-bit sound with more sophisticated sampled-MIDI synthesis will be available at about the same price point as 8 bit FM-synthesis capability today. The market is starting to witness several variations of offerings as products are combined with graphics and portable versions emerge. Media Vision, with its portable AudioPort ($199), has been joined by Video Associate Labs and VocalTec in offering versions targeted for use by the portable computer user, attaching to the parallel port and providing audio I/O and synthesis.

Figure 5-16
Computer Sound Application Trend



Source: Dataquest (November 1992) G2001221

Figure 5-17
Computer Sound Technology Trend



Source: Dataquest (November 1992) G2001222

MIDI

MIDI, a digital protocol that allows musical instruments to communicate with each other and to computers, is moving from the recording studio to the home and office. At compression ratios of 400:1 over regular digital audio, MIDI can manage 16 different channels or instruments simultaneously. A MIDI file is essentially a musical composition in computerized format. Key data such as notes, force of the notes, pitch movement (bend), and type of instrument can be encoded.

With a MIDI file (sequence), information from a computer controlled synthesizer can emulate an entire orchestra. Synthesis can be accomplished in many ways. The four-operator OPL-3 standard from Yamaha, which can generate 20 voices (combination of instruments and rhythms), is the most widely used in low-end applications (for example, the MPC 1.0 specification). The use of sampled sound synthesis is migrating from professional MIDI systems to mainstream usage. This latter technique entails mixing actual recorded sound elements from instruments stored in ROM chips.

General MIDI is a common subset of MIDI implementations and prescribes the designations for instrument program locations (patches). Another de facto standard concerns sound boards from Creative Labs and Media Vision, which have special software drivers that standardize patch assignments.

Software that captures, edits, and plays MIDI-based compositions from the computer are called sequencers. Midisoft's Midisoft Studio for Windows ($249 list) is an example of one such sequencer.

Sound Board Players

The computer sound board market was launched into its current state by Creative Labs and AdLib. AdLib has had some recent financial trouble, but Creative Labs has shipped well over 1 million boards, bringing improved computer sound and MIDI capability to IBM-compatible PC owners. We estimate that Creative Labs will have about 50 percent of the computer sound board market in revenue in 1992, followed by Media Vision with 30 percent. Roland, IBM, Turtle Beach, and ATI will split another 10 percent. Leading sound board OEMs are noted in Table 5-6.

Other sound board companies include VocalTec, Video Associates, Zoltrix, and Digitan Systems. Companies that make full-scale MIDI synthesizer boxes include Akai, Casio, E-mu, Ensoniq, Korg, Kurzweil, Peavey, Roland, and Studer.

Sound Board Forecast

The outlook for sound boards is bright, as many application software providers support sound. As it moves from exclusively the home-game/music environment to the school, office, and various vertical applications such as musicians and information kiosks, the

Table 5-6
Leading Sound Board OEMs

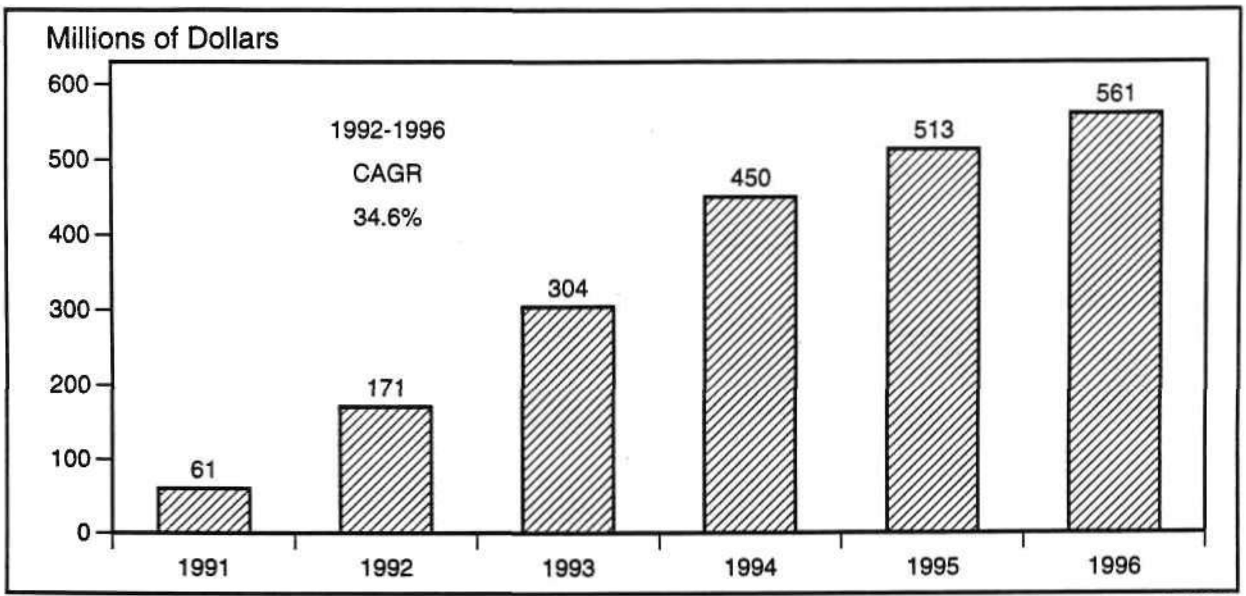
Company	Location	Key Products
AdLib	Quebec, Canada	Gold
ATI Technologies	Scarborough, Ontario	VGA & Stereo F/X ($149-299) (IBM)
Cardinal Technologies	Lancaster, PA	Soundvision ($399) (IBM)
Creative Labs	Milpitas, CA Singapore	Sound Blaster (Pro/16), MIDI Blaster ($99-349) (IBM)
Digidesign	Menlo Park, CA	Sound Tools II ($3,500, Audio Media II ($1,300) (Apple)
E-mu System	Scotts Valley, CA	SoundEngine
IBM	Atlanta, GA	M-audio (IBM)
Media Vision	Fremont, CA	Pro Audio Spectrum (Plus), Thunderboard, The Audioport (IBM)
Roland	Los Angeles, CA	SCC-1
RTM	Irwindale, CA	AudioMaster ($299) (IBM)
Spectral Synthesis	Woodinville, WA	The Digital Studio (IBM)
Sunrize Industries	Campbell, CA	AD1012 (IBM)
Turtle Beach	York, PA	MultiSound ($999) (IBM)

Source: Dataquest (November 1992)

annual volume is expected to approach 7 million units by 1996 (see Figures 5-18 and 5-19). An increasing percentage of the boards are being bundled into systems by PC and upgrade kit marketers. Retail stores and catalogs are the predominant channels for sound boards. This is expected to shift somewhat to the VAR, OEM, and distribution channels as upgrade kits and bundled systems become more popular.

We further expect the factory ASP to stay flat as increased functionality is brought on at the same price point. We expect 16-bit capability to grow to 90 percent of the market by 1996 and sampled sound (or equivalent quality) to comprise two-thirds of the market by then. In the latter part of this decade, the sound board market will flatten and drop as systems embedded with sound become dominant.

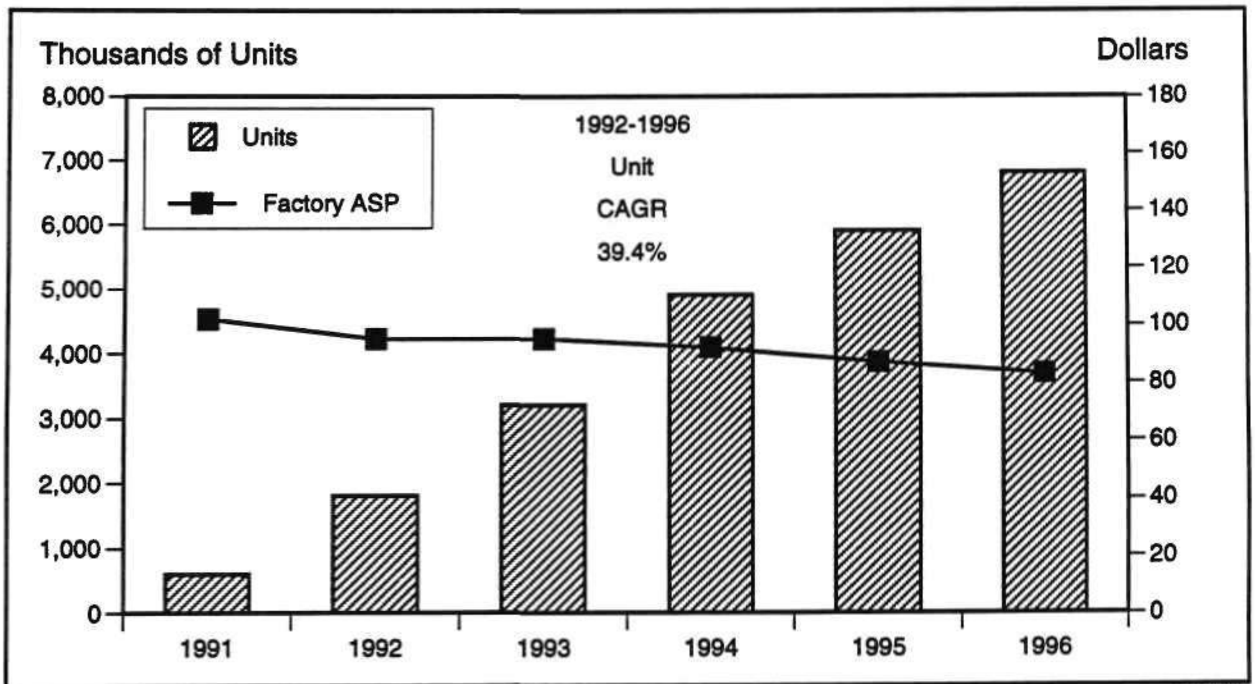
Figure 5-18
Worldwide Computer Sound Board Market Forecast (Factory Revenue)



Source: Dataquest (November 1992)

G2001223

Figure 5-19
Worldwide Computer Sound Board Market Forecast (Units and Factory ASP)



Source: Dataquest (November 1992)

G2001224

Dataquest Perspective on Sound Boards

Enhancing the PC and workstation with sound undoubtedly is a ready opportunity to be taken advantage of as users become convinced of the need and software rolls out. We do not believe that users will sit at their PCs to listen to stereo, but there are plenty of other uses where it will aid in productivity and user-friendliness. Although eventually nearly every new computer platform will have sound capability embedded, there remains a large number of installed systems globally in home, education, and training markets that will need aftermarket boards.

Although little stereo and 16-bit sound software exists today, these higher-end boards market better. We believe that the transition to sampled synthesis of music will happen quickly as several new semiconductor chip sets hit the market, helping drive prices down. The only limiting factor will be development of software driver standards for this higher level of performance.

Upgrade Kit Trends

The strategy to upgrade kits to add multimedia features to installed or new PCs through retail markets is apparently successful in part because of the recent steep price cuts by PC vendors, leaving budget for upgrading. With a minimum of a CD-ROM (internal or external) and a sound board, upgrade kits can include various combinations of the following:

- CD-ROM (of the various varieties) and optional host adapter board
- Sound board capable of capturing and outputting sound, including a digital form of music known as MIDI
- MIDI connector cables and sequencing software
- Digital video add-in board (of various varieties)
- Authoring software for creating multimedia material
- Game, reference, and educational CD-ROM titles
- Multimedia systems software (for example, Multimedia Extensions for Windows)
- Scanner (flatbed, hand-held)
- Microphone
- Speakers

Variability in the core constituents of upgrade kits revolves around the performance class of the CD-ROM (280ms through 850ms), the type of sound board (8 bit or 16 bit, FM or sampled), and the bundled titles. Low-performance upgrade kits can run as low as $550 retail, with the "average" running from $900 to $1,000. One interesting twist is Creative Labs' avoidance of a SCSI interface to the CD-ROM, taking some of the cost out. Creative's Sound Blaster Pro card provides a non-SCSI interface directly on it. Media

Vision's Pro AudioSpectrum (Plus) is the most widely adopted sound board by the upgrade kit providers, probably because of its 16-bit capability.

Upgrade Kit Multimedia Software

The software titles that go along with these kits can vary widely, but the following—which comes with Media Vision's Pro 16 Multimedia System—exemplify what is available with a sophisticated kit:

- Microsoft Windows 3.1 with Multimedia Extensions 1.0
- Lotus 1-2-3 with SmartHelp
- Compton's Multimedia Encyclopaedia
- King's Quest V (stereo adventure game)
- MacroMind Action! (multimedia presentations)
- Stereo Studio F/X (sound editor)
- TrakBlaster Pro (a four-track studio)
- Nautilus Multimedia CD (multimedia magazine)
- SP Spectrum (MIDI sequencer)
- Pro Speech (text-to-speech synthesizer)
- Control Panel (software controlled mixer)
- Audio Mate (DOS-based audio application)
- Music and sound effect library

Upgrade Kits of the Future

Current upgrade kits are a good value for the buyer. The sum of the individual components can easily exceed the packaged price by two to three times. We expect packagers will tier their offerings perhaps at the $500, $1,000, and $1,500 price points to appeal to different budgets. Packages will also differentiate themselves on the CD-ROM titles because they target versions at markets such as home education/entertainment, schools, and the home office. The low end will offer the basic hardware (with slower drives), multimedia systems software, and perhaps one or two titles such as a presentation package and information reference.

Upgrade Kit Players

The dominant packagers and marketers of upgrade kits are those associated with the MPC effort, which is becoming a recognizable specification for the IBM-compatible market. It also is the specification most broadly supported by the ISVs. Key kit players include sound board makers such as Creative Labs and Media Vision, CD-ROM drive makers such as NEC, and PC clone makers such as CompuAdd and Samsung (see Table 5-7). We can expect non-manufacturing channel value-adders to become involved. Computer superstores and catalog houses are examples.

Table 5-7
Selected Upgrade Kit Providers

Company	Key Products (Sound Board Used)
CompuAdd	Multimedia Upgrade Kit (Sound Blaster Pro)
Creative Labs	Sound Blaster Multimedia Upgrade Kit (Pro)
Media Resources	MK A/B (Pro Audio Spectrum, SCC-1)
NEC	Multimedia Upgrade Kit (Pro Audio Spectrum)
Samsung	MediaWizard (Media Master)
Swan Technology	Swan Multimedia Update Kit (Sound Blaster Pro)
Tandy	Multimedia Upgrade Kit (Sound Blaster Pro)
Turtle Beach	MultiSound Multimedia Upgrade Kit (MultiSound)

Source: MPC World, Dataquest (November 1992)

Upgrade Kit Market Forecast

Figures 5-20 and 5-21 present Dataquest's worldwide forecast for upgrade kits. As a minimum, an upgrade kit contains a CD-ROM drive (reader) and sound board in this forecast. We estimate that 1992 factory revenue will be $268 million, based on 675,000 units shipped and a factory ASP of $397. We believe that the market will continue ramping through 1994, when it will begin to decline to the submillion-unit level because of the entry of a variety of consumer targeted and MPC PCs that will embed CD-ROM drives and sound functionality.

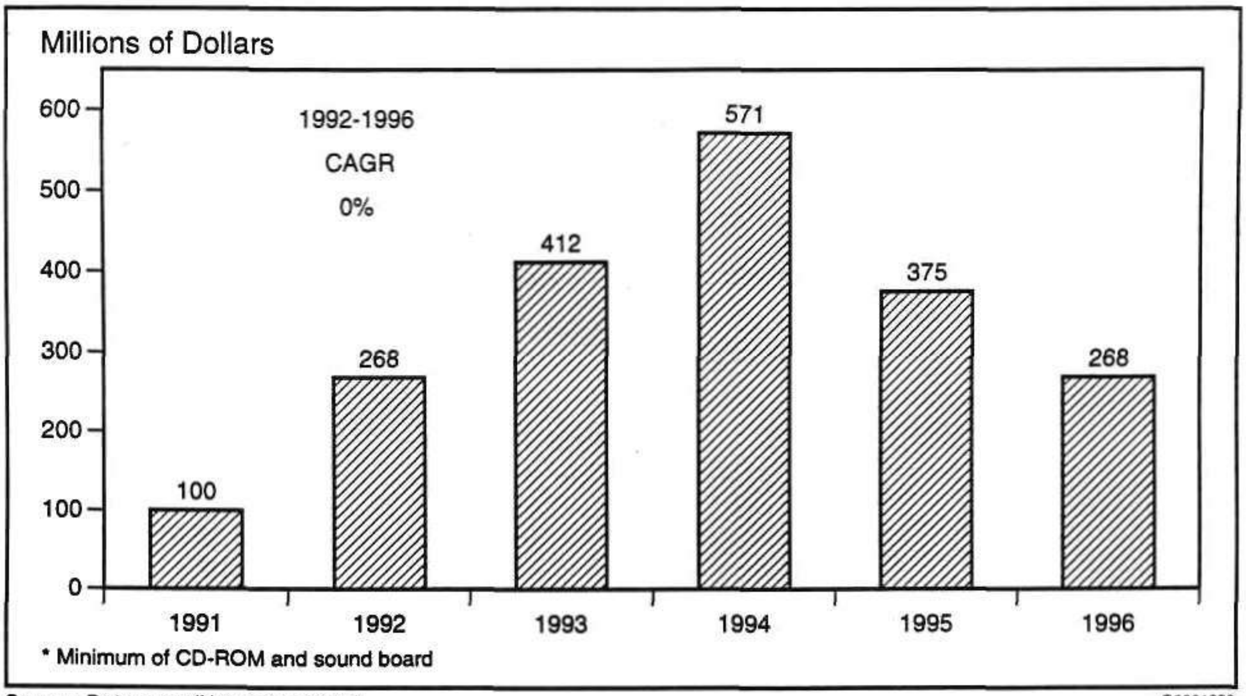
The principal initial markets for upgrade kits are the same as those we have identified elsewhere in this report: the home market, schools, and corporate market communication and training. We estimate that 60 percent of the market is in North America, with 30 percent in Europe, and 6 percent in Japan. This mix should shift to about 45 percent North America, 35 percent Europe, 10 percent Japan, and 10 percent ROW by 1994. Retail stores and catalogs will be the principal channels for upgrade kits.

Dataquest Perspective on the Multimedia Upgrade Kits

Upgrade kits should have a substantial market window of opportunity over the next two to three years. The installed base of home and office 386-based machines is large, and our projections are modest in comparison. As stated earlier, we believe that the kits will be targeted at certain user markets, with performance and software selection being the difference.

Perhaps the most interesting story will be the diversity of kit providers that will spring up. However, if they want to use the MPC logo, the fees will be steep, which will limit some interlopers.

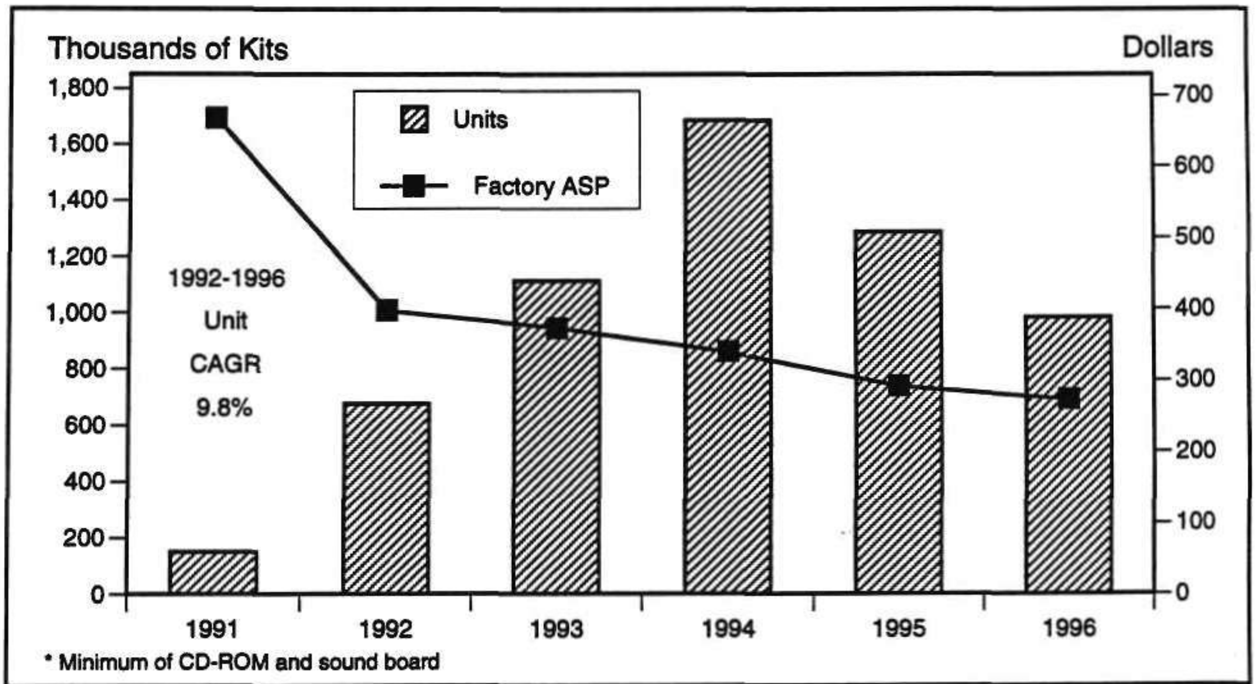
Figure 5-20
Worldwide Multimedia Upgrade Kit* Market Forecast (Factory Revenue)



Source: Dataquest (November 1992)

G2001225

Figure 5-21
Worldwide Multimedia Upgrade Kit* Market Forecast (Units and Factory ASP)



Source: Dataquest (November 1992)

G2001226

Key Vendor Profiles

Creative Technology Ltd. (Also Known As Creative Labs Inc.) (U.S. Subsidiary)

Corporate Statistics

Headquarters Location	Singapore
Chairman	Sim Wong Hoo
Founded	1981
1991 Revenue	$60.7 million (nine months ended March 1992)
Number of Employees	486

Overview

Creative Technology is the leader in IBM-compatible PC add-in sound boards, based on the success of its Sound Blaster products. It has diversified into multimedia upgrade kits for PCs and digital video boards. The company is a member of MPC and continues to work closely with Microsoft and others on future multimedia specifications.

The company recently went public, selling 4.8 million shares worldwide. In the United States, the stock is traded on NASDAQ under the ticker "CREAF." The current trading price is $12.

The company recently purchased, for $1.75 million, the rights to E-mu Systems' SoundEngine chips and sound library to create new products. It designs and manufactures its products in Singapore and distributes them worldwide.

Financials and Market Position

According to Creative's prospectus, it is en route to $100 million in calendar-year 1992 sales. Given the strength of the fourth quarter (for Christmas) for home PC upgrade products, 20 or 30 percent more than that total is possible. The company had a net income of $6.5 million and a 23 percent after-tax margin for the latest quarter reported in March 1992. North America accounted for 56 percent of its recent sales; 27 percent were in Europe, and 17 percent in Rest of World.

Dataquest estimates that the company will have about half the 1992 sound add-in board market, which is down from an estimated 80 percent share in 1991. The prime competitor has become Media Vision, with others gaining strength as well. Creative Labs and Media Vision are suing each other, with Creative claiming encroachment on its Sound Blaster technology and Media Vision claiming unlawful competitive practices.

The company also has a coleadership position in the MPC upgrade kit business, as brand name recognition aids pull-through. It has a solid second-tier position in the digital video business with its Video Blaster product, which delivers substantial performance for a $495 retail list price.

The company has announced OEM relationships with Packard Bell, Tandon, Philips, Tandy, and Wang. In April it announced the signing of Egghead Discount Software as a major distributor.

Products

Creative offers a variety of sound, video, and multimedia upgrade products.

Sound Products. The company's sound products are as follows:

- Sound Blaster: Audio sampling and playback, FM music synthesizer, MIDI interface, game port and software ($149 list).
- Sound Blaster Pro Basic: Similar to Sound Blaster but includes stereo and a CD-ROM interface ($229).
- Sound Blaster Pro: Same as Basic but includes MIDI Kit (sequencer and cables) ($299).
- Sound Blaster 16: 16-bit Sound Blaster-compatible, with four-operator FM Synthesis and 44.1-MHz sampling ($349 not yet released).
- Sound Blaster: Software and manual for sound/music drivers and Developer Kit technical information ($99).
- MIDI Kit: Sequencer software and cabling ($79).
- MIDI Blaster: High-performance board that features PCM wave-sampled sounds; capable of 128 sounds, 33 effects, and 55 drums. Roland Sound Canvas-compatible. Includes MIDI software and titles ($499, not yet released).

Video Products. The company's video product is as follows:

- Video Blaster: Video capture, overlay, and display subsystem with multimedia and JPEG compression software ($495).

Upgrade Products. The company's upgrade products are as follows:

- Multimedia Upgrade: CD-ROM drive, Sound Blaster Pro, MIDI Kit, Windows 3.1, and various CD-ROM titles ($799).
- Creative Multimedia: Same as previous but excludes sound board ($549) Upgrade Kit.
- Multimedia Starter Kit: Same as full kit but excludes MIDI kit and some CD-ROM titles ($650).

Strategy

Creative is diversifying rapidly from its Sound Blaster roots, trying to capture all aspects of multimedia growth. It rolls out its new products in 16-bit sound, digital video, and MIDI with a goal of cost sensitivity in mind. The company has plentiful profits and a cash infusion from the public offering to continue filling product line holes and extend the price/performance envelope. Sampled sound products from the recent E-mu deal reflect one direction for the company.

Creative is struggling to retain the control over the de facto standard (drivers) that software and titles are written for. The proprietary interface (not SCSI) to the Matsushita CD-ROM drives could keep those customers that invested in the drive primed for future board products.

The company will continue leveraging its brand name recognition and position as the leading sound board manufacturer to gain a larger share of the upgrade kit business.

Dataquest Perspective

The company has a severe challenge as success catches up with it. The early market leader often gets arrows in the back, but Creative Technologies just might succeed as a major multimedia player. The balance and cost-effectivity of recent offerings suggest that the company is using its cash wisely. Its brand name recognition should help it maintain a distance from other players in the retail channels. If the company can succeed in bringing to market sub-$400 sampled sound capability, it might continue leading the pack for some time.

Media Vision Inc.

Corporate Statistics

Headquarters Location	Fremont, California
President/CEO	Paul Jain
Founded	1990
1991 Revenue	$8.5 million
Number of Employees	60

Overview

Media Vision provides multimedia enhancement products to the PC marketplace. It was founded with funding from Brentwood Associates, Advanced Technology Ventures, Phoenix Partners, Nazem and Company, 3i Ventures, and Cirrus Logic. To date it has specialized in sound and upgrade kits areas. It contracts out its manufacturing.

The company has an alliance with Cirrus Logic to design and sell sound chip sets. It is also working with Stanford University's Center of Computer Research in Music and Acoustics on new audio technology. It also is a member of the MPC Council. The company announced that several software vendors, including WordPerfect and Broderbund, are writing Pro Audio Spectrum-compatible applications and titles.

Financials and Market Position

The company is private, and thus not much financial detail is available. Media Vision estimates that it could grow its revenue by 10 times in 1992. Dataquest estimates that it could capture as much as 30 percent of the PC sound board business in 1992. The company is also among the market leaders in upgrade subsystems and kits and is estimated to have a $10 million dollar sound chip set business in 1992.

Products

The company offers a range of products specializing in audio and upgrade kits and systems, as follows:

- Audioport, a credit card-size "sound board" that attaches to the parallel port of a portable or desktop PC and has audio processing, synthesis, and a speaker ($199 list).
- CDPC, a multimedia subsystem that attaches to PCs and includes a CD-ROM drive, sound boards, stereo speakers, and multimedia software ($1,295).
- Pro 16 Multimedia, an upgrade kit with Pro Audio Spectrum/16 sound system board, a 280ms NEC CD-ROM drive, and several multimedia titles.
- MPC Upgrade Kit, with a Sony CDU 535 CD-ROM drive, Pro AudioSpectrum Plus sound board, Windows 3.1 software, and various multimedia titles ($1,199).
- Pro Audio Spectrum, with 8- and 16-bit CD-quality (44.1-MHz sampling), Plus/16 OPL-3 synthesis, MIDI I/F, software, and drivers ($279/$349).
- Thunder Board, which includes a Windows version, 8 bits, and Sound Blaster compatibility ($169/$179).
- Thunder and a combined Thunderboard, with 24-bit color and Lightning VGA graphics ($349).
- MIDI Mate and MIDI connections.

Strategy

Media Vision has been successful at grabbing a big piece of the sound market in a short time. Offering a cost-effective 16-bit solution has helped it gain retail shelf space and a chance to land good OEM and upgrade packaging deals. Innovations with the Audioport and CDPC have also helped differentiate the company. The alliance with Cirrus Logic on chips allows Media Vision to integrate state-of-the-chip-based technology without having to foot the bill entirely on its own.

We expect the company to move into higher-fidelity sound products and possibly even to video after Microsoft's AVI strategy is unveiled. Because of the graphics background of the founders, we also expect more integrated graphics products.

Dataquest Perspective

Media Vision basically has the same challenge as Creative Technology: staying on the bucking bronco of an infant high-growth market. There is probably room for both companies, and more. The move to open their standard for software compatibility is good; perhaps it can get an edge on name-brand recognition as compatible titles follow.

The company has a strong mind-share with fellow upgrade kit vendors because of its entrenched 16-bit recognition. This will aid it in keeping developers and allies on board. The relationship with Cirrus Logic is like having an in-house chip group, and this should allow Media Vision to stay ahead with state-of-the-art, cost-effective technology.

Chapter 6
Multimedia Storage Requirements

Introduction

Multimedia computing is coming of age in the 1990s. But the industry is still struggling with a definition: What is multimedia? An ancient Chinese tale best describes the situation. Four blind people are touching an elephant trying to decide what it is. The one touching the nose says it is a snake, the one touching the leg reports it is a pole. Another person touching the body thought it was a wall. The person touching the ear thought it was just a fan. Of course, the name of that elephant is multimedia. Indeed, multimedia means different things to different people, depending on in which industry they are.

In the previous chapters, Dataquest defined multimedia computing. In doing so, Dataquest observed that there are many standards and platforms. The computer companies are using multimedia to enhance the particular computer architecture or format they are selling. Perhaps a more plausible approach is to consider the minimum requirement for multimedia software—and then think about necessary CPU and other hardware. This "basic" machine approach could enable the industry to produce a common format, which will, in turn, accelerate the market growth.

In this chapter, Dataquest takes this "basic" machine approach to multimedia storage requirements. The chapter presents an analysis of the multimedia software programs and their requirements for storage and reviews the various storage components that comprise multimedia computer storage, with a focus on CD-ROM technology as a distribution medium. Dataquest will also discuss factors that will cause the market to grow, provide an analysis of the size of the market with five-year growth forecasts, and profile the leading CD-ROM drive manufacturers and title development software companies.

Definition of Storage Devices

Rigid Disk Drives

The rigid disk drives (RDDs) reviewed in this section store digital data on platters with magnetically sensitive recording surfaces. These platters are fixed and nonremovable. The disk media substrates are nonflexible and can be made of aluminum, plastic, glass, or other rigid material.

Units are defined as single spindles. In the case of large (8- to 14-inch) drives, spindles are calculated as equivalent-capacity IBM spindles. Disk drives with multiple actuators are counted as single spindles and placed in the diameter category of their external form factor.

Dataquest defines the fixed media RDD market according to the following segmentation scheme:

- The total RDDs
  - 1.8-inch RDDs
  - 2.5-inch RDDs
  - 3.5-inch RDDs
  - 5.25-inch RDDs
  - 8- to 10-inch RDDs
  - 14-inch RDDs

Dataquest further segments the RDD market by the following eight capacity categories:

- 30MB or less
- 31MB through 60MB
- 61MB through 100MB
- 101MB through 200MB
- 201MB through 500MB
- 501MB through 1GB
- 1GB through 2GB
- More than 2GB

Flexible Disk Drives

This product is a drive that houses a removable flexible diskette make of a 3-millimeter polyester substrate coated with gamma ferric oxide particles dispersed in an epoxy binder and encased in a vinyl jacket.

Dataquest defines the flexible disk drive (FDD) market according to the following segmentation scheme:

- Total FDDs
  - 3.5-inch FDDs with the following formatted capacity ranges:
    - 720KB
    - 1.44MB
    - 2.88MB
    - More than 2.88 MB

- 5.25-inch FDDs with the following formatted capacity ranges:
  - 360KB
  - 1.2MB

Tape Drives

A class of computer backup devices that uses reel-to-reel, cartridge, or cassette tapes as media.

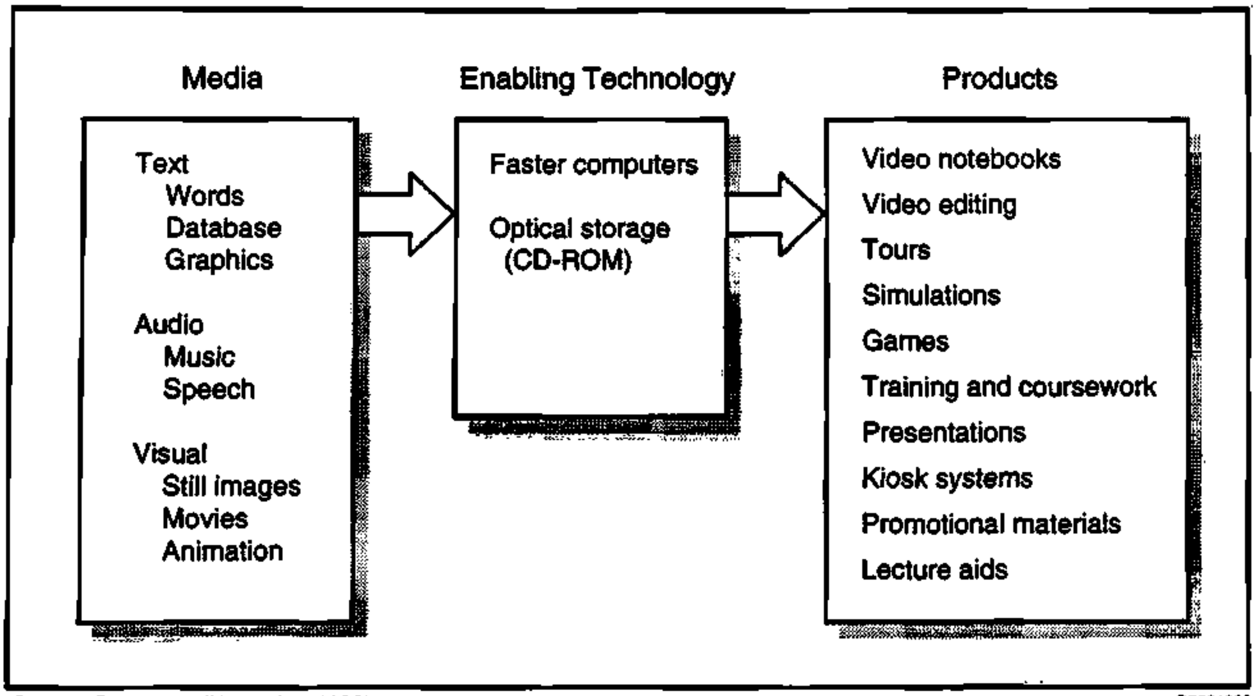
Optical Disk Drives

A data storage device that uses laser technology. Types of optical storage include compact disc read-only memory (CD-ROM), CD-Recordable, write-once/read-many (WORM), and erasable optical disk drives.

Role of Mass Storage in Multimedia Computing

Multimedia computing can be simplified and examined in three parts for the purpose of this study. These three parts are media, technologies, and products, as shown in Figure 6-1. Media includes text, audio, and visual. Technologies that make multimedia possible include optical mass storage and faster computer platforms at reasonable prices. The resulting products include training and courseware, presentations, information kiosk systems, recreational programs such as games, references, and online tutorials and help systems for using software applications and multimedia-enabled business applications.

Figure 6-1
Key Multimedia Elements



Source: Dataquest (November 1992) G2001809

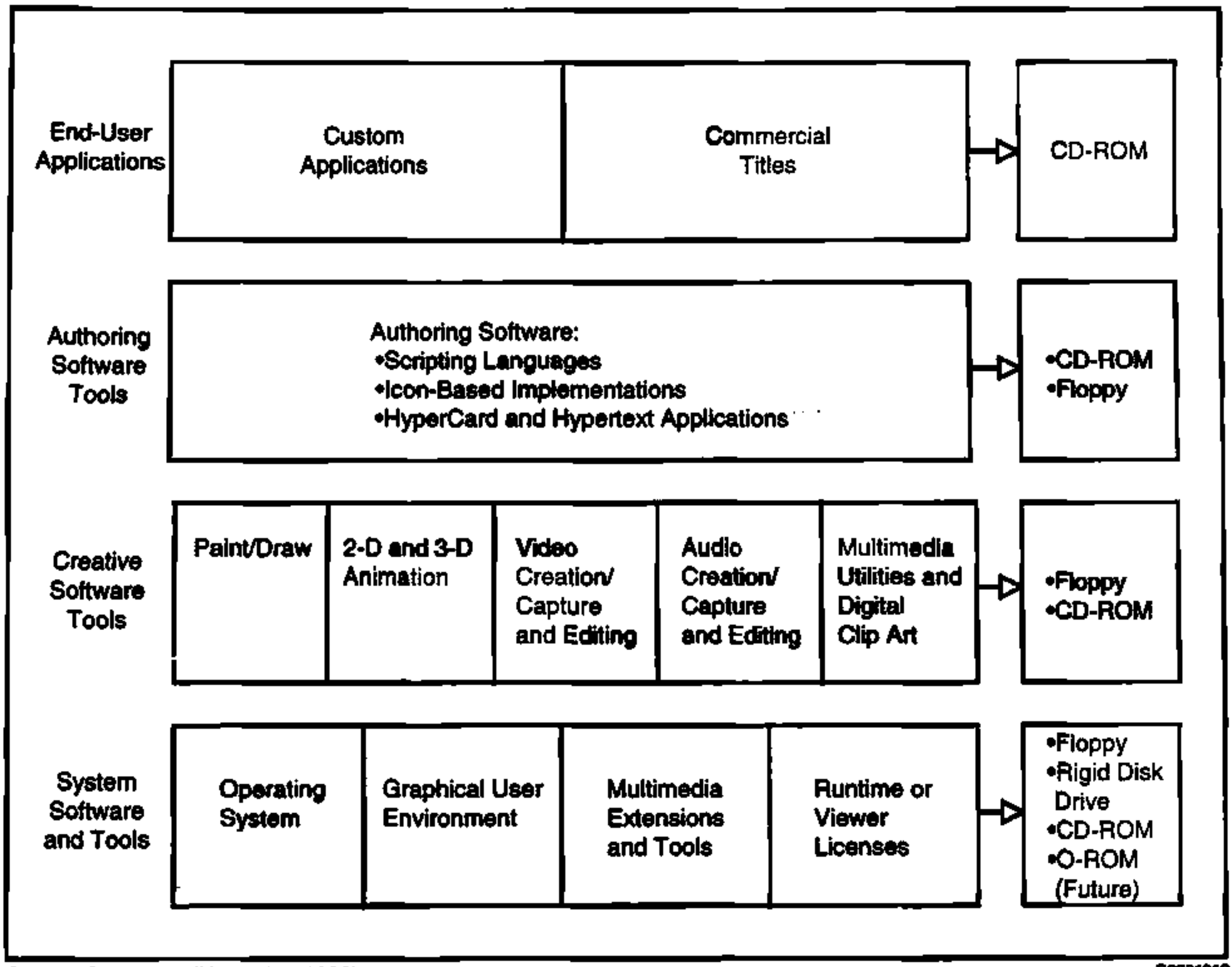
Delivering true multimedia such as graphics, sound, and especially video, requires large amounts of mass storage. For example, one still color picture occupies 20MB of memory without compression. Storage of 72 minutes of full-frame, full-motion video using MPEG-1 compression requires the full 680MB capacity of a CD-ROM.

Dataquest represents the multimedia software layers and requirements for various storage medium in Figure 6-2. Dataquest believes that multimedia computing represents additional opportunities for all types of storage devices.

Most of the desktop computer installed base has less than 100MB of RDD capacity. Figure 6-3 shows the projected RDD capacity in PCs.

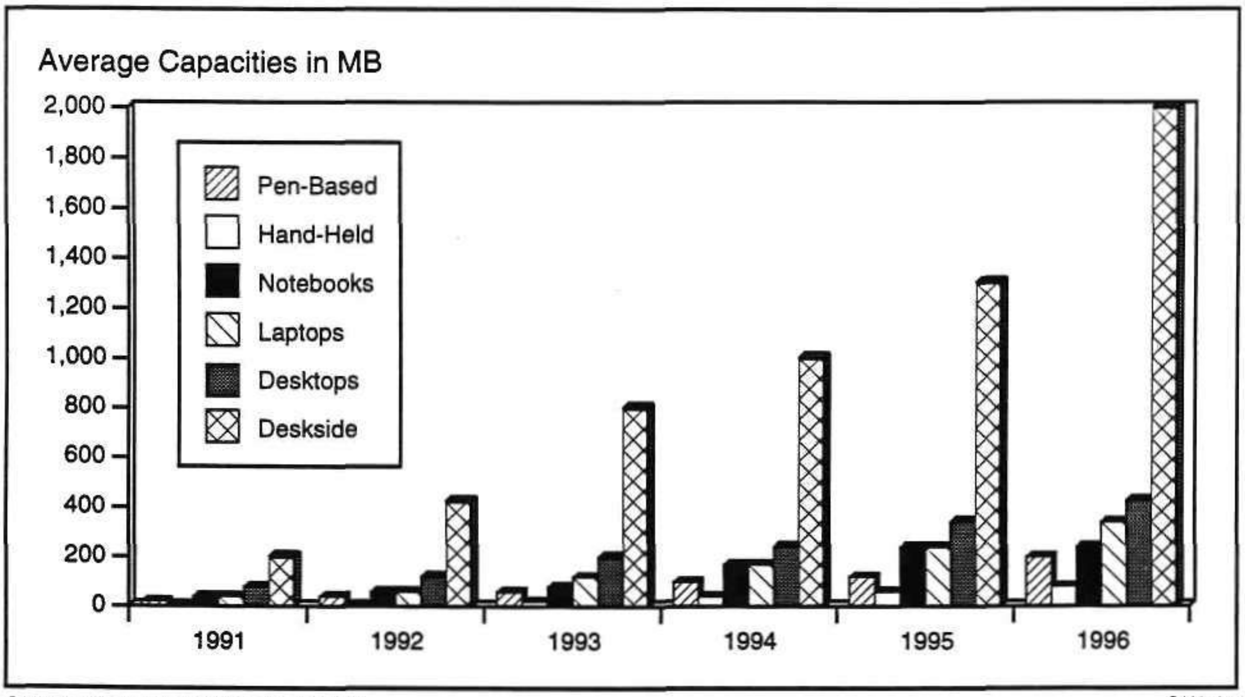
For desktop computers, the average RDD capacities are projected to be 120MB this year, growing to 425MB in 1996. It is apparent that substantial multimedia programs, especially high-end multimedia, require

Figure 6-2
Multimedia Software Layers and Requirements for Storage



Source: Dataquest (November 1992) G2001810

Figure 6-3
History and Forecast of Average RDD Capacity in PCs: 1991 to 1996



Source: Dataquest (November 1992) G2001811

mass storage beyond the capacity of user's available desktop hard disk space. As Dataquest projects in Figure 6-3, the average size of hard disks purchased for new PCs has been, and will be, growing rapidly. This makes it feasible to store small to moderate amounts of graphics and low- to medium-quality sound along with existing applications, but storage of all but short clips of low-resolution video remains impractical. Multimedia programs with substantial content will continue to exceed the available capacity of user's hard disks for several more years.

An alternative is to store material on a LAN server, instead of an individual's hard disk. This can sometimes help because the capacity of the server tends to be larger than an individual's hard disk. However, transfer of material over the network is problematic because of the high bandwidth required.

Use of multimedia files on hard disks and servers is also limited by the number of floppy disks users are willing to load. The means of loading a hard disk are a problem, as well as the amount of available storage. Even if 100MB of hard disk space were available, the user would need to load 70 high-density (1.44MB) floppy disks, which would take much time and effort. Other high-capacity methods for loading drives, such as streaming tape and digital audio tape (DAT), are available but only at a few sites. By 1994, Dataquest projects that 64 percent of 3.5-inch floppy disk drives shipped with PCs will be

2.88MB rather than 1.44MB. This doubled capacity will accelerate distribution of still images and audio but will still be too small for video programs.

Cost is also a consideration. Table 6-1 compares the cost per megabyte among the removable mass-storage devices.

Among the removable storage devices, CD-ROM drives have the best attributes to be the distribution medium of choice for multimedia computing. Because CD-ROM is not rewritable, Dataquest believes that CD-ROM should be classified as a publishing medium rather than a storage device. CD-ROM technology is appropriate for distributing large volumes of information as required by multimedia applications. The RDD will continue its dominant position as the primary storage of multimedia-enabled desktop computers.

In Dataquest's opinion, a typical multimedia-ready computer with reasonable performance should have 4MB of RAM, a 100MB hard disk, a 1.44MB 3.5-inch floppy drive, and a CD-ROM drive. The CD-ROM drive should have a transfer rate of at least 150 KB/sec, the ability to play CD audio, and an average access time of less than 400ms.

CD-ROM: The Distribution Medium of Choice for Multimedia

CD-ROM is a technology for distribution and retrieval of digital information on optical disks played on CD-ROM drives attached to a workstation, PC, or Macintosh or placed on a CD-ROM server and accessed over a LAN.

CD-ROM has a storage capacity of 680MB, and the media is removable. Replication costs in quantity are about $1.2 to $1.50 per disk, plus setup costs (prices range from $1,500 to $2,000). It is the one area where a single, clear, official, and de facto market standard is already in place.

High capacity at significantly lower costs than other distribution alternatives is often cited as the major advantage of CD-ROM in the context of multimedia. One CD-ROM disk can hold up to the following amounts of information:

- 250,000 pages of text, if delivered on paper
- 12,000 images
- 50,000 computer pages of data

However, the low cost of the media and distribution for CD-ROM and its large capacity are only the beginning of the story. CD-ROM technology has many additional advantages such as the following: permanence of media and data; random access of data; low data error rates; well-established standards for formats; compatibility with PCs and LANs; superior searching, sorting, and retrieval capabilities; digital

Table 6-1
Cost Comparison among the Removable Mass Storage Devices

	Form Factor (Inches)	Capacity (MB)	Average Access Time (ms)	Data Transfer Rate (KB/sec)	End-User Drive Price ($)	OEM Media Media Cost ($)	($/MB)
Rewritable	3.5	128	38	900	1,200	25	0.195
Optical	5.25	650	37	600	3,000	70	0.108
Write-Once	5.25	940	90	690	2,800	75	0.080
Optical	12.0	6,500	400	600	15,550	260	0.040
CD-ROM	4.72	640	380	300	300	1.50	0.002
						1,500 (master)	
Flexible Disk Drive	3.5	1.44	94	60	47	0.65	0.451
	5.25	1.2	91	60	57	0.40	0.333
Magnetic Removable Disk Drive	5.25	88	29.32	1,250	575	70	0.795

Source: Dataquest (November 1992)

media capable of delivering text, data, graphics, sound, and video; and, last but not least, a rapidly growing installed base. These characteristics make CD-ROM drives an ideal publishing medium for multimedia applications. Actually, CD-ROM drives are often associated with multimedia as one of the key enabling technologies.

For the above reasons, CD-ROM has emerged as the medium of choice for distributing multimedia titles.

However, because CD-ROM disks are read-only and are usually manufactured in volume in large plants, CD-ROM is more suitable for distributing many copies of a given large program than for one-of-a-kind or low-volume programs. For prototyping and low-volume programs, CD-Recordable came into play as a natural extension to CD-ROM technology.

CD-ROM Technology Trends

To discuss CD-ROM technology trends, a quick review of CD-ROM technology is necessary.

A Brief History of CD-ROM Technology

CD-ROM technology has its roots in the highly successful audio technology, which has largely displaced the venerable phonograph record. The key driving force behind CD technology has been N.V. Philips in the Netherlands. Philips initiated research projects in 1969 to investigate and develop optical disk recording techniques for video, audio, and text/data. By 1973, Philips-Polygram had produced the first laser-read disks. In 1978, Philips defined the compact disc (digital audio) in a document that became known as the Red Book.

The first working model was shown to the press in 1979; at the same time, a cooperative agreement was signed with Sony Corporation of America Inc. By 1980, the CD standard was accepted by the Japanese Digital Audio Disc committee, and licenses were offered to other companies. The enormous success of audio CD was followed by the introduction of the CD-ROM in 1984, defined in a new Philips document called the Yellow Book.

Hitachi Ltd., Philips, and Sony began shipping CD-ROM drives in 1985. In late 1986, Philips followed up with its Green Book, defining its CD-Interactive system, which began shipping in mid-1991. Meanwhile Philips and Sony have collaborated on an Orange Book, which defines rewritable-CD technology.

CD drives operating in mode 1 (CD-ROM) have an additional layer of error correction as compared with drives operating in mode 2 (audio CD). This error correction and the interface to the host are the only difference between the two CDs. Most recent CD-ROM models will operate in either mode and will have the appropriate I/O connections to do so.

CD-ROM Characteristics

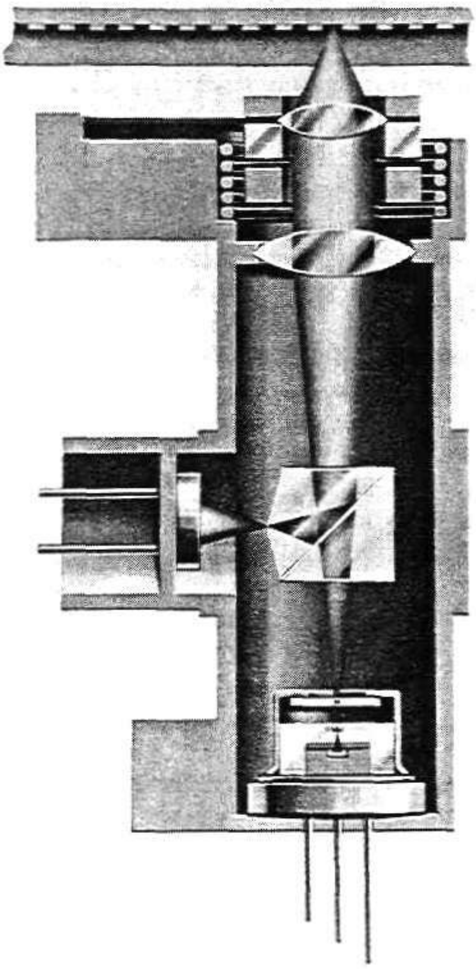
The CD-ROM Disk and its Replication

The read-only disk is made with a process very similar to the manufacture of phonograph records. The disk manufacturer creates a glass master (with pits corresponding to the binary data) using a laser-cutting lathe directed by data read from magnetic tape. The glass master is used to create a metal master, a metal mother, and then a metal stamper. Finally, the disks are replicated in clear polycarbonate plastic by the tens of thousands, using an injection-molding process. Each disk is coated with an aluminum reflective layer and then coated with a protective layer of transparent resin and tested and labeled for shipment. Most media manufacturers are offering mastering and replicating services to the industry.

Reading the Data

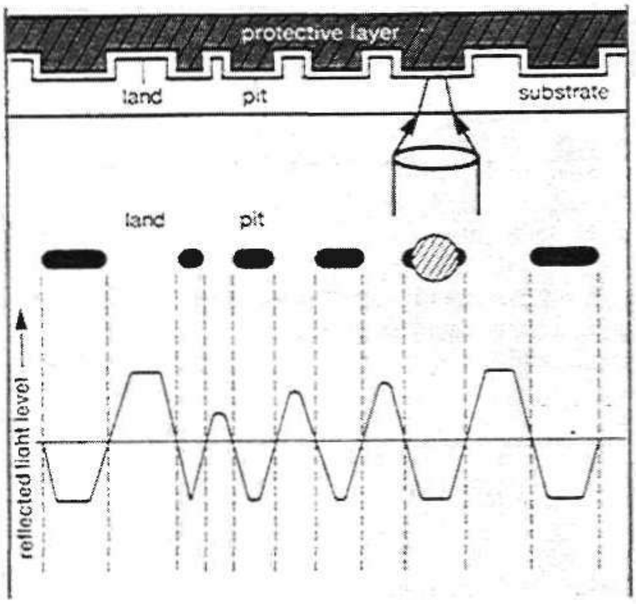
The disk is read by a noncontact optical stylus (see Figures 6-4 and 6-5) utilizing a gallium arsenide laser as a light source and both

Figure 6-4
Typical CD-ROM Optical Stylus Assembly



Source: Philips Subsystems and Peripherals Incorporated

Figure 6-5
CD-ROM Read Method



Note: The optical system receives low light levels from the pits (scattering) and high levels from the lands (reflecting).

Source: Philips Subsystems and Peripherals Incorporated

tracking and focus servos to recover the data without physically touching the disk. Light reflected by the surface pits and lands is directed back to two diode pairs in the optical system's assembly, which detect both focus errors and radial tracking errors and enable the servo system to make position corrections (see Figures 6-6, 6-7, and 6-8). Positioning the optical assembly is done with a rotary actuator (see Figure 6-9) (Philips) or a flat linear motor (Sony).

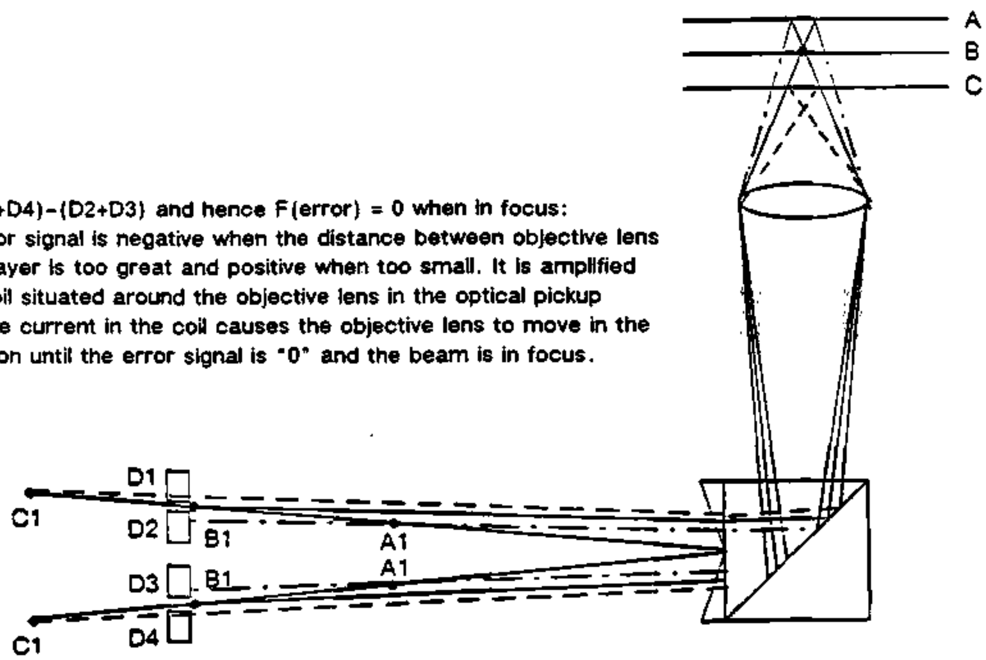
Physical Recording Format

The data in the CD disk are stored as true digital data, unlike LaserVideo, which is an FM analog approach. Because the data are stored as binary information that the computer can recognize, it can manipulate and interact with the data. The physical recording format is one in which any change of state signifies a binary one. That is, the change from a land to a pit signifies a binary one, as does change from pit to land. No change of state during a cell time signifies a binary zero. Thus, the continuation of a pit or a land during a data cell time is interpreted as a binary zero. The direction of the inversion makes no difference—any inversion is a one (see Figures 6-10 and 6-11).

Channel Code

In the CD-ROM mastering process, the 8-bit data code is converted into a 14-bit channel code by the use of a lookup table (see Figure 6-12). This code is known as 8-to-14 modulation (EFM). This 14-bit symbol is chosen such that two 1s in succession never occur. as this causes problems with the ability of the optical system to resolve the very close together changes of state on the disk. Therefore, the symbol always puts at least two 0s between 1s.

Figure 6-6
The Principle of Focus Control

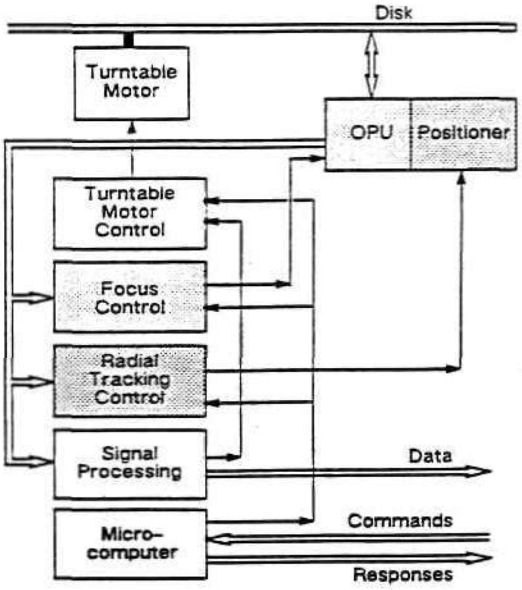


Note: F(error) = (D1+D4)-(D2+D3) and hence F(error) = 0 when in focus: This focus error signal is negative when the distance between objective lens and reflective layer is too great and positive when too small. It is amplified and fed to a coil situated around the objective lens in the optical pickup unit (OPU). The current in the coil causes the objective lens to move in the relevant direction until the error signal is "0" and the beam is in focus.

Source: Philips Subsystems and Peripherals Incorporated

Conversely, too many 0s in succession require a data channel low-frequency response that gets down into the servo signal passband and could cause interaction problems. The number of 0s is arbitrarily run-length limited to 11. The resulting 14-bit symbol (3 + 11) avoids adjacent 1s and runs of more than 11 0s—but contiguous symbols could have adjacent 1s. Therefore, three merging bits are inserted between 14-bit symbols to avoid this situation (see Figure 6-13). A 27-bit synchronous pattern followed by 17-bit symbols representing control and display (17 = 1 17 bits), data (408 = 24 17 bits), and error correction (136 = 8 17 bits) result in a basic frame of 588 channel bits (see Figure 6-14). When the CD-ROM reads the disk, it ignores the three merge bits and translates the 14-bit channel code symbol back to an 8-bit data byte. Data are arranged in sectors, which consist of 98 frames. The 98 frames multiplied by 24 bytes of user data yield 2,352 bytes per sector. Every sector begins with 12 bytes of synchronization followed by 3 bytes of address information and a 1-byte mode indication. This leaves 2,336 bytes of user data in what is known as mode 2. In mode 1 operation, an additional layer of error correction consumes 288 bytes, leaving 2,048 bytes for user data. The 8 bytes of error correction in the basic mode 2 frame is called Cross Interleaved Reed-Solomon Code (CIRC). The CD-ROM has been designed to compensate for "burst" errors that may arise due

Figure 6-7
The Basic Servo System



Note: Focus control is maintained via vertical movement of the objective lens; tracking control is maintained via radial movement.

Source: Philips Subsystems and Peripherals Incorporated

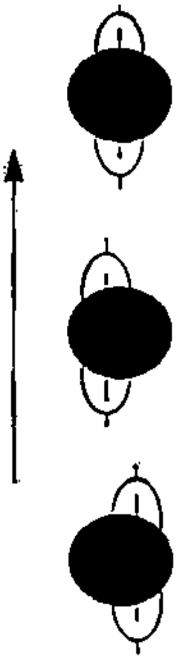
to disk defects or contamination and may extend over several frames. This is done by employing two Reed-Solomon codes that are interleaved to extend error correction over a number of adjacent frames. This is known as the CIRC. An example of the interleaving technique is shown in Figure 6-15. The 288 additional error correction bytes in mode 1 are called Error Detection And Correction (EDAC). Mode 2 is adequate for audio, but mode 1 is needed for data applications. There are 270,000 sectors available on the disk for a 60-minute playing time, which yields 553MB of user storage. It is possible to extend the playing time to 74 minutes and 682MB, but this puts data on the outermost area of the disc, which is the most error prone because of mechanical magnification of spindle run-out, disk run-out, and clamping errors.

Digital Sum Value

The previously described criteria of no adjacent "1s" and a minimum of two "0s" in succession could have been satisfied by two "merging" bits. The third bit is to satisfy an additional criterion.

This concerns the minimization of spectral power at low frequencies, which represent electrical noise to the servo system. The basic requirement of the servo system is a low (ideally zero) DC signal content. This can only occur when the lengths of pits and lands

Figure 6-8
Centering on the Track



Source: Philips Subsystems and Peripherals Incorporated

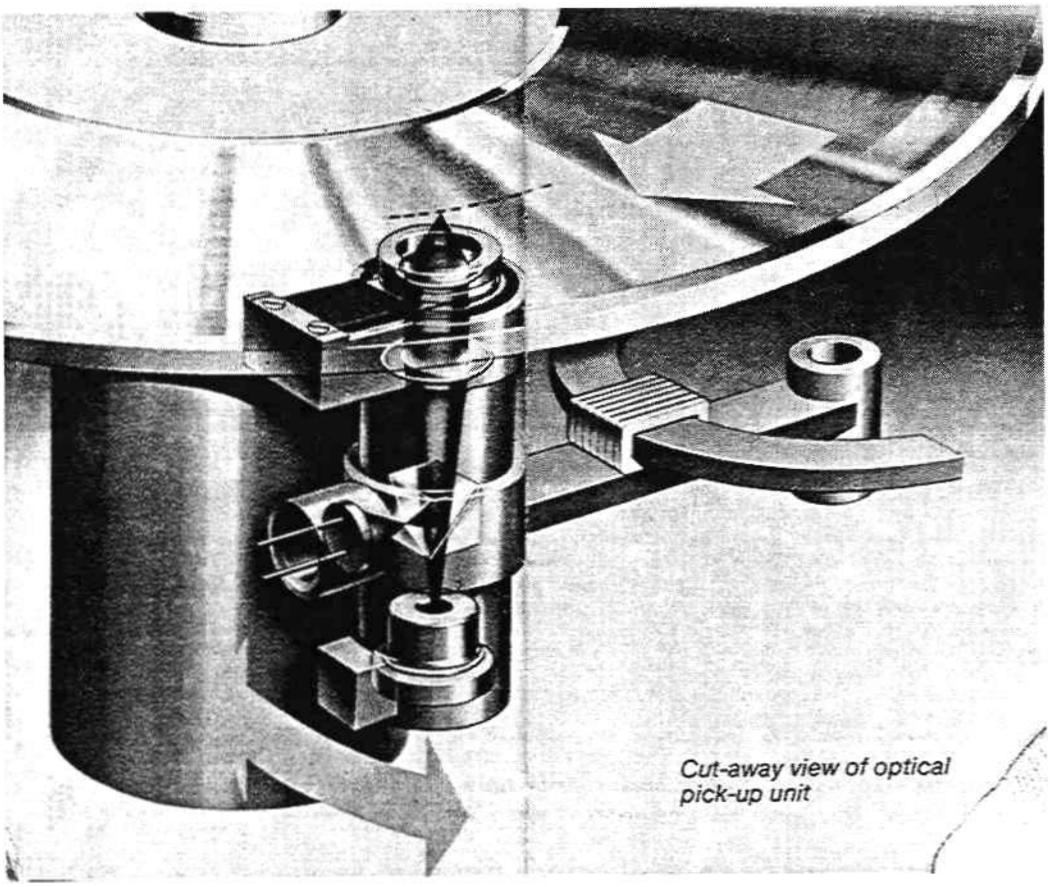
along the track are equal. The digital sum value (DSV) rises linearly for periods of lands and falls for periods of pits (see Figure 6-16).

To minimize the DSV, a third bit is added to the two "merging" bits that are required for the minimal run-length constraint previously described. With the three bits—"XMM"—both the merging requirement and the minimum DSV requirement can be satisfied. As shoen in Figure 6-16, "X" must be a "0" to satisfy the minimal run length of two "0s" in succession. That leaves a choice of "000," or "010," or "001," all three of which meet the merging requirement. The influence of each of these choices on the DSV clearly indicates that the best choice is "000." This choice is done automatically. At the modulation stage, the mastering system that produces the disks looks ahead and makes the best choice of "merging" bits that the run-length constraints allow.

Technical Limitations

Despite the impressive amount of low-cost storage available on CD-ROM, there are also some very real performance limitations. The CD-ROM uses a constant linear velocity (CLV) spindle drive, which means that spindle speed changes continuously from inner diameter to outer diameter to keep bit density the same at all points on the spiral track (see Figure 6-17). Thus, it gets somewhat more storage capacity than a constant angular velocity (fixed

Figure 6-9
Typical CD-ROM Construction

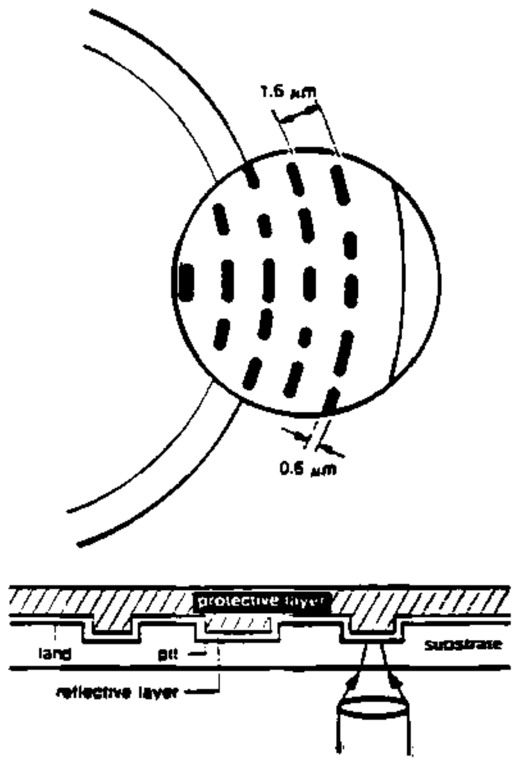


Source: Philips Subsystems and Peripherals Incorporated

spindle speed) would have achieved. The CLV equals 1.3 meters/second. The CLV approach made sense in the original audio application to achieve more playing time. In random-access data applications, however, it takes a very long time to change spindle speeds. Average radial access times are more than 300ms compared with 85ms for stepper motor actuator Winchester drives and 12ms to 30ms for voice coil actuator Winchester drives, which have the advantage of being constant angular velocity drives. Furthermore, CD-ROM rotational latency times are 60ms to 150ms, comparable with flexible disk drives at 83ms and 100ms, and the 8.3ms typical of Winchesters. Thus, average access times are very slow when compared with magnetic storage devices. Data transfer rates at 1.41 Mbps are closer to flexible disks (250 and 500 KB/sec) than to small Winchesters at 5 Mbps. The CD-ROM transfer rate will not support full-motion video without data compression, but it will support animation.

Another result of the CD audio background and the CLV approach to spindle speed is that addresses are expressed in units of 0 to 58 minutes, 0 to 59 seconds, and 0 to 74 sectors.

Figure 6-10
CD-ROM Disk Construction



Note: Data are impressed into the substrate as a series of pits of variable length and are read by laser through the transparent substrate.

Source: Philips Subsystems and Peripherals Incorporated

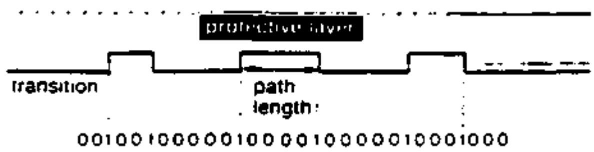
Future Trends

CD-ROM drives will become faster. In the past three years, average access times for CD-ROM drives have dropped from nearly a 1 second down to 300ms to 400ms. Most of the drives available today meet the MPC Marketing Council's specifications, that is, they have average access times of less than 1 second. Based on users' feedback, a CD-ROM drive with less than 400ms of average access time is more desirable to run multimedia applications.

The improvement in access time comes largely from shorter latency time and shorter time for feeding optical pickup to the data processing point. The key technology development work can be expected to center around high-speed, accuracy-control spindle motors to achieve higher rotational speed and high-speed feeding mechanisms for high-speed transporting of optical pickup.

We expect to see this development trend continue in the next two years. As the access time drops below 300ms, smooth, full-motion video applications for multimedia will become even more appealing to end users.

Figure 6-11
CD-ROM Data Pattern



Note: A binary "1" is represented by a land/pit or pit/land transition; the number of "0s" is defined by the path-length between transitions.

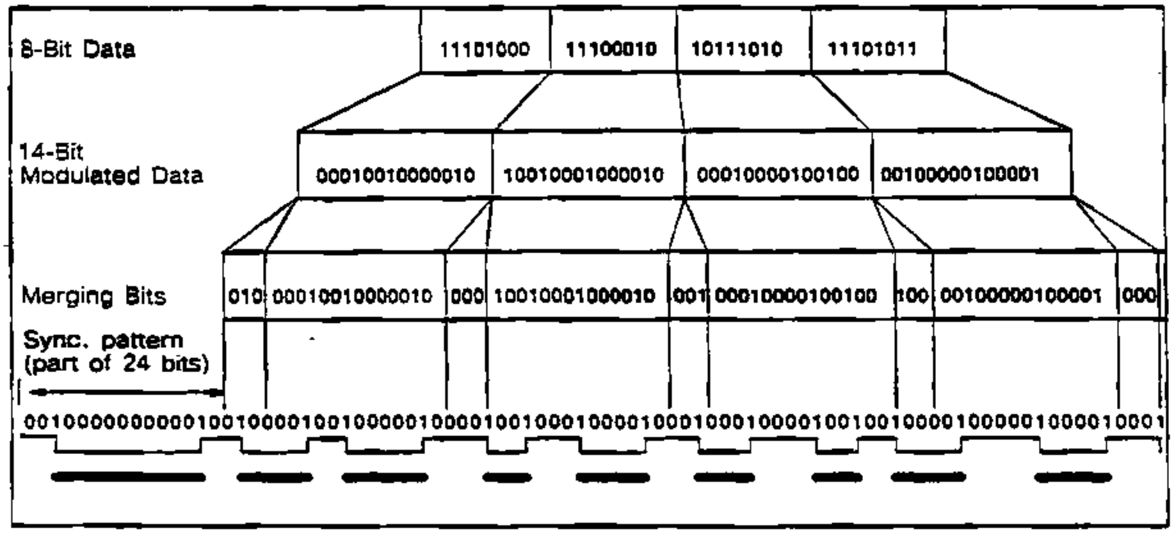
Source: Philips Subsystems and Peripherals Incorporated

Figure 6-12
Part of the 8-to-14 Code Conversion Table

	Data Bits	Channel Bits
0	00000000	01001000100000
1	00000001	10000100000000
2	00000010	10010000100000
3	00000011	10001000100000
4	00000100	01000100000000
5	00000101	00000100010000
6	00000110	00010000100000
7	00000111	00100100000000
8	00001000	01001001000000
9	00001001	10000001000000
10	00001010	10010001000000

Source: Philips Subsystems and Peripherals Incorporated

Figure 6-13
Data to Channel Code to Physical Disk Relationship



Note: A "1" is represented by the transition from a land to a pit or a pit to a land. "0s" are represented by the run length between transitions; that is, length of a pit or land.

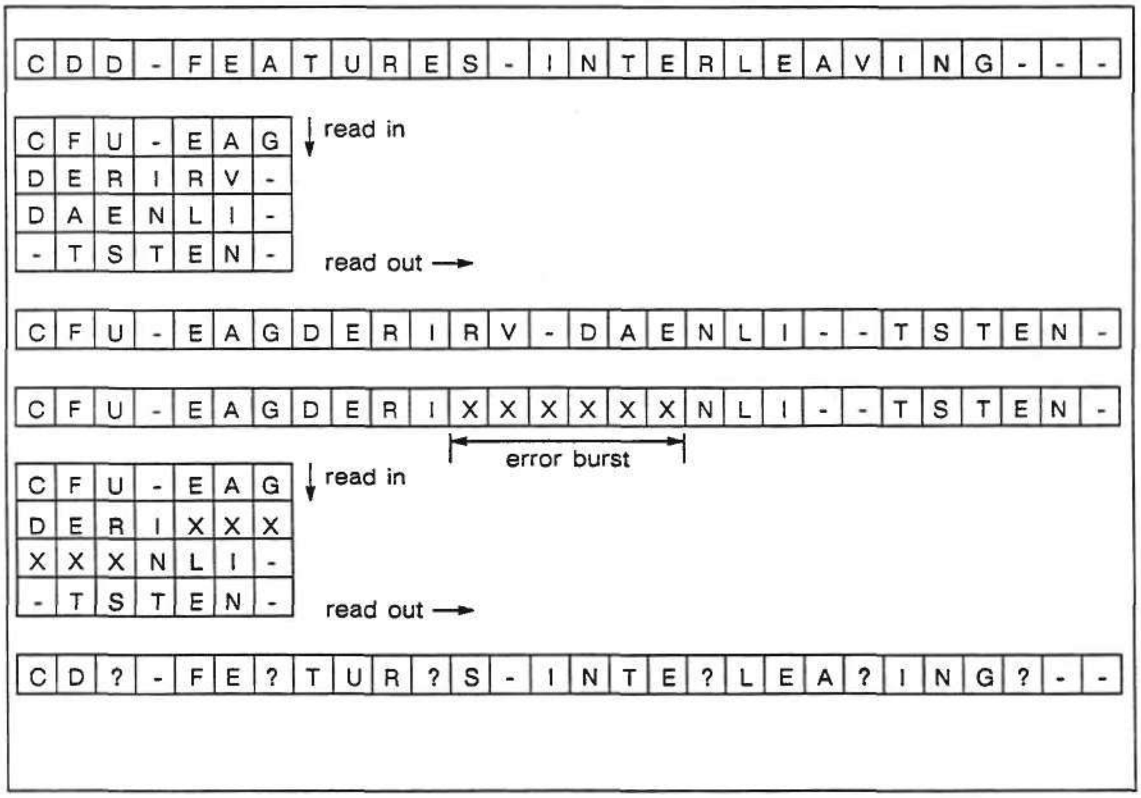
Source: Philips Subsystems and Peripherals Incorporated

Figure 6-14
CD-ROM Format Frame

Sync. pattern	24	+3 channel bits
Control and display	1 x	(14 + 3) channel bits
Data	24 x	(14 + 3) channel bits
Error correction	8 x	(14 + 3) channel bits
		total 588 channel bits

Source: Philips Subsystems and Peripherals Incorporated

Figure 6-15
Interleaving



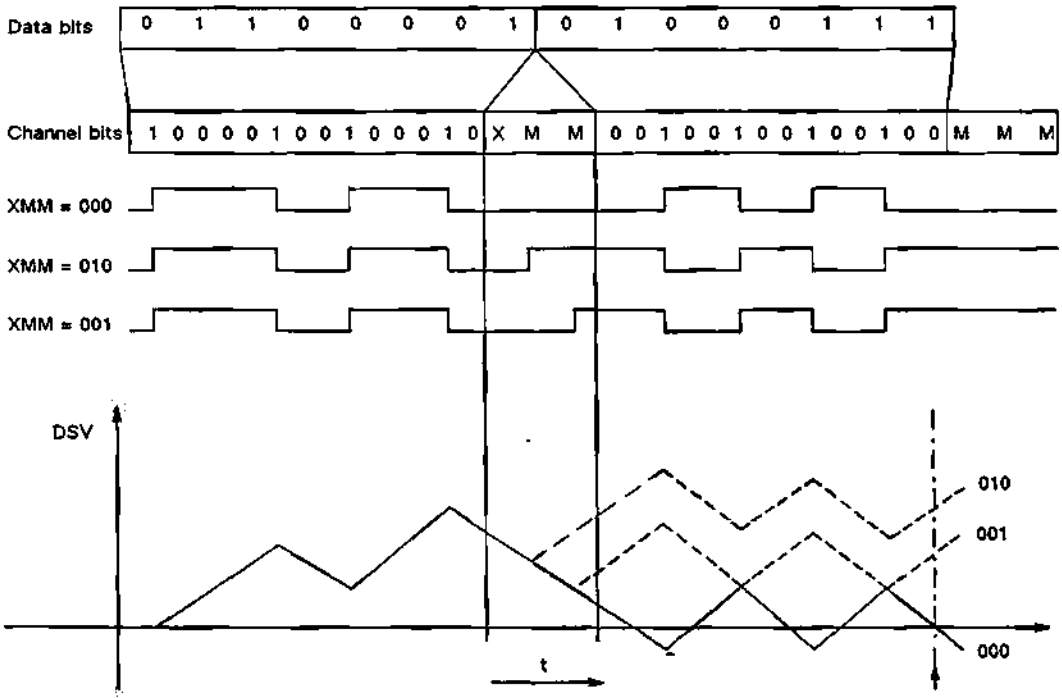
Note: Interleaving spreads an error burst over several frames. This is equivalent to reading data into the columns of a RAM and then reading the data out from the rows. Thus, a 6-symbol drop out is spread throughout the data stream, enabling it to be error corrected.

Source: Philips Subsystems and Peripherals Incorporated

Significant improvement will also come in the form of increased throughput because of the use of high-speed, accuracy-control spindle motors for higher rotational speed and new ASICs—Digital Signal Processing (DSP)—to achieve high-speed data processing. High-performance optical pickup with high-frequency respondent actuator and photodetector will also contribute to the increased data transfer rate.

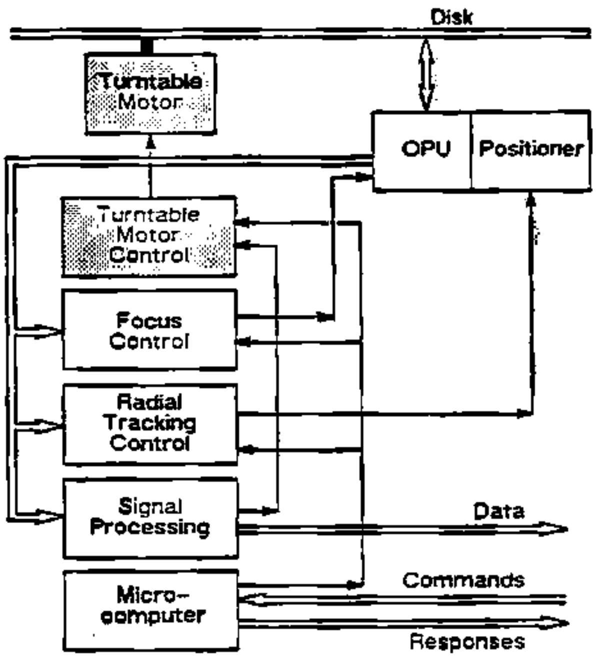
Some vendors employ faster motors to spin the disks at twice, or even four times, the rate of audio CDs for nonaudio operations, as specified by CD-ROM standards. NEC, Sony, and Texel America have rolled out doubled throughput drives. Toshiba is readying its double-speed drive for use in multimedia that it will launch with Apple Computer Inc. Pioneer is shipping samples of a "quadruple-speed" CD-ROM drive that can transfer data at 600 KB/sec and has an average access time of 300ms. Volume shipment is planned for the beginning of 1993.

Figure 6-16
Digital Sum Value



Source: Philips Subsystems and Peripherals Incorporated

Figure 6-17
Servo Control of Motor Speed to Ensure Constant Data Rate



Source: Philips Subsystems and Peripherals Incorporated

The current double-speed CD-ROM drives may have the capability to handle MPEG-1 at a data transfer rate of 1.2 Mbps; but the quadruple-speed drives from Pioneer have the potential to handle MPEG-2, if its data transfer rate is specified between 4 and 6 Mbps.

DSP of 16 bits is standard today. Dataquest expects to see a migration to 32-bit DSP in the next two to three years as the average access time approaches 100ms, especially for internal CD-ROM drives that are attached to the local bus in the high-performance PCs. Dataquest also expects to see more sophisticated areal correction schemes to accommodate the higher throughput of CD-ROM drives.

For mission-critical applications, reliability is more important than speed. Reliability is often achieved by keeping dust off the disk. Dataquest expects new drives to have sealed and enclosed doors covering the caddy slots, lenses that are cleaned automatically each time the disk is inserted, and fanless operation as a result of a more efficient power supply.

In some applications, larger disk capacity is critical. Disk-mastering houses, such as Sony's Electronic Publishing division, can put up to 780MB on conventional CD-ROM disks. This is a good incremental capacity to the normal 680MB limit. Larger capacity beyond that will need MPEG compression/decompression circuitry in the computer. This will enable 1.2GB of compressed data to be stored on International Standards Organization (ISO) 9660 disks. Compared with software-only compression schemes, it will decompress data more rapidly, even for full-motion video, benefiting multimedia applications.

Looking beyond the next five years, commercially available, shorter-wavelength laser will be able to increase the density of the disk more than the current red-light models. Surmounting this threshold may prove difficult because a new format may be needed for going beyond the single spiral track design now specified by ISO 9660.

Another important technology trend is miniaturization. The multimedia market will open up initially through packaged media, for example, a self-contained CD-ROM device with attractive software. This does not have to be connected to a desktop computer. Sony's three-inch Data Discman is indicative of the advent of this trend. NEC is also pioneering the use of small, lightweight, portable models for mobile workers. This technology trend will expand the CD-ROM drives market beyond desktop computing.

Standards Issues

CD-ROM's success in the market can be attributed to the early development of standards for the physical disks and file formats used to record them. This means that a CD-ROM disk can be used in any CD-ROM disc drive, regardless of the manufacturer.

The Red Book, Yellow Book, and ISO 9660 are sufficient for describing data on CD-ROM disks. When the disks are to deliver multimedia, including audio or video, a host of proposals for standardization are emerging. Examples include Compact-Disc Read-Only Memory Extended Architecture (CD-ROM XA), Compact-Disc Interactive (CD-I), CD-TV, and digital video interface (DVI). None of those proposals has gained wide acceptance. Formatting disks for multimedia today means selecting a format based on the immediate needs of the target customers.

Dataquest believes that standardization is instrumental in the proliferation of multimedia computing. In this section, Dataquest will discuss the role and impact of various CD standards on multimedia computing.

Compact Disc Read-Only Memory (CD-ROM)

CD-ROM was codeveloped by N.V. Philips and Sony with the same constant linear velocity (CLV) spiral format as compact audio disks and some videodisks. The physical standards for CD audio disks and the standards for recording data on these disks are described in the Red Book and Yellow Book, respectively. The logical formatting of information on a CD-ROM disk is described in ISO 9660, which details the logical arrangement of data on a disk.

Starting in 1991, the barriers to CD-ROM applications have fallen considerably. On the top of the list of barriers is the price of the CD-ROM drives and performance. We have seen the price decrease significantly in 1992. Some low-end drives can be purchased from retail outlets for less than $200, end-user price. This price decline will continue and act as an accelerator for the acceptance of CD technology. The costs of mastering and replication are coming down as well. Also, more powerful PCs are coming into the market at much lower prices. Finally, attractive multimedia software became available. According to MPC Marketing Council, more than 75 multimedia software packages are available on CD-ROM, as of this writing. On the development side, retrieval software has been optimized for optical disks and made available for multiplatform and multilanguage distribution.

CD-ROM XA

Compact Disc Read-Only Memory Extended Architecture (CD-ROM XA) is an extension of the CD-ROM standard. It is billed as a hybrid of CD-ROM and CD-I and promoted by Sony and Microsoft. As a spin-off technology from CD-I, CD-ROM XA employs some of the same features, such as the audio encoding techniques. The extension adds adaptive differential pulse code modulation audio to permit the interleaving of sound and video data to animation and sound synchronization. CD-ROM XA is an essential component of Microsoft's plan for multimedia computing.

Most CD-ROM drives sold in 1991 conformed to the original Sony/Philips standard for CD-ROM, which lacks the capability for mixing audio for real-time playback with other data. A subsequent extension to the CD-ROM standard—CD-ROM XA—was initiated by Microsoft and Sony to add interleaved audio to the standard. The standard allows compressed audio to be read and played from the disk, while other data is being read. The MPC standard and IBM's M57 UltiMedia PC both use CD-ROM XA. CD-ROM XA is supported strongly by Sony, Philips, Microsoft, and Meridian Data.

Dataquest believes that CD-ROM XA will prevail in multimedia markets for the following reasons:

- Most users can immediately appreciate the added sound capability.
- The price difference between the two is minimal.
- The MPC standard recommends a CD-ROM XA drive as an option.
- Many new titles include CD-ROM XA audio.
- CD-ROM XA has sufficient support from leading vendors.

CD-Interactive

Compact Disc-Interactive (CD-I) is a CD format developed by N.V. Philips and Sony and specified in the Green Book. The standard describes an interactive format and playback mechanism. CD-I disks are a different format than ISO 9660.

To establish CD-I as the standard for multimedia, the challenge to Philips is twofold. First, there is a software and hardware synergy effect. Second, there are consumer tastes. The first challenge can be answered by more evangelism among software developers to write more CD-I titles and lower prices to create a large user base and, hence, establish CD-I as the de facto standard for the interactive entertainment and professional market. Those two elements are interrelated. Software developers will not write CD-I software, unless there is a large installed base; while a large installed base will not become a reality, unless there is plenty of attractive software. The consumer tastes can only be tested by time.

CD-Recordable

CD-Recordable (CD-R) is a write-once CD technology. The CD-R drive can record image, text, and sound once to a CD-R disk and the data can be accessed an unlimited number of times. Standardization is one of the strengths of CD-R. The recorded CD-R disks are compatible with CD-ROM, CD-I, Photo-CD, and CD-DA players—which means media interchangeability between CD-R drives and CD-ROM drives, regardless of the manufacturer.

CD-R is governed by the Orange Book. ISO 9660 was specified for read-only and does not support incremental write and other CD-R features. Philips invited several companies to a meeting in Frankfurt, Germany, in May 1990 and formed the Frankfurt Group. This group of companies has become the driving force for establishing the CD-R format specifications as an internationally accepted file format. Several companies then formed the Frankfurt Consortium, which acts as the marketing arm for the Frankfurt Group. The objectives of the Frankfurt Consortium are threefold, as follows:

- Promote CD-R as a standard for low-quantity multimedia publishing
- Create end-user awareness
- Position CD-R

Because of the endorsement by the major CD vendors (such as Philips, Sony, Meridian Data, Ricoh, JVC, Digital Equipment Corporation, the Eastman Kodak Company, Pioneer, Yamaha, and TEAC), Frankfurt's specifications are expected to be approved by ISO. Table 6-2 shows the comparison between ISO 9660 and Frankfurt Proposal.

Philips believes that CD-R is another important, enabling technology for multimedia because it unleashes the power of CD-ROM publishing to the less-professional desktop users and enables small-quantity CD multimedia publishing. As a result, the availability of CD-R drives and disks will bring the proliferation of multimedia applications and stimulate the demand for multimedia computing. Dataquest tends to agree with this assessment. Indeed, CD-R can be one of the most important CD technologies in the coming year. Figure 6-18 shows Philips' view of how CD-R technology will assist the growth of the multimedia market.

Market Analysis

Market Segmentation

From a storage market perspective, Dataquest segments multimedia hardware opportunities into three basic categories: multimedia-ready computer, upgrade kits, and consumer systems and subsystems, as follows:

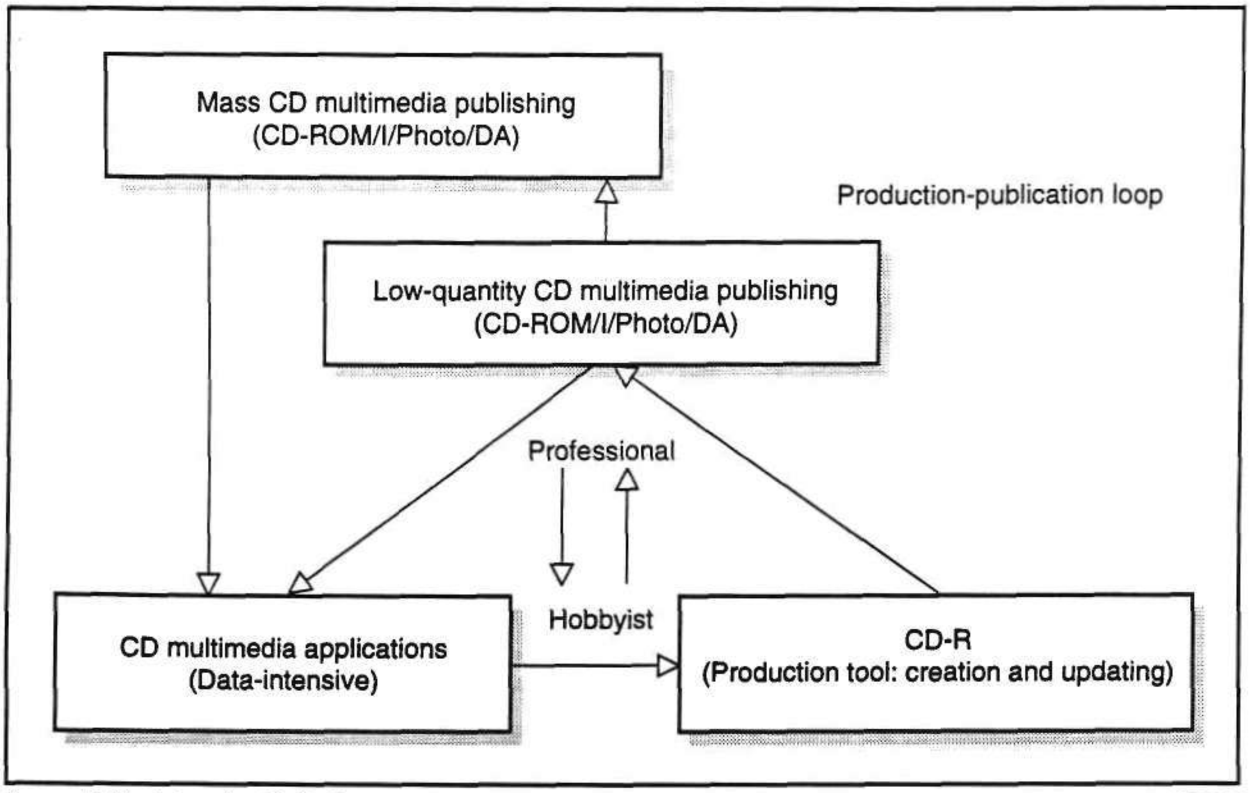
- Computer platforms
  - IBM PC and PC compatibles
  - Macintoshes

Table 6-2
Comparison between ISO 9660 and Frankfurt Proposal

	ISO 9660	Frankfurt
Universal File Exchange Structure	X	X
Single- or Multiple-Data Tracks	X	X
Read Support	X	X
High Performance		X
Support New Operating Systems	X	
Write Support		X

Source: Philips Interactive Media Systems

Figure 6-18
Philip's View of CD-R Technology



Source: Philips Interactive Media Systems G2001812

- Workstations
- Kiosks

- Multimedia upgrade kits
  - Entry-level (with 8-bit sound card and low-performance CD-ROM drive plus two to four titles, retail priced at less than $500)
  - Midrange (16-bit sound card with medium-performance CD-ROM drive plus more than four titles, retail priced at less than $900)
  - High end (16-bit sound card with high-performance CD-ROM drive plus more than 10 titles, retail priced at $1,000 or more)
- Consumer (see Chapter 3 for details)
  - Information and entertainment center
  - Interactive and on-demand systems
  - Specialized consumer products: karaoke and filmless photography and viewing (that is, Photo-CD)
  - CD-ROM-enhanced video games

A multimedia upgrade kit contains everything a user needs to turn his or her current PC into a multimedia-enabled platform. At the center of the multimedia upgrade kit is a relatively high-performance CD-ROM drive, a sound card, and bundled multimedia CD-ROM titles. Those users who have already bought a CD-ROM drive and want to upgrade to run multimedia can buy an upgrade kit without a CD-ROM drive. For example, Tiger Software Inc. in Coral Gables, Florida, offers a multimedia upgrade kit that includes Microsoft 3.1 Multimedia Extensions, Media Vision audio board, CD-ROM SCSI interface and speakers, and a CD-ROM caddy with room for 30 titles and 17 CD-ROM software packages. The whole package is retailed at $799.

Market Opportunities

As stated in Chapter 2, multimedia is a very compute-intensive, multifaceted application in a world of desktop devices that are unequipped to run it. Dataquest estimates that only 1 million out of approximately 124 million desktop PCs installed worldwide are equipped with the necessary processing power, memory, high-resolution color displays, CD-ROM drives, sound systems, and video and audio adapter cards required to run multimedia applications efficiently.

Technical workstations are much better suited from a raw processing power point of view to run multimedia, except that most still lack CD-ROM drives. For example, Dataquest estimates 1 out of 20 Sun workstations has a CD-ROM attached. Sun is the leading vendor in the workstation market, holding about 34.5 percent of the total 1991 workstation market share.

But the total workstation market represents less than 1 percent of the total installed base of desktop devices (the installed base of technical workstations numbered approximately 1.5 million). This picture will definitely change on both the PC and workstation fronts over the decade as users upgrade desktop workstations through equipment replacement cycles, as multimedia PCs and upgrade kits become available at affordable prices, and as the boundary between a PC and a workstation blurs. Today, the availability of multimedia desktop platforms is definitely an issue.

The recent price war in the PC market will keep the PC vendors on their toes to look for new ways to enhance their products and add more value. Multimedia is definitely on their agenda to explore. Some major PC vendors have already introduced multimedia-ready machines, including IBM, Tandy, and Acer. Dataquest believes that it will take time for other PC vendors to figure out what their multimedia machine should be. Meanwhile, the multimedia market will initially take off in the upgrade kit segment. Therefore, CD-ROM drive vendors are better off focusing on the multimedia upgrade kit market for immediate market share expansion.

The driving force behind the multimedia upgrade kit market is threefold. First, based on our end-user buying behavior analysis, users will not throw away their current machines, they upgrade according to applications. Microsoft Windows is the catalyst for migration to larger screens, and it is relatively painless and easy to upgrade to a large color monitor. Now, as more attractive multimedia software is becoming available at affordable prices, it is natural for users to add sound and CD-ROM drives to run those applications.

The availability of the multimedia upgrade kits is the second contributing factor. Currently, more than 10 hardware vendors offer upgrade kits. The promotion activities of those vendors are generating awareness and stimulating interest.

Lastly, opening up the reseller channel helps to penetrate into both horizontal and vertical markets. The primary distribution channel for multimedia upgrade kits are distributors, computer specialty stores, value-added resellers (VARs), and computer dealers. All major national and regional distributors are carrying upgrade kits including D&H, Ingram, Merisel, Tech Data, and Micro United. The following list shows the number of authorized resellers that sell multimedia upgrade kits. Considering that vendors started shipping upgrade kits only at the beginning of 1992, it is remarkable how fast the resellers embraced the concept and invested in carrying the products.

- Creative Labs has 1,500 resellers.
- Media Vision has 2,350 resellers.
- NEC Technology has 125 direct resellers.
- Turtle Beach has 400 resellers.

The reseller channel is very important in the multimedia upgrade kit business for several reasons. The early adopters are mostly home computer users and in the education sector because the bundled multimedia software is geared for those markets. Reseller channels are proven to be the most effective way to reach the highly fragmented home and education markets. The kit manufacturers offer and maintain good margins for their resellers. In some cases, resellers can get a 30 percent margin on each multimedia upgrade kit they sell.

Dataquest further classifies the multimedia upgrade kit suppliers into three types as follows:

- CD-ROM manufacturers
  - Example: NEC, with CD Express and Multimedia Gallery
- Sound board manufacturers
  - Example: Creative Labs, with Sound Blaster Multimedia Upgrade Kit

- Resellers
  - Example: TigerSoftware, with the Multimedia CD Bundle

Dataquest expects more CD-ROM drive manufacturers to get into the upgrade kit business with different approaches. Some manufacturers will market under their own brand name, and some will bundle the products for their resellers. But one thing is for sure: they will continue to lower the price of the CD-ROM drive and will bundle more software for different market segments. Dataquest projects that multimedia upgrade kits will evolve into three segments in 1992. The entry-level and midrange with entertainment and education titles will target price-sensitive users. The high end will be bundled kits with presentation, business, and training titles for power users in the business environment.

Market Forecast Assumptions

Dataquest believes that CD-ROM is, and will, remain the de facto standard for mass replication and distribution of multimedia titles (applications).

The average price paid by an end user for an add-on CD-ROM drive will decrease from $621 in 1991 to $255 in 1993 and then $120 in 1996. No other type of optical drive or removable storage device will approach CD-ROM's price performance ratio in the forecast period.

The factory average selling price (ASP) includes only the drive, excluding device-driver software and control card. Most of the CD-ROM drive manufacturers are, and will be, major Japanese companies that are shifting their drive manufacturing base offshore in search of lower costs of production both at the component and complete system level.

The competition and economies of scale leveraged off the CD-player manufacturing and volume shipments anticipated by major suppliers will continue to drive the price down. The price declines will act as a strong market accelerator.

The CD-ROM drive products are segmented into low end, midrange, and high end. More than three-quarters of the total CD-ROM drives shipped in 1992 are estimated to be multimedia-capable and purchased for running multimedia applications. The remaining CD-ROMs shipped will be used for low-end text-only applications (such as software distribution). However, Dataquest believes that, by 1993, all CD-ROM drives will have the necessary performance to run multimedia applications. Users are more likely to buy CD-ROM drives for running multiple applications, including text-only and multimedia.

Because most of the installed PCs or workstations equipped with CD-ROM drives can be upgraded to run multimedia without buying a new CD-ROM drive, Dataquest believes that the total accumulative shipment is more representative of the multimedia-capable hardware base.

CD-ROM networking will grow rapidly because of information and hardware cost savings. Major software vendors will offer CD-networking software to provide another alternative to multimedia upgrade kits for individual users. This could positively impact the multimedia market in general and the business market segment in particular, by breaking down the barriers of entry associated with the installation difficulties and high cost. But this market segment is still operating from a very small installed base. Dataquest estimates that less than 4 percent of installed CD-ROM drives are currently connected on a network.

CD-ROM XA will eventually replace CD-ROM for most applications because most users can immediately appreciate the added sound capability. Also, the price premium for CD-ROM XA, compared with standard CD-ROM drives, is low. Most important, many new titles include CD-ROM XA audio capability.

Included in this forecast are drives embedded in CD-I and CD-TV players, but not drives for video games such as NEC's PC Engine. Sales of CD-ROM drives in consumer products such as CD-I will not reach high levels until after 1995. Except special multimedia PC models with built-in drives, most CD-ROM drives will be sold as a separate option until 1995.

Sony and Philips are developing standards for CD-R with considerable industry support and participation. Dataquest expects more than six vendors to introduce CD-R products while the Orange Book is being finalized. With so many competing for a limited market share, the factory ASP of CD-R will drop from $6,000 to $3,000 in the next 18 months—and even more later. Affordable CD-R drives will be widely used by developers, both in-house and commercial, in authoring systems, and for certain low-volume projects, benefiting multimedia markets by creating more multimedia applications.

Dataquest assumes that there will be no manufacturing constraints in producing CD-R. Currently, the demand seems to outstrip the supply. Dataquest projects that the situation is temporary, until sometime in 1993. Dataquest further assumes that there will be no shortage of CD-R disks at reasonable prices. The factory ASP for CD-R drives includes the drive itself; while the end-user price includes premastering software, the controller, and the recording drive.

The big uncertainty associated with this forecast is that additional multimedia software will not come to market soon. Without attractive, reasonably priced software, few users will pay the additional cost of a multimedia PC or upgrade kit.

Market Forecast

Table 6-3 presents a forecast of CD-ROM drives shipped for multimedia applications.

Table 6-4 presents a forecast for CD-R devices.

Table 6-3
History and Forecast of Worldwide CD-ROM Drives

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
New Shipments (Thousands of Units)	240	856	1,498	2,246	3,617	4,228	4,990	35
Factory ASP ($)	248	207	145	102	80	68	60	-20
Factory Revenue (U.S.$M)	60	177	217	229	252	257	276	6
End-User ASP ($)	745	621	435	255	199	170	150	-23
End-User Revenue (U.S.$M)	178.80	531.58	651.63	572.73	719.78	718.76	748.50	4
Cummulative Shipments (Thousands of Units)	527	1,383	2,881	5,127	8,744	12,972	17,962	58

Source: Dataquest (November 1992)

Table 6-4
History and Forecast of Worldwide CD-R

	1990	1991	1992	1993	1994	1995	1996	CAGR (%) 1992-1996
New Shipments (Thousands of Units)	0	0.10	1.50	10.00	25.00	90.00	120.00	199
Factory ASP ($)	0	18,000.00	6,000.00	3,000.00	2,500.00	1,500.00	1,400.00	-30
Factory Revenue (U.S.$M)	0	1.80	9.00	30.00	62.50	135.00	168.00	168
End-User ASP ($)	0	30,000.00	9,000.00	6,000.00	5,000.00	3,500.00	3,000.00	-24
End-user Revenue (U.S.$M)	0	3.00	13.50	60.00	125.00	315.00	360.00	127
Cummulative Shipments (Thousands of Units)	0	0.10	1.60	11.60	36.60	126.60	246.60	252

Source: Dataquest (November 1992)

Vendor Profiles

Dataware Technologies Inc.

Company Statistics

Headquarters Location	Cambridge, Massachusetts
President and CEO	Kurt Mueller
Founded	1988
Fiscal 1991 Revenue	$5.85 million
Number of Employees	90
Number of Resellers	15
Installed Base	230
Number of Users	50,000
Number of Titles Developed	350

Overview

Dataware Technologies Inc. and Reference Technology Inc. were merged in February 1992. The new merged company retained the name of Dataware Technologies Inc. and offers a full range of production and support for CD-ROM and multimedia customers worldwide. This includes services to convert, scan, and digitize all types of information at the front end of the process, all the way through to shipping, supporting, and maintaining CD-ROM drives and software at the publishers' end-user sites. With combined resources, product line, and customer installed base, the company supports a wide range of CD-ROM and multimedia platforms including MS-DOS, MS-Windows, Macintosh, UNIX, OS/2, and CD-I, as well as various Japanese hardware platforms and operating systems.

Financial

Dataware is a private company owned by its employees, by venture capital firms such as Oxford Partners, Morgan Holland, Information Partners, and TVM, and by corporate investors such as R. R. Donnelley & Sons and Computer 2000 AG.

Dataquest estimates that Dataware's revenue was $5.85 million in 1991. Combined revenue for the merged company is estimated at $15 million for 1992. Dataquest further estimates that about 40 percent of the company's sales revenue comes from its international sales.

Strategy

Dataware positions itself as the leading vendor to facilitate publishers and corporate customers in moving their large databases to CD-ROM distribution medium. Dataware focuses on three markets: professional publishers such as McGraw-Hill, corporate users such as Kodak, and government agencies such as the U.S. Patent Office. Dataware clearly recognizes that the CD-ROM authoring business is not a shrink-wrapped one and formulated its strategy accordingly. Dataware has been relatively successful in penetrating into those target accounts, with a strong direct sales team of about 25 people.

Because of the complexity and investment involved in developing CD-ROM titles, Dataware offers a complete range of products and consulting services and support. According to Dataware, services accounts for more than 50 percent of its total 1991 revenue. It also has broad geographic coverage including the United States, 12 European countries, Australia, Canada, and Japan. Dataware claims that more than 350 CD-ROM titles have been developed with its authoring software and distributed in more than 90 countries.

Dataware's current core business is conventional CD-ROM authoring tools (text+graphics+databases), which accounts for more than 90 percent of its total revenue. In the future, Dataware envisions that its market will expand further into multimedia by providing linkages between regular CD-ROM titles with multimedia playback schemes.

To lower the entry cost of using CD-ROM technology as the information distribution medium, Dataware is pursuing CD-R market opportunity. It has put together all the pieces necessary to unleash the power of making a CD-ROM disk available to the less-experienced user for less than $20,000. Dataware's CD-R solution addresses some issues that have hampered users' wider acceptance of CD-ROM technology. The first one is that conventional CD-ROM is not suitable for distribution of information with quick turnaround time requirements. The second one is that producing low-volume CD-ROM replicas is not economic with conventional CD-ROM production. With CD-R technology, users can avoid mastering and turnaround time normally required in CD-ROM production and are able to make CD-ROM replicas in small quantities for prototype purposes.

As an early supplier of this exciting, new, enabling technology solution, Dataware has a good chance to capture a substantial share of this emerging market.

Products

Dataware offers a complete range of products, services, and support for CD-ROM and multimedia publishing. Its product offerings can be classified into five areas as follows:

- Development and retrieval software
  - CD Author
    - CD Answer
    - Advanced Design Library

    - HyperText
    - CD Answer HyperText
    - HyperText Design Library
  - ReferenceSet
    - Text Build
    - ReferenceSet Record Build
    - ReferenceSet Image Build
  - Text
    - Reference Book
    - Record Reference Book
    - Record Reference Book
- Title Development Services Software and Hardware
  - Text and Data Conversion and Indexing
  - Information Capture
  - Project Consulting
  - Custom Development
  - Multimedia Development
  - The CD Record System
- Premastering
  - ISO 9660 Formatting Software
  - Input Devices
  - Magnetic Disk Drives
  - Output and Backup Devices
  - CD-Recordable drive
  - Device drive
  - Premastering software
  - Reference set
- End-User Product Support
  - CD-ROM Drives and Maintenance
  - Customer Support and Services

- CD-ROM Preparation and Services
  - Premastering and Testing
  - Mastering and Distribution

Currently, Dataware supports all the major hardware platforms and operating systems. In the future, Dataware plans to support OS-9 (CD-I) in its standard retrieval engines and MS-Windows in its standard user interfaces. The following shows the platforms and operating systems that Dataware supports:

- Authoring tools
  - IBM PC and compatibles
  - VAX/VMS
  - Sun/UNIX
- Standard retrieval engines
  - IBM PC
  - Macintosh
  - UNIX
  - MS-Windows
- Standard user interfaces
  - IBM PC
  - Macintosh
- Custom user interfaces
  - IBM PC
  - MS-Windows
  - Macintosh
  - UNIX
  - OS-9

Dataquest Perspective

Dataware has gained a critical mass in the CD-ROM authoring software market. Being an early player and evangelist for the technology in an emerging marketplace, Dataware has set out to establish a strong corporate image as a software development partner. Its relationship with quality customers, who are in the business for the long run, has helped the company to snowball new businesses. Dataquest is most impressed with its marketing capability to get the products and services to customers. For example, Dataware conducts regular technical seminars for potential publishers and corporate users about CD-ROM technology and its benefits. These technical seminars help the company get its message across to a well-focused group and generate quality leads for its direct sale force for potential businesses.

For a small start-up company to be a pioneer in an emerging market, securing sufficient financial resources is normally a challenge for the management team. Dataware seems to have enough financial backing to sustain it in the business. According to the company, Dataware is profitable.

The challenge for Dataware in an emerging market lies in the company's ability to correctly anticipate new markets and competitive developments, continually bring to the market enhanced products, and ensure customer satisfaction.

Meridian Data Inc.

Company Statistics

Headquarters Location	Scotts Valley, California
Chairman	Frederick P. Meyer
President and CEO	Whitney G. Lynn
Founded	1986
Fiscal 1991 Revenue	$10 million
Number of Employees	58

Overview

As a pioneer in PC-based CD-ROM publishing and CD-ROM networking, Meridian Data has been a key catalyst behind the growing CD-ROM market. Since its inception in 1986, Meridian Data has been involved at the high levels of standards committees for CD-ROM, including the High Sierra Committee, the Frankfurt Group, and the Frankfurt Consortium (which is the marketing arm for the Frankfurt Group). Meridian Data focuses on providing solutions for CD-ROM-based information management tools. Now, Meridian Data is poised to push CD-ROM and CD-R into the desktop network computing environment.

Financial

Meridian Data is a privately held company with financial backing from institutional and industrial investors, such as Southern California Ventures, Oxford Partners, HMS Capital, Sears Pension Fund, and Third Millennium Ventures. In August 1991, Meridian Data finished its third round of capitalization and raised $2.5 million.

Dataquest estimates that Meridian Data's 1991 revenue was about $10 million from sales of its CD-ROM publishing equipment and software and CD Net software. Its 1992 revenue is estimated at $11 million.

Strategy

Meridian Data is at a transition crossroads. The company has been successful penetrating the professional CD-ROM publishing market. According to the company, Meridian Data holds more than 80 percent of the total CD-ROM publishing equipment market with an installed base of 500 units worldwide. Meridian Data believes that its professional CD-ROM publishing market is saturated, and little growth is anticipated. In search for a growing market, Meridian Data found CD-R and CD-ROM networking software a natural extension for its expertise.

Meridian Data is a true believer in standardization. One of its strategies is to be very active in setting the standards in CD-ROM technology. It is heavily involved in the Frankfurt Group, which proposed the CD-R format specifications as an internationally accepted file format to ISO.

On the marketing side, Meridian Data is repositioning itself as the CD networking company. The company has teamed up with Philips and other CD-R drive companies to promote its NETSCRIBE as the software architecture to connect CD-R drives over computer networks. The combination of the NETSCRIBE and CD-R drives results in a solution—similar to a shared laser printer—that allows users to transparently print and retrieve information, except that the information is earmarked for compact disk, not paper.

With this solution, Meridian Data targets applications in the following areas:

- Network CD creation
  - Multimedia presentations
  - Imaging
  - COM replacement
  - LAN backup
- Network CD retrieval
  - Online archive
  - Image management
  - Database access

On the distribution side, Meridian Data first aims at OEMs and resellers that have vertical applications.

Products

Meridian Data offers products that cover all the processes necessary to deliver information on the CD-ROM medium.

These are CD development products, CD networking products, and CD NETSCRIBE, as shown below.

- CD development products
  - Professional CD Publisher Software
  - Personal CD Publisher Software with support for CD-R recorders
  - CD Publisher and CD Professional
  - VR Publisher, VR Professional, VRX Professional
  - CD Master
- CD networking products
  - Integrated hardware and software systems
  - CD Net Model 428
  - CD Net Model 314
  - CD Net Model 100 NC
  - Standalone software
  - CD Net Software
  - CD Net Software NetWare Loadable Module (NLM) Version
- NETSCRIBE Software
  - NETSCRIBE is a software architecture connecting CD-R drives over computer network topologies such as Ethernet. It includes an application program interface (API) that enables commercial software developers and users to access powerful features unique to CD through their own programs. NETSCRIBE is licensed to OEMs and ISVs with a developer kit.
- NETSCRIBE developer program
  - Developer documentation
  - Sample libraries
  - Technical support
  - Marketing support

Dataquest Perspective

People at Meridian Data are truly visionaries. Meridian was asking about multimedia long before it became such a hot buzzword. The company's early participation in the CD-ROM market is evidenced by its impressive history of innovation, as shown in the following:

- PC-based CD-ROM publishing in 1986
- CD-ROM networking product in 1988

- CD-ROM recording system in 1989
- Software architecture for networking CD-R drives in 1992

Meridian Data's core business has been in CD-ROM publishing equipment, in which the company integrates hardware and software for the CD-ROM publishing professional. Meridian Data claims that it holds about 80 percent of that market and that 60 percent of CD-ROM applications have been developed on Meridian systems. Unfortunately, the professional CD-ROM publishing market has been saturated and will have little growth in equipment demand. Meridian Data needs new products to sustain its position in the CD-ROM publishing market and bring itself to the next plateau for future growth.

Apparently, Meridian Data has chosen to bet its horses on CD-R technology, with the NETSCRIBE software architecture. Its rationale is compelling. First, CD-R has been introduced with standards in place. Second, shared resources lower the cost per user and will help lower the cost barrier and expand the market. NETSCRIBE CD-R reads and writes all disk types, including CD ROM and multimedia disks; therefore, CD-R should have more appeal to a broader base of users. But, so far, there is no rush to buy those products.

Then what is missing? First, CD-R drives and disks are not available in large quantities yet. Dataquest anticipates that, in the next 18 months, the market will see some first-volume shipments of CD-R drives and disks. Second, one user making a CD-R disk cross the network will deprive other users on the network access to the drive. It seems logical to use a CD-R autochanger or library subsystems. But those products are not available yet, either. Third, positioning NETSCRIBE combined with CD-R drives as backup solutions is not cost-effective compared with alternative technologies such as tape.

The real demand for NETSCRIBE CD-R perhaps comes first from the software developers in workgroups that develop multimedia applications either for internal use or for the commercial market. Those developers will appreciate the lower entry cost for making a prototype CD and the quicker time to market.

Dataquest gauges the success of a company such as Meridian Data by three categories: its ability to get major OEM commitments; the size of its total installed base; and the number of software developers. If Meridian Data can successfully copy the business model of Adobe Systems Inc., Dataquest believes that the company will carve out a nice niche for its products and secure a strong position in the emerging multimedia and CD-R market.

NEC Corporation

Company Statistics

Headquarters Location	Tokyo, Japan
Chairman	Atsuyoshi Ouchi
President and CEO	Tadahiro Sekimoto
Founded	1899
Fiscal 1990 Revenue	$25.6 billion
Fiscal 1991 Revenue	$27.5 billion
Number of Employees	39,000

Overview

NEC started as a manufacturer and importer of telephones and telephone-switching equipment. It is now the world's largest maker of semiconductors for outside sale and Japan's leading producer of PCs for the domestic market.

NEC's participation in the emerging multimedia market is in its CD-ROM programs and its active involvement with the MPC Marketing Council through NEC Technologies Inc.—a wholly owned subsidiary of NEC Corporation.

Financial

Dataquest estimates that NEC's 1991 sales revenue from its CD-ROM product line was about $40 million. NEC expects its sales revenue to grow by 120 percent in 1992.

Strategy

NEC views the emerging multimedia market as strategically important for the long-term growth of its computer business. NEC is the first company that offered the double-speed CD-ROM drive bundled with software, and NEC also sells upgrade kits to specifically address the need of multimedia computing requirements. NEC is also a driving force behind the MPC Marketing Council through its U.S. subsidiary, NEC Technologies, Inc.

NEC trademarked its MultiSpin CD-ROM drive with the hope that users will identify the brand name with the huge success of its MultiSync monitor product line. Because those two peripherals products are sold by similar channels, NEC clearly is leveraging the strength and name recognition it gained with its monitor products by cross-selling. NEC has been very creative with its promotional programs as well. For example, in one of NEC's promotions, when buying an NEC monitor and graphics card, the customer can get an NEC CDR-37 for free.

NEC will focus on the multimedia consumer market by providing a full range of CD-ROM products and upgrade kits. At the entry level, NEC will introduce a multimedia package for less than $500, and at the high end, a multimedia upgrade kit for less than $1,000. These multimedia kits will contain everything a consumer needs to turn a PC into a multimedia-capable platform.

Products

NEC Technologies Inc. recently introduced three new CD-ROM drives specifically designed for meeting the high-performance requirements of multimedia computing. The new products are CDR-74 (external), CDR-84 (internal), and CDR-37 (portable) CD-ROM readers. The highlights of the products include the following:

- Use of MultiSpin technology, which enables the InterSect CDR-74 and CDR-84 to spin at 300 KB/sec when retrieving text, graphics, and video information
- Quicker access time of 280ms for CDR-74 and CDR-84
- A 64K cache memory
- Improved reliability with a new protective double-dust door and easily upgradable socketed firmware
- Smaller form factor—CDR-37 weighs 2.2 pounds and is MPC-compliant, with an access time of 450ms and data transfer rate of 150 KB/sec
- Multiplatform flexibility offered by NEC Interface Kits, which are bundled with the drives for XT/AT, Macintosh, PS/2 or parallel to SCSI platforms

All three models are currently shipping and can be purchased individually or bundled with other NEC products such as NEC Multimedia Upgrade Kit and CD Gallery. All the drives come with a two-year limited warranty and are available through NEC's authorized dealers.

The suggested retail prices of NEC's new InterSect line of CD-ROM readers and Interface Kit bundles are listed as follows:

- InterSect CDR-74 external CD-ROM reader—$675
- InterSect CDR-84 internal CD-ROM reader—$599
- InterSect CDR-37 portable CD-ROM reader—$449
- Optional battery pack for CDR-37—$99
- InterSect CDR-37 with XT/AT Interface Kit—$539
- InterSect CDR-37 with Mac Interface Kit—$485
- InterSect CDR-37 with PS/2 Interface Kit—$598
- InterSect CDR-37 with parallel to SCSI—$559
- InterSect CDR-74 with XT/AT Interface Kit—$765
- InterSect CDR-74 with Mac Interface Kit—$712

- InterSect CDR-74 with PS/2 Interface Kit—$824
- InterSect CDR-84 with XT/AT Interface Kit—$689
- InterSect CDR-84 with PS/2 Interface Kit—$749

NEC's new entry-level multimedia upgrade kit family is called CD Express. It includes CDR-25, CD Express-PC, and CD Express-Mac. CDR-25 is an MPC-compliant, portable reader with 10 software titles. Table 6-5 shows the entry-level product lineup. Both PC and Macintosh versions of CD Express come with self-amplified stereo speakers, XT/AT interface, and four C-cell batteries.

NEC also has a high-end multimedia bundle that is sold to the consumer market for $999. The Multimedia Gallery comes in two versions—PC and Macintosh. It contains an NEC CDR-74 CD-ROM reader with NEC SCSI/Audio board and cable for one-slot solution, self-amplified stereo speakers, stereo headphones, and four C-cell batteries. Both are bundled with six multimedia titles.

Dataquest Perspective

NEC is a serious challenger for Sony, which currently holds the No. 1 position in CD-ROM market share. NEC seems to be gaining on Sony with its emphasis on multimedia in the consumer market. First, NEC went into head-on competition with Sony's Laser Library by introducing the CD Gallery. The CD Gallery included seven software titles and comes in both PC and Macintosh versions. Laser Library comes with six titles and supports only PCs. Within the first eight months of the introduction, NEC sold more than 30,000 units of CD Gallery. Dataquest believes that NEC's gain in the market is at the expense of Sony. Then, NEC announced its MultiSpin CD-ROM drive and offered its installed base an enhancement program to upgrade their old NEC drives to the new ones. NEC has teamed up with Asymetrix Corporation to supply a Multimedia PC (MPC) Upgrade Kit targeted at the business market.

Now, NEC has introduced two new bundles, which again target the consumer market. Both CD Express and Multimedia Gallery are priced to sell. At the low end, the performance is lacking. At the

Table 6-5
NEC Entry-Level Multimedia Hardware and Software Bundle

Package	Average Access Time (ms)	Data Transfer (KB/sec)	Retail Price ($)
Portable CDR-25	650	150	499
CD Express-PC CDR-235 (10 titles)	650	150	499
CD Express-Mac CDR-235 (10 titles)	650	150	499

Source: NEC, Dataquest (November 1992)

suggested retail price of $499, it is a good value for home users who just wish to explore CD-ROM technology. For performance seekers, Multimedia Gallery delivers the needed performance at the right price.

NEC has come up with a new bundled offering every six months. What will be NEC's next move? Dataquest believes that NEC will continue its thrust to build a higher visibility among consumers. In the data processing market, NEC has a lead against Sony to a certain degree because NEC is the largest PC vendor in Japan. But, in the consumer electronics market, NEC does not have the brand recognition that Sony has. To sustain its market penetration rate, NEC is likely to pay more attention to point-of-sales promotion, provide incentive programs for resellers, and do more cross-selling and general advertising. The big challenge for NEC is to manage its relationship with the multimedia upgrade kits vendors because NEC is selling CD-ROM drives to those companies as an OEM supplier and, at the same time, NEC is marketing its own brand name upgrade kits.

Dataquest believes that NEC's strategy is working. NEC's high-performance CD-ROM products, combined with marketing shrewdness and rapid introductions of bundled packages targeted at different market segments, seem to have made its competitors find it hard to catch up.

N.V. Philips Gloeilampenfabrieken

Company Statistics

Headquarters Location	Eindhoven, the Netherlands
Chairman and CEO	Jan D. Timmer
President	Jan D. Timmer
Founded	1891
Fiscal 1991 Revenue	$56,986 million
Number of Employees	43,000

Overview

N.V. Philips Gloeilampenfabrieken (Philips) is a widely diversified multinational group of companies, engaged primarily in the manufacturing and distribution of electronic and electrical products, systems, and equipment. Philips Industries functions as the primary holding company for the company's numerous national organizations, which are wholly owned subsidiaries operating in more than 60 countries. These subsidiaries' businesses vary from simple marketing organizations to fully integrated manufacturing and marketing and sales concerns. Philips' product activities are grouped into five sectors: Lighting, Consumer Products, Professional Products and Systems, Components, and Miscellaneous.

Philips Consumer Electronics is the business unit within Philips that is most relevant in the context of multimedia. It includes the consumer electronics product division, PolyGram Records division, domestic appliances, and personal care products. Major categories in consumer electronics are audio, video, interactive media systems, and home office equipment. CD-ROM, CD-R, and CD-I are products managed by this subsidiary.

Laser Magnetic Storage International Company (LMSI) in Colorado Springs, Colorado, is a wholly owned subsidiary of N.V. Philips of the Netherlands and a subsidiary of the North American Philips Company division of N.V. Philips. LMSI designs, manufactures, and markets mass storage tape and optical products to OEMs, systems integrators (SIs), VARs, and value-added distributors.

Financial

The 1991 annual sales of Philips Consumer Electronics is estimated at $6,064 million, which results in a net profit of $8.1 million. The company's return to profitability was primarily a result of the elimination of a charge for restructuring, which reduced earnings by $339.9 million in 1990, combined with overall cost reductions.

Strategy

Philips pursues a strategy of brand name segmentation. It markets and sells CD-ROM drive products under three different brands—Philips, Magnavox, and LMSI. Philips brand name focuses on the computer specialty channels, that is, computer distributors and resellers such as Merisel and Ingram Micro. Magnavox targets the consumer market; while LMSI is chartered to penetrate major OEM accounts, VARs, and SIs. The advantage of this approach is that Philips is able to maintain a clean channel.

Products

CD-I. The Philips CDI910 Compact Disc-Interactive player, retailing for $799 at consumer electronics and department stores nationwide, plays CD-I disks (more than 50 available). Philips plans to have close to 100 CD-I disks by the end of 1992. CD-I disks are normally priced from $20 to $60, suggested retail.

The Philips CDI910 connects to any television, and the five-inch disks load like music CDs. CD-I is operated by moving a cursor on the TV screen via a joystick remote control, which comes with the player. Users rest the cursor on a menu item and press an action button to move through the programs.

Philips' Compact-Disc Interactive was launched in October 1991 in the United States and since has been introduced in Japan, the United Kingdom, and Europe.

The professional version of CD-I sells for a retail price of $1,595. The system includes a 1.44MB floppy drive and two RS-232-C ports. It can be connected to a PC display and includes a user "shell" that is controlled with a mouse. The device can read CD-I disks, audio CDs, and Photo-CD.

Philips has a Portable CD-I player in the pipeline. The Philips Portable CD-I System weighs 4.4 pounds, has a 6-inch active-matrix color LCD and a built-in pointing device, and runs on AC or optional battery-pack power. This portable player will be released late this year with a suggested retail price of $1,500. The Portable CD-I player can be connected to any TV set or PC display and includes interfaces to remote control devices. Built-in speakers will project sound from the 7.5 × 1.9 × 11.5-inch system.

CD-R. The CDD 521/10 desktop CD recorder can read and write information in every CD format, including CD-ROM XA, Photo-CD, CD-I, and audio CD. The recorder has a capacity of 600MB, average access time of 1,000ms, and a sustained transfer rate of 307.2 KB/sec. It uses SCSI interface and has a data buffer of 256KB. The recorder is priced at $6,000 for end users, and blank disks cost about $25 each.

CD-ROM. The CM50 is a low-cost hardware solution. It has full CD audio capabilities and comes with a memory-resistant audio control utility. The package includes a portable CD-ROM drive, device-driver software, and additional accessories. This product has been discontinued as of this writing.

The CDD461RS is a CD-ROM drive bundled with such titles as the *New Grolier Electronic Encyclopedia, Microsoft Bookshelf,* and the *PC Globe Electronic Atlas.* It is priced at $549. The drive has an average access time of 700ms, and the transfer rate is 150 KB/sec. CDD461RS reads both music CDs and CD-ROMs; it uses the same mechanism as in the CD-I drive. This product is sold under both Philips and Magnavox brand names.

The CM200 Series is assembled by LMSI in Colorado Springs. The CM200 Series drives have average access times of 370ms and a data transfer rate of 150 KB/sec. The suggested retail price is $499 for a bare-bones drive, a Philips interface card, and control software. A bundled version, the CM205, is priced at $549 with two titles.

The CDD461MM is an enhanced version of the CDD461RS drive. It will have multisession capability to read Photo-CD. The drive has an average access time of 500ms. The suggested retail price is $499 for the drive, interface card, and device-driver software. Philips also intends to bundle four titles with the product for $549.

Dataquest Perspective

N.V. Philips has a long-standing leadership role and commitment to optical data storage, including audio and video data. The company has been a pioneer in this technology and in the standards activities relating to it, ranging from CD-Audio to CD-ROM to CD-ROM XA to CD-I to CD-R.

In spite of its prominence in CD standards activities, the company has lagged behind the competition in CD-ROM drive performance and marketing creativity. Its CD-ROM products are just not competitive in performance to meet the challenge of multimedia. Its newest drive, the CDD462, will still have an average access time of 500ms and a data transfer rate of 150 KB/sec, while the other major players have been shipping drives with less than 300ms of average access time and 300 KB/sec data transfer rates. In terms of marketing, Philips is no match for its counterparts in Japan, notably Sony, Toshiba, and NEC. Philips seems unable to respond to competition quickly. All the major Japanese players have launched a promotional blitz in the past few months; every three to six months, they introduce a new bundling package targeted at various market segments at different price points.

When comparing Philips with Sony, Philips has the equivalent engineering power, technical expertise, and manufacturing capabilities as Sony does, except that Philips does not control contents as Sony does with ownership of Columbia Pictures. And, Sony has a distributed marketing and sales organization to implement local strategy. That makes a big difference in their respective market positions. When introducing a new product, Sony will put the necessary marketing resources behind it. Sony has been more successful than Philips in leveraging its strengths in consumer electronics into marketing computer-related products, more so in CD-ROM technology than other products. Sony has been the No. 1 CD-ROM drive supplier for the past two years, while Philips' sales of its CD-ROM products have been flat compared with the growing market. Dataquest does not believe that Philips will increase its market share in the CD-ROM market for 1992.

CD-I and CD-R are promising new technologies but will take time to evolve into profitable business.

Philips has taken major cost-cutting measures in the past year that included deep personnel cuts and R&D expense cuts in all divisions. However, Philips still carries the widest range of CD technology products—ranging from CD-I to CD-ROM to CD-R. Perhaps, Philips has too much on its plate and is spread too thin with its limited marketing resources.

Philips was the inventor of CD technology. Its prominence in the standards activity and its commitment to compatibility and top-notch engineering capabilities are among the major competitive advantages of Philips and should not be ignored by its competition. Because Philips is a rather centralized organization—compared with Sony, which has a more distributed and flexible organization—creative marketing ideas may get lost in the clouds of its bureaucracy. Philips can benefit a great deal from a streamlined decision-making process if it is serious about dislodging its major competitors in the CD-ROM market. In addition, Philips must focus on its core technology and flagship products with sufficient marketing resources, while cultivating new products for future growth.

Sony Corporation

Corporate Statistics

Headquarters Location	Tokyo, Japan
Chairman	Akio Morita
President and CEO	Norio Ohga
Founded	May 1946
Fiscal Year 1990 Sales Revenue	¥2,879,856 million
Fiscal Year 1991 Sales Revenue	¥3,616,517 million
Number of Employees Worldwide	95,600

Overview

Sony is a leading manufacturer and marketer of audio-video equipment and software. Sony's brand is well known all over the world. Sony has aimed for a global operation for the past 40 years and operates many affiliates at home and abroad, including 689 consolidated affiliates and 15 stockholding companies. Consolidated overseas sales account for 75 percent of its total sales.

Sony has two major operations in electronics and entertainment. The businesses under these two operations are as follows:

- Electronics
  - Video equipment—23 percent of total sales revenue
    - VCRs for home use, laser disk players, video equipment for broadcast and professional use, still-image video cameras, and videotapes
  - Audio equipment—25 percent of total sales revenue
    - CD players, minicomponent stereos, hi-fi components, radio-cassette tape recorders, headphone stereos, DAT players, radios, car stereos, audio tapes, and audio equipment for professional use
  - Televisions—16 percent of total sales revenue
    - Color television sets, monitors, satellite broadcast reception systems, projectors, displays for professional use, and giant display systems
  - Other products—16 percent of total sales revenue
    - Semiconductors, electronic components, computers, telephones, telecommunications equipment and AF systems, and data storage products
- Entertainment
  - Music entertainment—11 percent of total sales revenue
    - Music- and image-based software produced by Sony Music Entertainment Inc. and Sony Music Entertainment (Japan) Inc.

- Film entertainment—9 percent of total sales revenue
  - Columbia Pictures Entertainment Inc.—which includes Columbia Pictures, Tri-Star Pictures, Columbia/Tri-Star International Releasing Corporation, Columbia Pictures Television, Merv Griffin Enterprises, and Loew's Theater Management Corporation

Sony's business mix shows a clear awareness of the interrelated nature of hardware and software. Through its firm commitment to R&D, Sony built a reputation as a pacesetter in the electronic equipment industry

Sony has aimed for a global operation for the past 40 years and operates many affiliates at home and abroad, including 689 consolidated allifiates and 15 stockholding companies.

Promising long-term products include the minidisc (MD), high-definition television (HDTV), and multimedia. Sony is investing considerably in these products. The MD is the digital audio replacement for the conventional cassette tape recorder and offers portability, fast program selection, and playback using 64mm-diameter photomagnetic disks. Sony has begun marketing a 32-inch HDTV for ¥1.3million and is demonstrating the format at its Tokyo and Osaka showrooms. Sony also supplies HDTV movies in the laser disk format. Together with the U.S. companies Apple, Microsoft, and Motorola, Sony is developing multimedia equipment in CD-ROM XA and interactive CD (CD-I) formats.

Financial

Dataquest estimates that Sony's factory revenue for its CD-ROM drives sales were about $77.6 million in 1991. Dataquest expects that figure to more than double in 1992.

Strategy

Sony has evolved into a diversified company with the capability of delivering many key elements of multimedia. Its keen awareness of the importance of software is evidenced in many strategic moves that Sony has made, including the acquisition of Columbia Pictures. Sony truly understands that it is attractive software that creates demand for its hardware. Sony has set out to cover all areas of multimedia—which are the publishing side, the infrastructure side, and consumer and computer system hardware side.

Publishing. Sony works closely with the content holders and publishing community in CD-ROM title development, either developing its own multimedia software, developing titles with other publishers, or licensing and acquiring previously developed titles for optical publishing and distribution.

Sony has a dedicated division to license, manufacture, and bundle software for its PC-compatible CD-ROM system for home use, as well as to develop and produce electronic books for the Sony Data Discman.

Sony owns Columbia Pictures, through which Sony can control the program creations.

Infrastructure. Sony has been instrumental in setting standards and will continue that important role. Until the market settles on one standard, Sony will bet on all the horses by supporting three formats, that is, Data Discman, CD-ROM XA, and CD-I. Dataquest believes that in the short term, Sony will focus on Data Discman and CD-ROM XA, while leaving CD-I software and market development work to Philips.

Because Sony proposed the CD-ROM XA platform as the first step on a path toward a universal multimedia format and CD-ROM XA is too simple, Sony is advocating that the industry "go back to High Sierra spirit" and develop a common CD-ROM for all computer formats.

The common format is critical and should not be bound by a particular CPU and operating system. Nevertheless, this is easier said than done for Sony because the company does not have a CPU platform or operating system. Nevertheless, as a major content provider and key peripherals device manufacturer, Sony is in a perfect position to push for a common multimedia format for both consumer and computer systems.

Consumer and Computer System Hardware. Sony's hardware strategy is to create a seamless world between a consumer viewer and a multimedia PC, eliminating the boundaries between those two previously separate markets.

Sony's Data Discman is aimed at consumer markets first in Japan, then the United States and Europe. Sony's strategy with this product is to offer portability, achieved by using the 8cm disk; reasonable price, achieved by clear-cut functions, and performance.

The CD-ROM XA player is designed to fill the gap between the Data Discman and CD-I in terms of complexity and price. According to Sony, it is PC-compatible, and many CD-ROM disks prepared for the PC can be used without modification by just putting the retrieval software on the CD-ROM disk. This is an excellent example of a PC-compatible product with consumer electronics look and feel.

Sony's strategy toward CD-I is wait and see. The challenge for CD-I is the software availability, that is, on the data preparation side. When Philips has enough attractive, useful software titles developed, Sony will stand ready to sell CD-I drives.

Sony strives to offer users and resellers one-stop shopping for multimedia peripherals including displays, CD-ROM drives, laser videodisk players, consumer camcorders, audio speakers, and VISCA-protocol-based products for computer/video integration.

Another important element of Sony's multimedia strategy is to educate the market. This includes both resellers and end users. Sony has developed a comprehensive, interactive training program on multimedia technology, issues, and applications. Produced on Sony CD-ROM, the interactive training system can be used for reseller training and end-user demonstrations.

Products

Sony's multimedia product line reflects the current status of the highly fragmented multimedia industry. Sony is exploring multiple formats with multiple products.

CD-ROM Drives. Sony offers seven CD-ROM drives to the OEM, VAR, and SI market. They include the following:

- CDU-541—5.25-inch, half-height internal drive, vertical or horizontal installation, with an embedded SCSI-2 (rev. 10) controller and 64KB ring buffer
- CDU-535—5.25-inch, half-height internal drive, vertical or horizontal installation, with a Sony bus controller and 8KB ring buffer
- CDU-561—5.25-inch, half-height internal double-speed drive with an embedded SCSI-2 controller and a 256KB ring buffer
- CDU-6211—5.25-inch, half-height external drive, vertical or horizontal installation, with an embedded SCSI-2 bus controller and 64KB ring buffer
- CDU-6205—5.25-inch, half-height external drive, vertical or horizontal installation, with a Sony bus controller and 8KB ring buffer
- CDU-6150—5.25-inch, dual-drive subsystem with a Sony bus controller and 8KB ring buffer (discontinued as of this writing)
- CDU-7211—5.25-inch, half-height external drive with SCSI bus interface and 64KB buffer

Sony also offers a bundled CD-ROM package, called Laser Library. Sony targets this product at the home market through retail channels. The bundled software titles include *Compton's Family Encyclopedia, Microsoft Bookshelf, Mammals: A Multimedia Encyclopedia, Mixed-Up Mother Goose, Languages of the World,* and *Software Toolworks World Atlas.* The Laser Library is sold at a retail price of $699.

CD-R. Sony announced its CDW-900E, a CD-R drive, in March 1992. The CDW-900E is an integrated encoder/recording device that can write information on a CD write-once disk. The disk recorded on the CDW-900E conforms to the Red Book (Audio CD), Yellow Book (CD-ROM), CD-ROM XA, and Green Book (CD-I) digital formats for use with currently available drives supporting these standards. According to Sony, the CDW-900E can record a CD-ROM disk to full capacity in about 30 minutes, or twice the speed of real-time recording. The subsystem can also record in real time. This new CD-R drive spins the CD write-once disk at double the rotational speed of previous-generation recorders and combines a high-power semiconductor laser with accurate focus and tracking servo electronics to cut recording time. The CDW-900E is targeted at applications of CD-ROM prototyping, premastering, in-house disk replication, and the secure publication of sensitive data. Dataquest does not believe that this product is in volume production as of this writing.

Sony intended to have an erasable optical disk compatible with the CD format, but Sony decided to postpone the introduction of this new device. Sony used the same technology on a smaller-size erasable disk named the Mini Disc, targeted at music applications for the next several years. The Mini Disc is suitable for some multimedia applications, but its main market is in the music area. The specifications for the Mini Disc are as follows:

- Channels—2-channel stereo
- Frequency response—5 to 20,000 Hz
- Dynamic range—105dB
- Wow/flutter—Below measurement limit
- Sampling frequency—44.1 KHz
- Coding system—Adaptive Transform Acoustic Coding (ATRAC)
- Modulation system—EFM
- Error correction system—CIRC
- Recording/playback time—Up to 74 minutes
- Cartridge size—68mm × 72mm × 5mm
- Disc diameter—64mm
- Data capacity—Approximately 160MB

Portable Viewers. Sony is the only company that offers portable viewers for multimedia applications. Specifications for these portable players are described in Table 6-6.

Multimedia Software. Sony's Multimedia Production Division, founded in April 1991, develops its own multimedia software and also works with other publishers to bring consumer titles to the market. In the first year of its inception, Multimedia Production developed a library of more than 300 consumer titles in a number of CD-ROM formats.

Dataquest Perspective

Sony strives to become a solution provider rather than just another hardware vendor. Sony's market segmentation strategy for multimedia is very shrewd. The three formats that Sony offers are targeted at three different market segments with specific, well-defined functions and price points. Sony's approach to the multimedia market is to provide a range of solutions to users so that they can access and retrieve information at their fingertips wherever they go.

Table 6-6
Specifications for Sony's Three Portable Players

	Data Discman	CD-ROM XA Player	CD-I
CPU	Z-80 (8 bit)	V20 (16 bit)	MC68000 (16 bit)
Operating System		MS-DOS	CD-RTOS
Disc Dimension (cm)	8	8/12	12
Resolution (pixels)	256 × 200	320 × 200	360 × 240
Market	Japan/United States/Europe	United States	Japan
Price ($)	550	950	NA
Availability	Now	Fall 1992	Now

NA = Not available
Source: Sony Corporation, Dataquest (November 1992)

As an enabling technology and integral part of multimedia computing, the CD-ROM product line is especially important in Sony's overall multimedia strategy. Sony was the codeveloper with Philip of the CD technology, both for audio and data storage. Sony will continue to drive the standards to meet the emerging market needs.

As the most consistently innovative manufacturer, Sony strives to expand its computer business. In its attempt to expand its computer business, Sony is applying its creative powers to transform the design of computer-related products the way it did consumer electronics. More significantly, Sony will transfer its successful marketing experience in consumer electronics and leverage its brand name to the marketing and sales of multimedia products. In the process, Sony is eliminating the boundary line between consumer and computer-electronics markets.

Today's Sony is not just another hardware manufacturer. Sony means a great deal more than its traditional hardware business. Sony owns all the key enablers of multimedia computing, ranging from display to contents (Columbia Picture division). No other company in the world has this diversity of resources. One thing that Sony does not have is a computer platform. But should Sony care about that? Perhaps not. Sony has been, and will likely remain, the major supplier of monitors and CD-ROM drives to OEM customers including Apple, Sun, and many first-tier PC-clone vendors.

Dataquest believes that Sony will continue its dominant position in the CD-ROM market in the foreseeable future.

Conclusions

Only a few years ago, CD-ROM technology was perceived as a solution looking for problems, with nowhere to go. Today, users can find anything on CD-ROM, from legal documents to financial data to multimedia. Although text-only applications will still be a majority for CD-ROMs, many other applications—such as multimedia references; presentation, education, and training (PET); online help systems; and entertainment disks—are arriving with great momentum, providing high-quality graphics, audio, video and animation. There is no doubt that CD-ROM is the next tsunami of computing.

Dataquest projects that worldwide shipments of CD-ROM drives will grow rapidly to 1.498 million units in 1992 and 4.9 million units in 1996, representing a 35.1 percent compound annual growth rate for the period. Included in this forecast are drives embedded in CD-I and CD-TV players, but not drives for video games such as NEC's PC Engine. Most of the projected CD-ROM drive shipments will gradually be for multimedia applications, in addition to the text-based applications. Sales of CD-ROM drives used only for databases and reference works will grow but remain limited to libraries and professional researchers.

By 1995, CD-ROM will have moved well into the mainstream of the PC market. Except special multimedia PC models with built-in drives, most CD-ROM drives will be sold as a separate option in the next three years.

Dataquest believes that we have presented a realistic projection of the future for multimedia CD-ROM applications. A summary of opportunities include the following:

- Clear and present opportunities exist in the multimedia upgrade kits market. More than 70 percent of the multimedia CD-ROM drives will be sold with upgrade kits.
- Large-volume opportunity also exists with the first-tier PC-clone vendors for long-term growth.
- The United Stated and Japan will be the first primary markets for multimedia CD-ROM products; the United Kingdom, Germany, and France will follow.

Successful CD-ROM drive vendors are already positioning themselves to take advantage of the emerging multimedia market opportunities. As multimedia computing comprises so many elements, no single product division within one company can cover all the areas and offer a complete solution. CD-ROM is just one element of the multimedia solution. Therefore, successful companies are forming a special division that puts together all the pieces and provides one-stop shopping for users, resellers, and business partners. More important, this new organization will be able to produce a consistent and coherent marketing program and coordinate across the entire company. As many CD-ROM drive manufacturers are also producers of other multimedia peripherals—such as speakers, monitors and other accessories—this organizational approach makes sense for cross-selling.

Successful companies also pay attention to software development and partner with title developers in bundling attractive titles with hardware. Proven success stories include Sony's Laser Library and NEC CD Gallery.

As the distribution channel dynamics change, more CD-ROM products will be moved through computer specialty stores and mass merchandise outlets; point-of-sale promotions and eye-catching packaging are key factors to success.

The PC pricing trend is pointing in only one direction—down. Multimedia-ready computers are no exception. The cheaper, more powerful computers are expanding the total available market for peripherals devices such as CD-ROM. That is the good news. The bad news is that users will not pay more than 20 percent of the total system cost for a peripherals device. The price pressure is on. Smart CD-ROM manufacturers are looking for ways to improve yield, further component integration, and move manufacturing sites to less costly geographic locations. Lower costs of manufacturing will give CD-ROM drive vendors more flexibility in preserving margins for the resellers, motivating these resellers to carry their particular brand of CD-ROM.

In summary, success with the emerging multimedia opportunities for CD-ROM vendors will depend on how well they execute the strategies and tactics. Aggressive pricing, appropriate selection of software, and name recognition are three key factors to success.

Chapter 7
Multimedia Telecommunications

Introduction

While it is possible to contain a multimedia application in a single, physical computer system—say a PC running a training program or a sales presentation being projected onto a screen—the truly interesting and innovative applications will involve telecommunications. These applications include desktop video conferencing, compound document production and publication, distance learning, mixed-media messaging, and image- and voice-enabled office automation applications.

Unfortunately, today's telecommunications networks—both local and wide area—were not designed with the switching and transmission requirements of multimedia in mind. The wide area network was designed to transmit voice signals at relatively low bandwidths, while local area networks were designed to transmit data at speeds and for durations lower than most expected multimedia traffic. This means that the multimedia telecommunications market is in a chicken-and-egg situation.

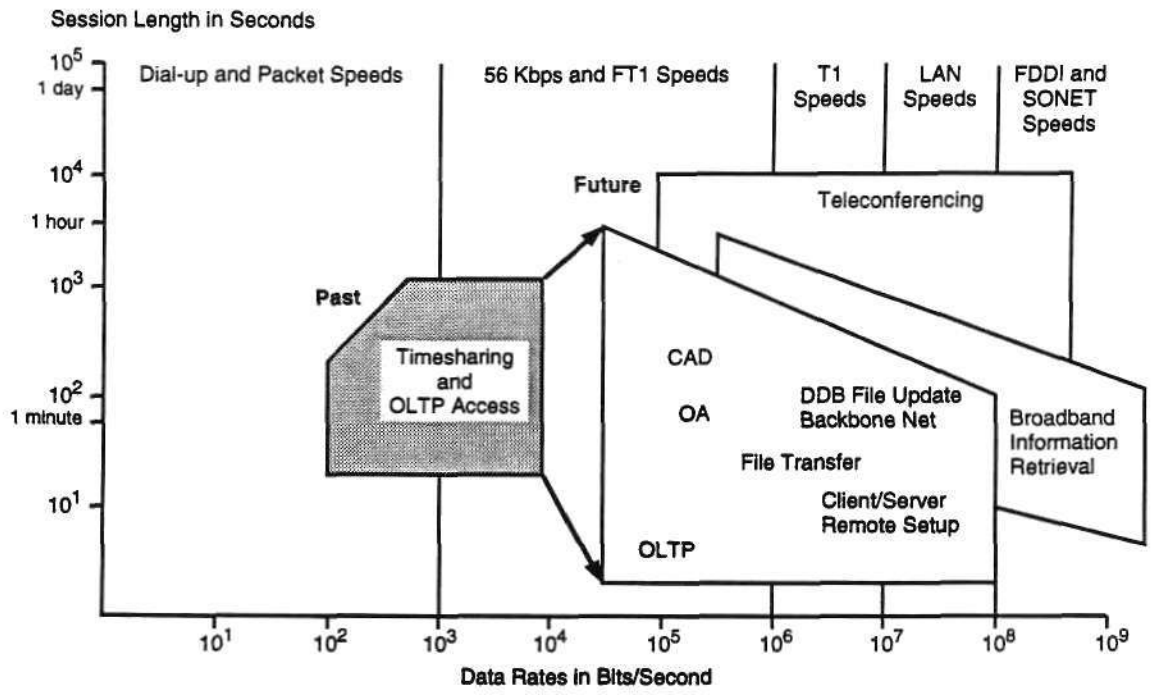
Communications suppliers, particularly the local and long distance carriers, would love for multimedia applications to take off. They see in the requirement of these applications to transmit video, graphics, and digitized voice data significant increases in ultimate demand for transmission, that is, more devices on the line longer and at higher speeds. Since much of the telephone plant is now digital, and subject to falling unit costs in conjunction with falling semiconductor component costs, only increased usage can offset falling unit prices and keep revenue growing.

At the same time, multimedia proponents look for a lot more out of the network than is currently offered—higher bandwidths, easier internetworking, protocol translation, and special circuits and services.

The crux of the issue can be seen in the chart contained in Figure 7-1, which shows the bandwidth and session demands made by the new kinds of applications supported by multimedia technology.

As shown in the graphic, the bandwidth and session-length requirements of the kinds of applications—like teleconferencing and broadband information retrieval—that qualify as multimedia not only require greater bandwidths and longer session lengths than traditional data networks, but the bandwidth and session-length spreads are

Figure 7-1
The Applications Challenge to Networking



Source: Bell Communications Research G2001195

much wider. This means that designing and operating networks to support multimedia applications is much harder since traffic is so much more variable. (Please refer to Part I of this report, Chapter 3: "Semiconductor Technologies and Opportunities in Multimedia," Table 3-4, which gives an inkling of the conundrum faced by network designers by multimedia. This table compares the traffic characteristics of data and video—with the point of illustrating how different the two traffic types are.)

But in a world of full multimedia, the networking situation is even worse. Table 7-1 shows the conflicting traffic characteristics of multiple media types. The difficulty for MIS application developers and corporate network designers and managers is coming up with suitable networks to support applications with such a mingling of different traffic types.

Table 7-1
The Mixed-Traffic Types of Multimedia

	Data	Voice	Graphic	Facsimile	Video	Combined
Traditional Switching	Packet	Circuit	Packet	Circuit	Circuit	Untraditional
Session Length	Predictable Seconds	Predictable Minutes	Unpredictable Seconds	Predictable Minutes	Predictable Minutes	Unpredictable Either
Burstiness	High Messages and Responses	High Variable Two-Way	Low File Transfer	Low Short Transfer	Low Stream Oriented	Variable Mixed
Typical Message/File Size to Terminal	2Kb	4 KHz (analog) 1-4MB (digital, compressed)	0.5-6MB	2-10KB	6 MHz (analog) 1-500 MB (digital, compressed)	KB to GB
Typical Message/File Size on WAN	2Kb	Megabytes	Megabytes	2-10KB	Gigabytes	KB to GB
Data Rates	Variable 2400-64 Kbps	Steady 64 Kbps	Variable 2400-100 Mbps	Steady 2400-64 Kbps	Steady 64 Kbps-150 Mbps	Variable 2400-150 Mbps
Network Storage/ Response Time	Megabytes Subsecond	Gigabytes Subsecond	Megabytes Sub 300 MS	Kilobytes Subsecond	Gigabytes Sub 150 MS	Gigabytes Sub 150 MS
Reliability	Must be High	Tolerates Errors	Tolerates Errors	Tolerates Errors	Tolerates Errors	Must be High
Packet Amenability	High	Medium	High	Medium	Low	Mixed

Source: Dataquest (November 1992)

Take simply the mixing of data and voice signals, for instance. Whether the data come from a terminal or PC and travels on a LAN or over a modem and terminal network, it will generally be amenable to transport in a packet mode and will rarely require more than 64 Kbps in transmission speed. Voice, even if it is digitized and compressed, will probably take at least 32 Kbps in transmission speed and will require different network conditions and capabilities. Sending voice in packets on a LAN, for example, is still practically impossible in any form that provides real-time communications. The control software and equipment for switching voice bits is different from that for switching data bits, error correction codes are different, and international de jure and de facto standards for sending and receiving the two types of traffic are different. Even wall jacks, plugs, and terminology are different.

Now add in the requirement that the voice traffic and data traffic be part of the same application—annotation of a compound document, say—and the coordination and control issues become even more difficult.

At times the barriers to multimedia acceptance posed by telecommunications issues seem almost insurmountable. The most significant limitations today include the following:

- The inability, because of insufficient bandwidth, of today's LANs and WANs to transport real-time video without such compression that resolution or fidelity suffers
- The high storage and compute requirements placed on servers handling multimedia files and images
- The overhead and incompatibilities of internetworking in mixed media settings
- The lack of predictability of multimedia traffic and the resultant strain on network design algorithms and management systems
- Incompatible and complete standards (If today's voice mail systems cannot talk to one another, much less to e-mail systems, how can we expect communications to occur between multimedia systems?)

Despite these barriers, carriers and equipment suppliers keep plugging away. Since many of the advances under way in switching and transmission are in support of general backbone networking or single-media applications, they can be expected to proceed at a pace not totally dependent on multimedia computing.

The high-speed fiber-optic backbone networks being proposed by the telephone companies, the Synchronous Optical NETwork (SONET) networks, are actually designed to help increase the efficiency of the long distance fiber plant already in place. The frame- and cell-relay network follow-ons to the packet networks that were installed in the 1980s are useful for backbone data networks, not just multimedia networks. And the higher-speed switched data networks already offered by the carriers—switched 56 Kbps, switched 384 Kbps, and other fractional T-1 services—were designed mostly for backbone data transmission.

But they have been instrumental in the development of the room-to-room video conferencing market, and they will help the multimedia market.

Market Segmentation

At the moment, the market for multimedia telecommunications is still a supply-driven market, since vendors must advance the state-of-the art in order for communications to go from being a market barrier to a market enabler.

As a result, the market may best be segmented by supplier type, which in turn tends to follow communications technology type. The following segments might thus be considered:

- Long distance carriers
- Local exchange carriers
- LAN and internetworking vendors
- Terminal equipment vendors
  - Voice
  - Video
  - Data
- Software vendors

Figure 7-2 depicts the impact the various vendor types will have on the adoption of multimedia computing.

Note that the efforts of many of the supplier types overlap. In fact, they are interdependent. Switched Multimegabit Data Services (SMDS) may be excellent for multimedia transport in a metropolitan area, and therefore a likely service for a local exchange carrier to offer, but unless the long distance carriers offer compatible long distance service, the usefulness of SMDS will be limited.

Similarly, the running of multimedia applications on a LAN makes sense in a workgroup setting—for sharing multimedia files and expensive peripherals—but full utility will only come if the applications can be passed between LANs or over wide area networks.

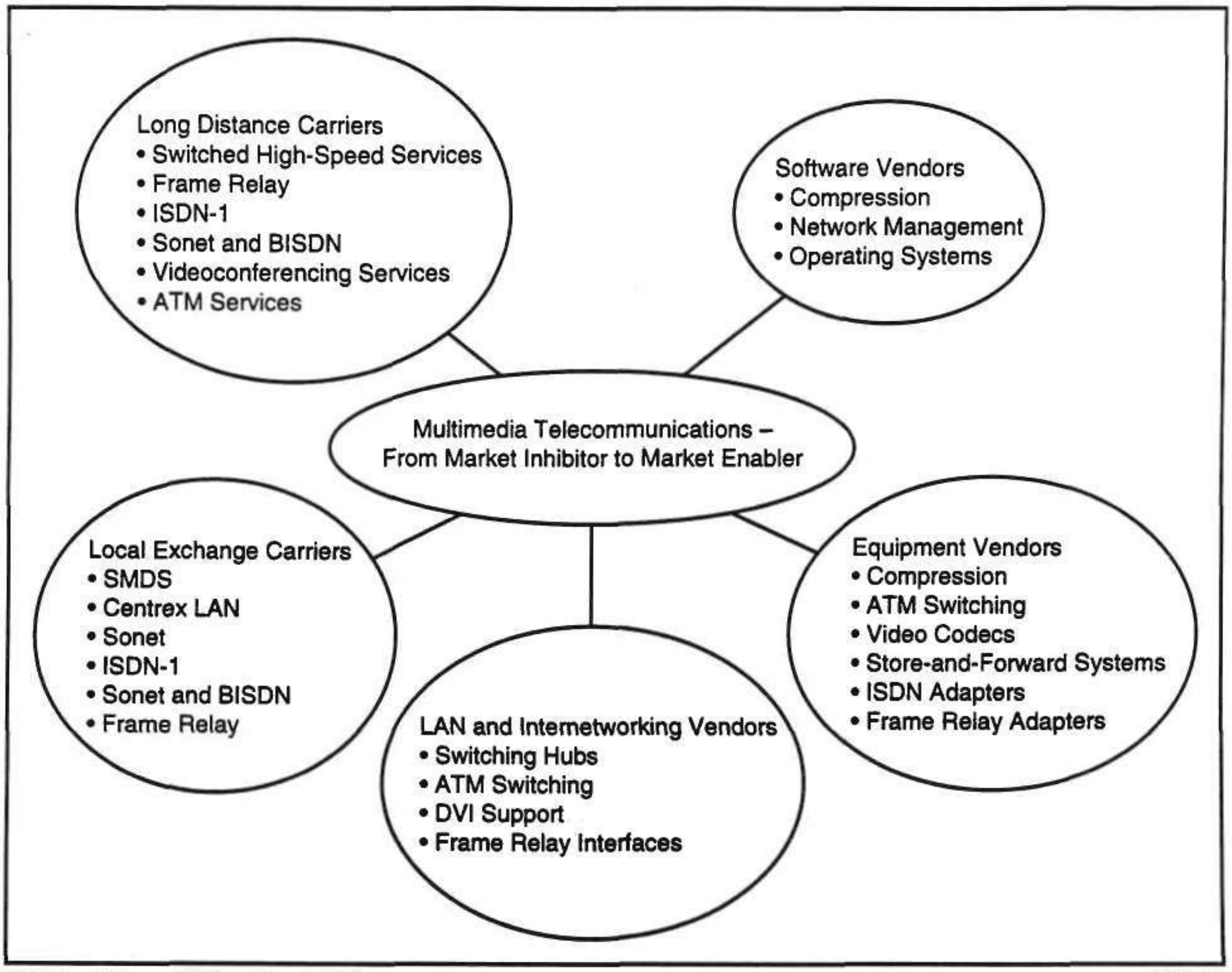
Market Dynamics

Three primary market forces will drive the development of multimedia communications. These are network technology limitations, multimedia internetworking, and network usage. These forces are discussed in this section.

Network Technology Limitations

Inasmuch as the multimedia telecommunications market is supplier-dependent at the moment, the key dynamics relate to the availability of communications services and equipment that fit the traffic profile of multimedia communications.

Figure 7-2
Key Player Contributions to Multimedia Telecommunications



Source: Dataquest (November 1992) G2001196

The immediate issue is bandwidth. Just consider the file sizes a network has to deal with when multimedia applications generate the file:

- A single second of sound is the equivalent of 15KB to 150KB of digital information, depending on fidelity.
- An 8-1/2 × 11-inch monochrome image can require between 50KB and 100KB for storage.
- The same image in 24-bit color can take up to 2.4Mb to store as digitized information.
- A second of full motion color video with the same size image would require up to 30 times as much storage as a 24-bit color image.

Obviously, compression algorithms can help lower the bandwidth requirement—but usually at a price, either in compression boards or in resolution.

By way of illustration, Figure 7-3 depicts the transmission times for various types of images at various data communication speeds.

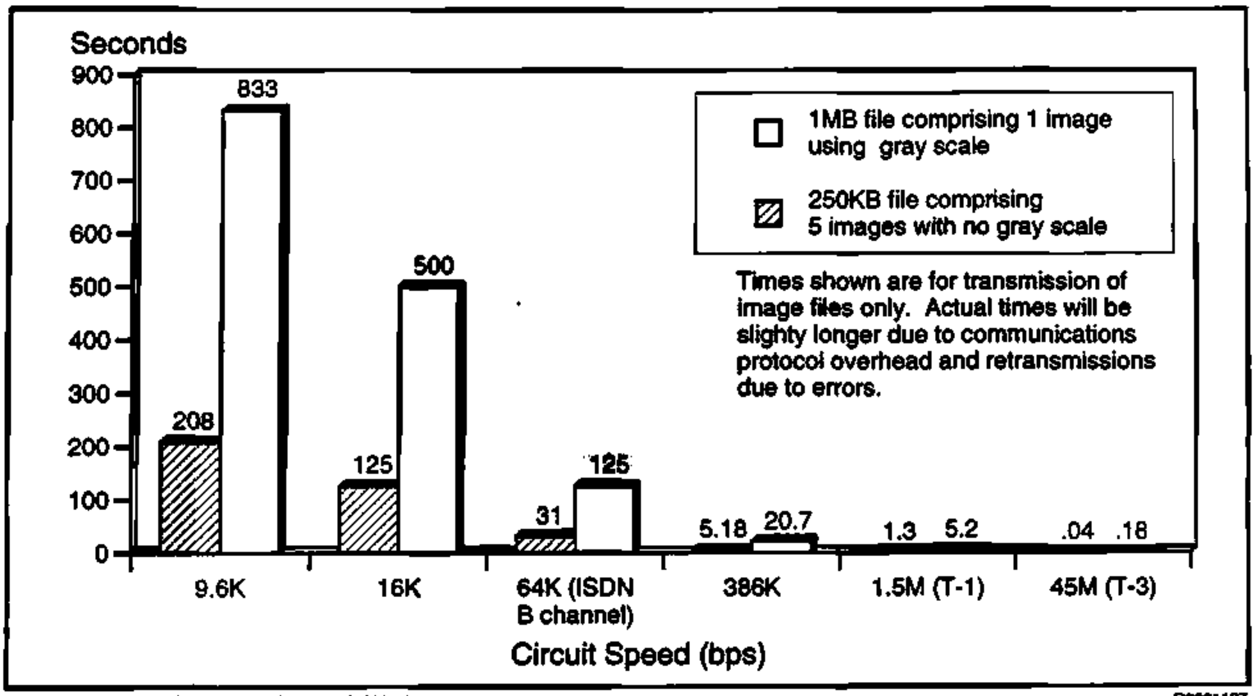
Naturally, color images and moving video represent the worst-case scenario for networking communications in support of multimedia applications, and naturally not all multimedia applications will use large color images or ask for high-resolution, full-motion, full-screen video.

But the point is obvious—multimedia applications put new and unusual bandwidth strain on most networks.

After bandwidth, the issue is throughput. All sorts of things can affect the speed with which a multimedia transaction gets executed—from the speed with which data packets get scrambled and unscrambled to the time it takes for transmissions to get from a PC to the LAN through the LAN adapter. In between there is circuit setup and tear-down time in circuit-switched WANs, routing delays in bridged LANs, retrieval time for files stored on the network, error detection and retransmission, database access times, and so on.

Figure 7-4 illustrates how many gating points—or bottlenecks—there can be in a multimedia transmission. All sorts of components in the end-to-end transmission path must not only work together but be optimized for the kind of traffic taking place. LAN administrators already know how important the PC adapter card can be in determining response times on the LAN. Imagine the effect on high

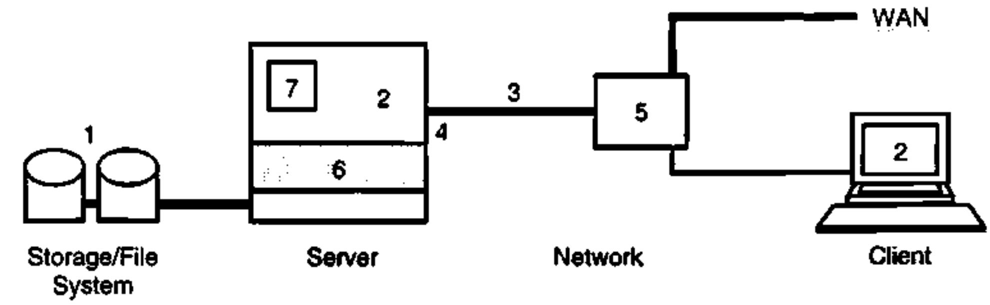
Figure 7-3
Image Transmission Times



Source: Ernst & Young and Network World

G2001197

Figure 7-4
Digital Video Transmission Bottlenecks



1. Continuous, real-time data disk controlling and file management
2. Client/server network protocol and data handling
3. Network access (sufficient and reliable bandwidth)
4. Server/network interface
5. Internetworking and wide area network (WAN) access
6. Bus/Backplane throughput
7. Server CPU when supporting fully capable traditional server functions

Source: Starlight Networks G2001198

volume, real-time traffic, like that in some multimedia applications. Another point of slowdown not shown in the figure can occur in the compression and decompression of voice and video on networks.

Throughput is also connected to synchronicity, which refers to getting the mixed digital data types—voice, data, and video—all delivered to the right place in the right order at the right speed. An example of how hard this is to get right can be seen in the trade-offs made in two desktop teleconferencing systems—IBM's Person to Person/2 system and the AT&T VideoPhone 2500.

In the former system, only digitized video and data are shipped over the desktop system. Any voice communication must take place by regular telephone, and early users complain of the lag between the video picture and the voice. It is like watching a bad lip synch singer. In the latter system, voice and video travel over the same linkage and the trade-off has been made in the quality and refresh speed in the video—and in lower-quality audio than in a normal phone.

And these are simple synchronization problems compared to those of linking multimedia stations across mixed media networks with store-and-forward capability.

If bandwidth, throughput, and synchronization are the first three problems, access must be the fourth. Here the trade-off is between faster response time and more expensive equipment at the desktop. High-bandwidth LAN adapters can cost 10 times what a commodity Ethernet adapter costs, compression cards can cost more than a thousand dollars, and the cost of CD-ROM players and titles can make resource sharing look attractive.

On the other hand, that kind of resource sharing generally requires significantly more network storage and better control software than exists today. And sizing servers and circuits can be a nightmare. It does not take too many users storing voice annotation or accessing stored video clips to bring a LAN to its knees. Delivering Fiber Distributed Data Interface (FDDI) signals to the desktop at 100 Mbps might solve some network sizing and bandwidth issues, but it will not solve server sizing issues or make resource sharing that much easier. And it will cost.

These problems are not all intractable. The single biggest alleviator of bandwidth and throughput problems will be compression (see the chapter of this report entitled "Semiconductor Technologies and Opportunities in Multimedia" for compression details).

The historical trend in video compression from 1978 through 1993 is shown in Figure 7-5. During the last 15 years, the acceptable data rate for video has dropped by a factor of almost 100. Further advances that couple new compression algorithms with semiconductor chips will make it possible to ship high-resolution frames over the same amount of bandwidth that used to support only low-resolution frames.

Similarly, compression algorithms for fax, voice, and graphic images will also improve the networking equation.

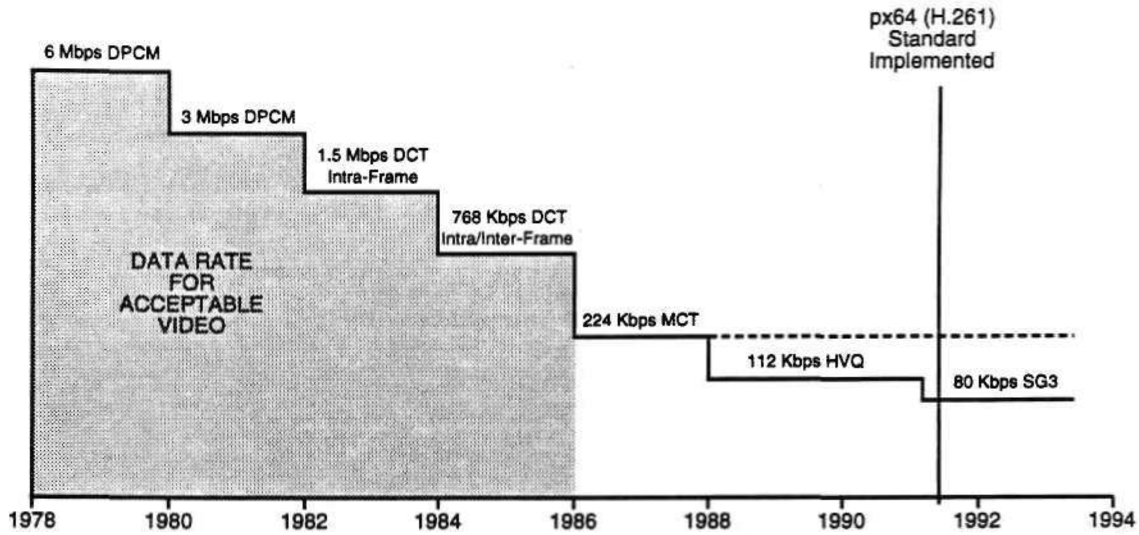
One of the issues with compression, however, is symmetry. For some applications, such as desktop teleconferencing, decompression algorithms have to be the inverse of the compression algorithms—meaning that, until standards like Px64 and H.261 are fully adopted and in the market, transmissions cannot cross vendor boundaries. For example, an AT&T videophone will not talk to an Apple Macintosh videophone (unless both use the same compression algorithm and chip).

Multimedia Internetworking

There are solutions to network bottlenecks afoot. They are twofold, as follows:

- The carriers and private network equipment providers are all working to design and install wider bandwidth networks.
- These networks are being designed with many common standards and subcomponents, meaning internetworking will be easier.

Figure 7-5
Video Compression Advances



Source: PictureTel Corporation

G2001199

Table 7-2 lays out the major network types coming on stream in the 1990s that are thought to be especially suitable for multimedia transmission. They run the gamut from ISDN—a requirement for certain desktop videophones but only just now being rolled out across the United States—to SONET, the proposed synchronous optical network still in the being-established-as-a-standard phase.

The relevance of these emerging network types to multimedia computing and commentary is provided in the following sections.

ISDN

Proposed along with the Open Systems Interconnect (OSI) reference standard in 1978, Integrated Services Digital Network (ISDN) has been in the networking lexicon ever since. Unfortunately, it has taken a long time to roll out, with the first major installations—at companies like MacDonald's—not coming until the late 1980s. Even now, most ISDN implementations are for local, private networks. One of the

Table 7-2
Network Technologies that Are Multimedia Enablers

Technology	Characteristics	Deployment Date	Status
ISDN Integrated Services Digital Network CCITT 1.43X	Two-voice and one low-speed data line over a single copper phone line (ISDN-Basic), or T-1 speed voice and data (ISDN-Primary); single wire to desktop; data line good for adding advanced features to voice calls.	1992	Standard virtually complete, end-to-end rollout across the United States this year (ISDN-1), better penetration in Europe; slow acceptance because of cost and lack of vendor support.
SMDS/MANs Switched Multimegabit Data Services/Metropolitan Area Networks IEEE 802.6	Data networks based on LAN-family standard (with SMDS a subset) for LAN-like traffic at 1.5644 Mbps to 45 Mbps (eventually 155 Mbps) over metropolitan areas; acts like LAN and interfaces with same underlying protocols.	1993	In beta test phase now with United States telcos; no convenient interlinking of SMDS regions; seen as competitive with frame relay but more compatible with Broadband-ISDN.
Frame Relay CCITT I.233, Q9X ANSI T1.61X	Fast packet switching technology that eliminates control overhead in network, letting equipment handle it. Speeds from 56 Kbps to 1.544 Mbps. Cuts costs of building router networks. Billed as a LAN interconnection technology.	1992	Offered by all major carriers now, usage began in 1992 in the United States. Has support of all major equipment vendors.
FDDI Fiber-Distributed Data Interface ISO 9314	Data networking up to 100 Mbps. FDDI-1 did not include packet voice, but FDDI-II will. High-speed LAN that is able to support longer distances.	1992	Major installations beginning this and next year; most major system vendors have an offering; developed for fiber but beginning to see protocol on copper phone lines.

(Continued)

Table 7-2 (Continued)
Network Technologies that Are Multimedia Enablers

Technology	Characteristics	Deployment Date	Status
ATM/SONET/BISDN Asynchronous Transfer Mode/Syncronous Optical Network/Broadband-ISDN	Long distance, high-speed fiber network (SONET) designed for data rates from 155 Mbps to 622 Mbps, with basic switching protocol (ATM) similar to that in MANs and becoming available in LAN hubs; ATM premises switches will work up to 195 Mbps initially; switches information in fixed packet-size cells and is also referred to as cell relay; B-ISDN adds services to basic transport system.	1994	SONET standard being completed by telcos and Bellcore now and tested in alpha sites; ATM switches being manufactured and tested. Carriers promising ATM services in 1993, hub vendors looking for ATM switches in hubs in 1993; B-ISDN to follow in 1995 time frame.
LANs with SuperServers	Existing Token Ring (16 Mbps) and Ethernet (10 Mbps) LANs with powerful servers optimzied for multimedia.	1992	Practically the only available alternative today to custom building a multimedia network; multimedia-specific servers announced this year.
Switching Hubs 10 Base T	Structured wiring (star networks) for linking desktops to on-premise switch that may include routing functions today; tomorrow will act like full digital switch and may include support for ATM.	1992	Intelligent hubs practically mandatory for department LANs and seeing more use for enterprise LANs; ATM switching promised by vendors.

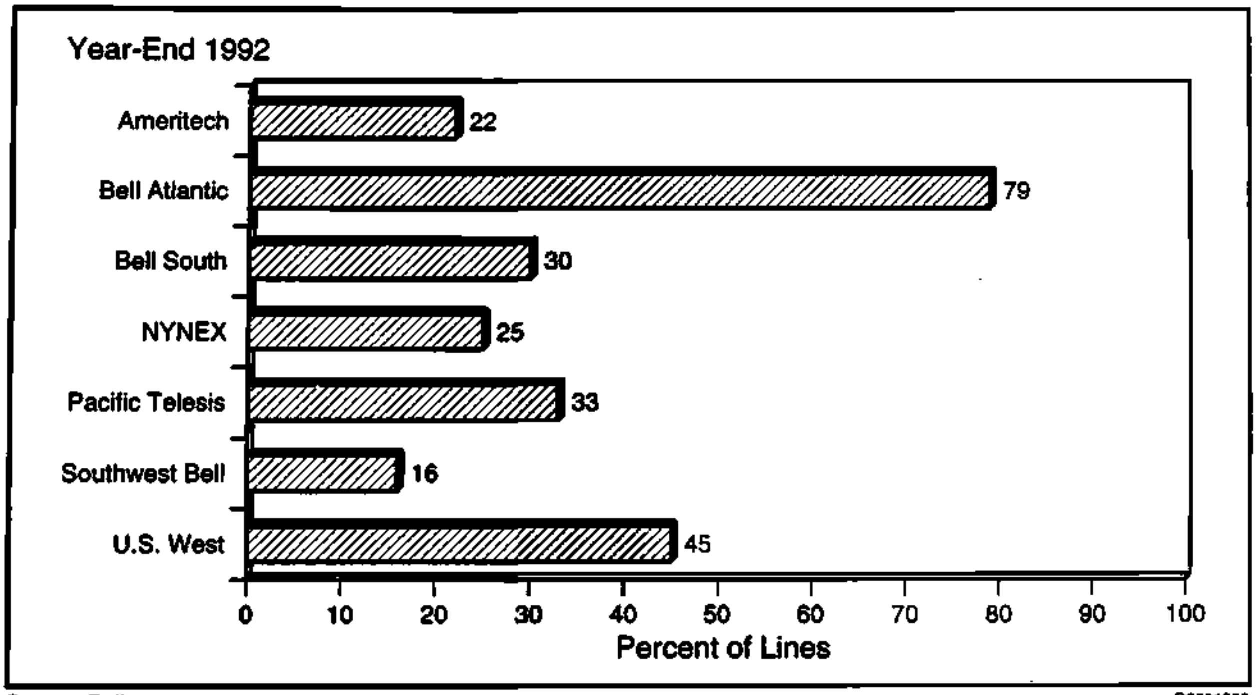
Source: Dataquest (November 1992)

reasons for slow market adoption of ISDN in the United States was lack of end-to-end connectivity across telephone company boundaries. To remedy that, in 1991 a number of equipment vendors and telephone companies got together under the aegis of Bell Communications Research (Bellcore) to agree on a specification and standard that would permit nationwide ISDN networking, called ISDN-1. This is being rolled out this year. At the same time, the local telephone companies are increasing the number of their circuits that will be ISDN-ready and the number of local switches than can support National ISDN. Figure 7-6, ISDN-Ready Lines in the United States, shows ISDN deployment by carrier as of the end of this year.

Because one ISDN line to a desktop can carry two voice circuits and one data circuit, ISDN is tailor-made for narrow bandwidth multimedia applications—one of the voice lines can be used for audio, the other for digitized video or image, while the data line can be used for screen sharing, data transmission, and telemetry. Video signals compressed to the Px64 standard can fit within one of the ISDN 64 Kbps voice lines for instance. This is why certain video phones require ISDN lines.

The issue for ISDN remains one of deployment and bandwidth. Even if the carriers offer a large number of ISDN-ready lines it is not clear that they will be used for ISDN. And, again, multimedia applications may have to sacrifice resolution or fidelity to achieve transmission.

Figure 7-6
ISDN-Ready Lines in the United States



Source: Bellcore

G2001200

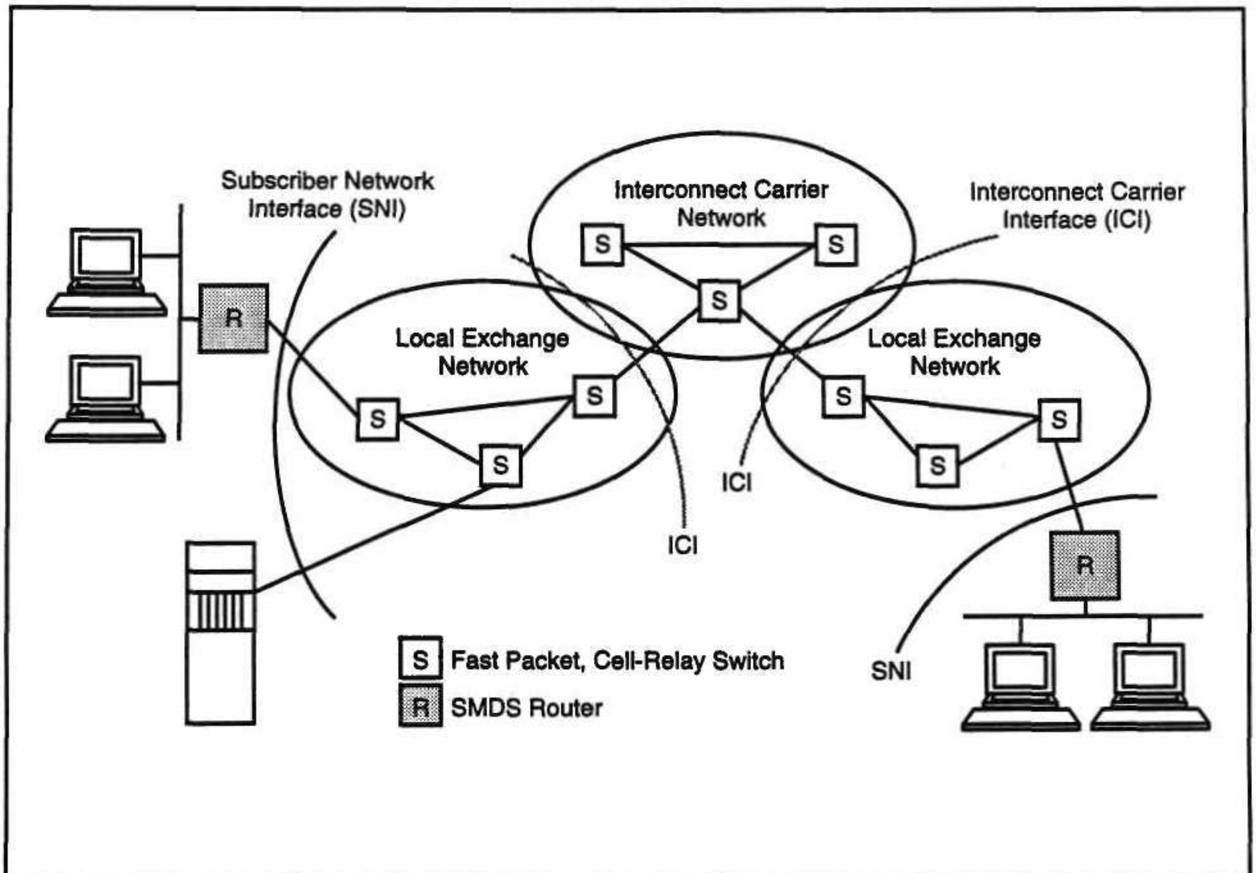
SMDS

Switched Multimegabit Data Services (SMDS) are carrier-provided services based on the Metropolitan Area Network (MAN) standards provided in IEEE 802.6. SMDS, in trial now at all regional phone companies, is really the only publicly available telecommunications supporting the 802.6 standard. SMDS services operate at 1.544 Mbps up to 34 Mbps from the user premise, up to 45 Mbps between telephone companies.

SMDS uses packet-oriented communications, meaning there is no call setup or tear-down time involved, and sends data through the network in relays of fixed-frame packets. Essentially it does what old X.25 packet networks did except a lot faster and without error checking in the network nodes. This fast packet, or cell relay, technique is the same used in ATM, or asynchronous transfer mode communications, although ATM and 802.6 are not totally equivalent.

In the multimedia environment, the importance of SMDS is as a LAN interconnection technology, as seen in Figure 7-7, since it will generally take traffic outbound of a router. To a user, the SMDS wide area

Figure 7-7
SMDS Network Architecture



Source: AT&T Corporation

G2001201

network would look simply like a LAN—and would presumably offer LAN-like response times.

Deployment of SMDS service began this year, although the major rollout will take place in 1993 and 1994. Bell Atlantic began offering SMDS in the Washington, D.C., area in May 1992 and now also has it in Philadelphia, Pittsburgh, and Newark; Bell South has been testing it in Atlanta; Pacific Bell, U S West, and GTE expect to have services in certain cities this fall; and NYNEX has promised it for New York late in 1993. The European community has similar efforts under way, having completed standardization of interfaces between European networks and IEEE 806.2 standards.

How fast SMDS on a nationwide or global basis rolls out will depend mostly on the United States and international carriers. Bellcore expects international connections to be available in 1994, but the same issue of end-to-end service will affect SMDS as has affected ISDN. At the moment, for instance, MCI appears to be the only major long distance carrier with the technical ability to offer SMDS to customers today and will do so on a custom basis; AT&T is still in trial phase. Most of the long distance carriers seem to be focusing on frame relay services.

Frame Relay

Frame relay is another fast packet technique that operates somewhat like SMDS but with variable packet sizes (fixed headers) and at slower speeds (56 Kbps to 1.544 Mbps). It obtains its efficiency by stripping out the error correction inherent in X.25 networks (where packets are disassembled and assembled and examined for errors at every switching point). It uses ISDN protocols for transmission.

As a natural upgrade to X.25 networks, rather than a brand new networking scheme, frame relay has developed quickly as a LAN interconnection methodology, with carrier services introduced late last year and more announced this year. AT&T, for instance, began offering its frame relay service this June, following earlier introductions by Sprint, MCI, British Telecom, and Compuserve. In addition, most data communications equipment vendors now offer frame relay adapters and connection devices.

One of the advantages of frame relay is that it offers a cheaper alternative, in terms of network line charges, to router networks built on leased lines. By switching based on international standards, it also offers better interoperability.

In the multimedia context, frame relay offers a good extension to overbuilt LANs, where internetworking delays can introduce intolerable delay times in mixed media messaging.

FDDI

Although a committee within the American National Standards Institute (ANSI) has been working on the Fiber-Distributed Data Interface

(FDDI) standard since 1983, the standard did not gain in importance until key LAN and terminal network vendors—most notably IBM and Digital—got interested. At the time FDDI was conceived, the fastest LANs in common use were 10 Mbps Ethernets; token ring LANs were still running at 4 Mbps. FDDI offered a way to get a tenfold increase in LAN performance, since FDDI networks will allow for speeds up to 100 Mbps on LAN rings 100km in circumference, with up to 2km between stations.

Although the standard is not yet fully adopted, it is complete enough that products have been on the market for several years and user installations are beginning. In fact, although FDDI was originally designed for use with fiber-optic cabling, recently vendors have begun introducing FDDI running over copper wire.

FDDI provides two advantages to multimedia users—first as a backbone LAN interconnect technology, since it offers greater bandwidth than either Ethernet or token ring; second as an option for desktop connection. Although when FDDI was conceived the prospect of ever needing 100 Mbps at the desktop was remote, now it seems not at all unlikely—only costly.

The drawback for FDDI is that it does not readily support voice (64 Kbps) or video (90 Mbps uncompressed) because of synchronization problems—at least not any more than your average LAN. Work within the standards organizations has gone on toward a FDDI-II standard that supports voice, but other technologies, such as ATM, may come on stream first.

ATM/SONET/B-ISDN

These are the higher-speed networking technologies currently under development. SONET, or the Synchronous Optical Network, is being developed by the world's telephone carriers to address the need for transmission speed—mostly between telephone offices—above T-3, or 45 Mbps. The SONET standards call for speeds from 51.8 Mbps to 4.98 Gbps. The SONET standard also calls for two forms of switching: one synchronous, the other asynchronous. The latter is the asynchronous transfer mode, ATM, much talked about in Chapter 3: "Semiconductor Technologies and Opportunity in Multimedia." ATM uses a fixed-length packet and cell-relay transmission, with switching speeds from 155 Mbps to 2.4 Gbps. B-ISDN, or Broadband ISDN, refers to services based on ATM switching and probably using SONET transmission.

While the deployment of SONET and B-ISDN services on top of it are more than a few years off, the ATM switching component is not—after all, it forms some of the basis of SMDS services. Now companies are starting to make plans and announcements about offering ATM switches for use in the LAN environment, particularly in conjunction with LAN hubs. BBN Communications, for instance, has promised to introduce an ATM switch next year. And at least one long distance carrier, Sprint, has promised to have an ATM service on stream in 1993.

One of the advantages of having an ATM switch at the LAN level is that it would then be easy to integrate with SONET and B-ISDN when they come along—making wide area networks appear as simple LANs. ATM also comes with immediate support for voice and video as well as data.

From the perspective of multimedia computing the availability of ATM switching means the capability of shipping mixed media messages and files across even long distances with interactive response. Such are the bandwidths and network latencies.

But there is also an immediate conundrum—which of the technologies to use now, which to wait for. ATM in the LAN environment is increasingly being seen as competitive with FDDI networks, frame-relay and long distance ATM with SMDS.

Some of the competitive trade-offs between FDDI and ATM are shown in Table 7-3.

LANs with Superservers

Perhaps the most suitable alternative to waiting for tomorrow's broadband networks is the use of existing LANs with new server technology. Critical here is the availability of high-performance servers, typically RISC-based or high-powered Intel chips, with software to handle synchronization and data management.

Table 7-3
FDDI versus ATM

Feature	FDDI	ATM
Topology	Token ring	Cell-relay switch
Maximum Speed	100 Mbps	195 Mbps today, gigabits tomorrow
Maximum Distance	100km	None if services available from carriers
Backbone Media	Fiber	Fiber
Desktop to Hub Media	Fiber or twisted pair	Fiber (shielded twisted pair later)
Data Types	Data, image; digital video	Voice, data, image; digital video (Voice with FDDI-II)
LAN Interoperability	High	Unknown
WAN Interoperability	Low	High (SMDS, BISDN)
Availability	Now	Late 1992

Source: Dataquest (November 1992)

Starlight Networks, for instance, backed by a number of LAN-oriented venture capitalists and at least one telephone company, has announced plans to offer server that specializes in delivery of video on a LAN. The beta test unit was built on an Intel 80486 platform with 10GB disk and had software that handled network server and storage management, allowing shared user access to digital motion video files on a server. One of the keys is the prioritization of video packets on the LAN—which addresses the synchronicity issue.

Another company, Meridian Data, recently announced products for putting recordable CDs, CD-R, onto a network, specifically through software that works with Novell NetWare as a NetWare Loadable Module.

Software is also being introduced that is application-specific. When Lotus Development Corporation recently began shipping its Multimedia SmartHelp for Lotus 1-2-3, a multimedia help program with animation and sound that sits on a CD-ROM, it also introduced software, called CD/Networker, that orchestrates the sharing of CD/ROM files on CD/ROM servers.

Switching Hubs

Perhaps one of the easiest and quickest ways to get communications relief for multimedia applications will be through the use of high-speed switching hubs. These would be next-generation LAN hubs that not only relay and route information but that provide intrapremise switching. One of the immediate advantages would be the ability to use the hub as a focal point for ATM switching.

For multimedia computing these are the technologies that will help break the networking logjam. Most likely all will see some kind of usage, and application developers and implementors will have to ferret their way through a thicket of communications alternatives. New server and premise-based switching will provide some immediate relief, but not until broadband networking is widely available will multimedia telecommunications become a real market enabler. Figure 7-8 illustrates in a simple way how a number of the technologies might be employed.

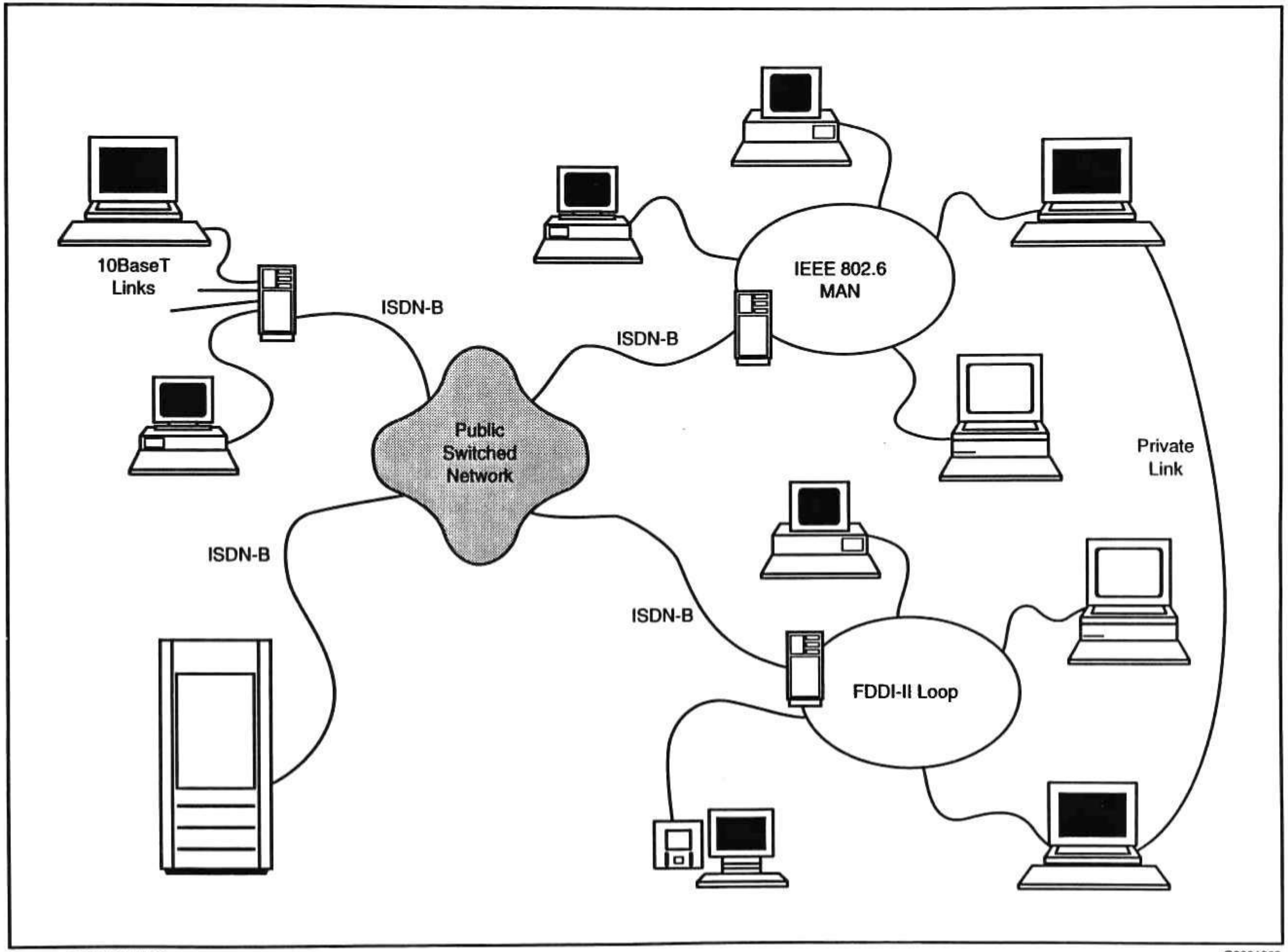
Network Usage

While some multimedia computing applications that use telecommunications will arise out of the minds of innovators and entrepreneurs, others will come as the natural evolution of existing applications that use telecommunications. As illustrated in Figure 7-9, we believe that existing voice, data, and video applications could likely evolve into multimedia applications.

Two of the more interesting application intersections are as follows:

- Voice and fax and data processing—In the telecommunications context that translates to integration and interoperability of e-mail, voice mail, and fax networks.
- Video and voice—Particularly in the newly developing area of videophones.

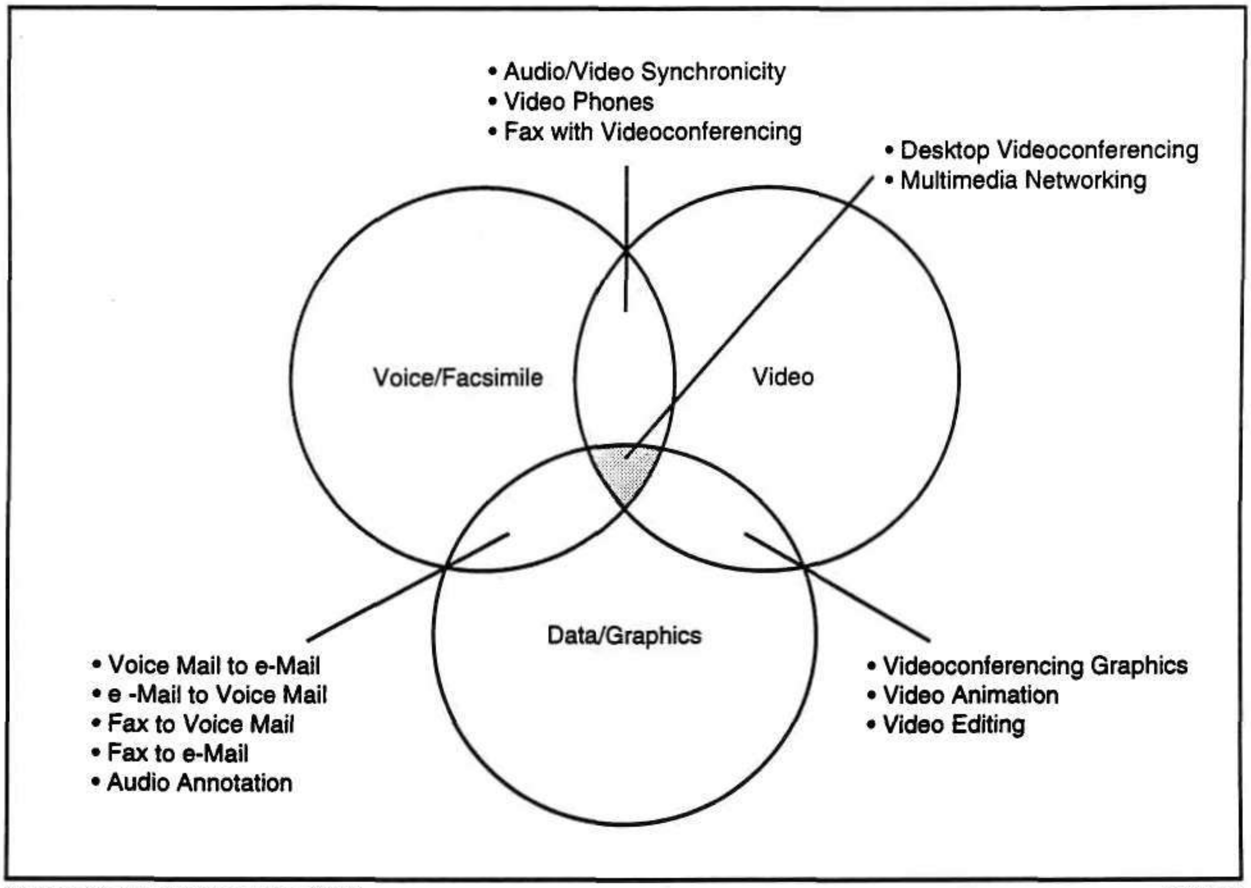
Figure 7-8
End-to-End Multimedia Telecommunications



Source: CONDATEC

G2001202

Figure 7-9
Multimedia Telecommunications – Merging Applications



Source: Dataquest (November 1992) G2001203

Neither of these areas may strictly qualify as multimedia computing, but one can see how they can evolve to it. Tie a store-and-forward system to compound documents manipulated on a PC and stored on a CD/ROM and you do have multimedia. Let the desktop videophone also send graphics and data in document form and you have multimedia conferencing.

In addition, the issues and barriers associated with the intersections of these technologies illustrate issues and barriers ahead for multimedia telecommunications. If there are no standards yet in place for voice mail systems to intercommunicate, how can we expect multimedia mail systems to communicate? If video phones today have inadequate audio and video synchronicity, how will desktop multimedia conferencing systems solve the problem?

Let's look at developments in these two areas in more depth.

Voice/Fax/Electronic Mail

With more than 20 million electronic mailboxes in the United States, 10 million voice mailboxes, and more than 50 million fax machines, there is sufficient impetus for various types of technologies to come together. Unfortunately, building a single integrated messaging system that handles voice, computer, and fax output is not a trivial task. It is, however, not impossible, and the last 18 months have been watershed ones for the emerging market of mixed media messaging systems, as they are called.

Starting with the introduction in 1989 of the Trilogue fax log system, which used plug-in fax boards and software to tack fax onto voice mail systems—from Comverse Technology—the fax voice submarket of the mixed media messaging market now supports more than 20 vendors with the big voice mail vendors like AT&T, Centigram, Applied Voice Technology, Octel, and VMX jumping on the bandwagon in 1991.

Dataquest expects to see rapid growth for combined voice and fax mail systems, as shown in Table 7-4. By the end of 1991, there were 6 million voice/fax store-and-forward mailboxes in the United States and a market less than $30 million. Within five years, that market will be more than $500 million.

Note that almost half the voice/fax store-and-forward ports installed each year are add-ons to existing voice mail systems, which makes fax messaging an important after market for voice mail vendors. The addition of fax capabilities also provides answering services with competitive differentiation.

There are a number of uses for the integration of fax and voice massaging systems, including, mobile office, private fax mailboxes, and overflow fax and guaranteed delivery messaging.

There are a number of ways this voice/fax messaging is implemented. The initial method used by Comverse integrates dedicated fax ports under the skin of a voice mail system. Octel offers it as a separate data module to its Aspen voice mail systems installed as a system retrofit. Digital Equipment delivers voice and fax over a LAN, with the application itself remaining on the host systems. Unisys, in its NAP line, uses a fax server concept.

Store-and-forward fax overlaid on voice mail is one thing. True integrated mixed media messaging—where modes can be mixed in a single message and where e-mail is included—X.500 for e-mail transmission and addressing and the emerging AMIS standard for voice mail interoperation mean that integrating e-mail, voice, and fax will someday no longer be an impossible task, merely a daunting one.

The issue is how to make the three types of systems interoperable—for instance, for a voice mail system to receive an incoming e-mail message and turn it into speech, or for an e-mail system to notify users where there is a voice annotation of a document in a voice mail box. Imagine being able to choose whether you wish to receive a particular stored message as a voice telephone call, incoming fax, or e-mail screen message.

Table 7-4
Total Voice/Fax Store-and-Forward Market

	1992	1993	1994	1995	1996	CAGR(%) 1992-1996
Annual Shipments (Units)						
Total	13,840	37,300	60,981	82,295	99,442	63.7
New	13,290	35,654	58,279	78,754	94,893	-
Add-On	550	1,646	2,702	3,541	4,549	-
Average Selling Price ($K per Unit)	5.8	5.7	5.5	5.3	5.1	-3.2
Total End-User Revenue ($M)	80.3	211.1	334.6	434.3	507.1	58.5
Revenue Growth (%)	182.6	163.0	58.5	29.8	16.8	-
Retirements from Installed Base (Units)	0	0	636	1,285	2,423	39.7
Year-End Installed Base (Units)	19,814	57,114	117,459	198,470	295,488	96.5
Installed Base Growth (%)	231.7	188.3	105.7	69.0	48.9	-

Source: Dataquest (November 1992)

None of the systems today can do all of these things, but the vendors *have* made progress. For example:

- Centigram's Audio e-mail system permits users to issue e-mail commands with the telephone keypad and has text to speech conversion. It also has notification and delivery options for IBM PROFS, Sprintmail, and fax.
- VaxMail has a system that converts e-mail text into speech and allows users to send voice mail messages back to an e-mail system using canned messages.
- Octel has a capability in its system for voice mail customers to use keypad input to reroute e-mail messages to other mailboxes.
- Digital's voice mail system, developed with VoiceSoft, integrates e-mail, voice mail, and fax in Digital's ALL-IN-1 office software. Using the system, it is possible to convert computer-generated text to separately addressed voice messages for such applications as dispatching.
- AT&T's system allows users to receive voice and fax in the same mailbox and retrieve both with a single call.
- Voice response system vendors, like InterVoice, Periphonics, and Syntellect, have begun offering fax and text-to-speech integration. And PBX vendors, like Rolm and Northern, have begun adding fax to their voice mail systems.

There are, however, some significant barriers to development of truly universal mixed-media messaging systems, not the least of which is the lack of any universal standards for even simple tasks, such as message notification. Voice mail vendors hoping to tie into e-mail systems will have to do so by emulating the popular systems, such as IBM PROFS, Digital's ALL-IN-1, and cc:Mail.

E-mail (and voice mail) vendors hoping to tie into voice mail (or other vendor voice mail) systems are all relying on the AMIS standard, which is still evolving and not present in any big way in actual products. Just being able to accommodate the variety of user interfaces available today—telephone keypads, pagers, terminals, PCs, and Macintoshes—creates a challenge in cross mode notification and delivery.

But it is happening, and rapid advances in the PC multimedia world will diminish some of these challenges. LAN-based e-mail system vendors are now adding voice messages to documents through the same kind of "object oriented" technology that allows the Apple Macintosh or PCs running Microsoft Windows to integrate applications through geographical user interfaces. So, just as voice mail vendors are adding e-mail and fax, e-mail vendors are adding voice capabilities.

Videophones

Early this year, 28 years after unveiling the Picturephone at the 1964 World's fair, AT&T introduced the VideoPhone 2500, based on technology from Compression Labs (CLI). Coming with a small video screen and camera mounted on it, the system costs $1,499. At announcement time AT&T talked about getting the device into the hands of millions in the next 18 months.

Shortly thereafter, CLI announced the merchant version of the same technology, the Cameo Personal Video System, which works with a desktop computer or workstation to provide two-way, full-color, motion video over ISDN lines. The initial model is the Model 2001, built on a Mac II or higher-running QuickTime. Cost of the CLI gear is under $2,100. Future announcements will include PC-based videophones and ones that work with analog lines and that are compatible with AT&T's VideoPhone 2500.

Other companies expected to announce videophones soon include British Telecom, Hitachi, Mitsubishi, and Matsushita (Panasonic brand name).

While the VideoPhone 2500 is simply a phone with a compressed digital video pipe, and not really a multimedia device—it is more like two devices of two different media stuck on the same desk set—the CLI system has the makings of a real multimedia conferencing application, since existing programs can run while the video portion of the system is activated.

The two videophone systems illustrate some of the problems of integrating the two media:

- To use the AT&T phone you must have two similar phones, separate power supplies, and recipients willing to learn how to use the system. Early users complain about the resolution, audio quality, motion resolution, and field of vision. It has been seen as a device useful in specific security or health care applications, but not general consumer use.
- The CLI system requires Mac System 7.0 software (and the memory to run it on), ISDN adapters, and ISDN lines, for a total system cost significantly higher than $2,100. And, again, it will not work unless the other recipient has ISDN and a compatible PC.

Note another problem: incompatibility between videophones. This may be solved in the future by the H.261 video communications standard, but at demos earlier this year of interoperating PictureTel and CLI video conferencing systems using the H.261 standard the consensus was that resolution and audio were not as good as with proprietary systems.

As a result, there is an inherent conflict between technologies evolving into desktop multimedia conferencing—the phone with video and maybe data added and the PC with video and maybe voice added (such as IBM's Person to Person/2). The former is cheaper but does not scale upward into an enterprise computing system very well; the latter does not offer the simplicity or low cost of a videophone.

Multimedia applications that rely on telecommunications—whether it is CD-ROM networking on a LAN or desktop teleconferencing over

ISDN lines—will face interoperability, system design, and management issues for years to come. As a result, they will most likely be employed as point solutions—to support a single corporate application, like remote radiology, or project consulting—rather than as general infrastructure. At the same time the growing list of supporting standards, from the AMIS standard for voice mail systems to the H.261 for digital video, will help vendors inch toward true network interoperability.

Market Size

Because of their need for bandwidth and advanced switching, multimedia applications are high on the list of potential revenue sources for carriers, LAN vendors, and equipment makers.

Yet, it is almost impossible to quantify the market for the telecommunications portion of multimedia computing because much of the traffic will be bundled onto existing local area and wide area backbones. Many of the telcos, and certainly Bellcore and AT&T, have tried to quantify the impact of multimedia on future revenue from services, but with little success.

This is not surprising. If network designers have little insight into exactly how multimedia applications will generate future network traffic, how can carriers assess what that traffic will generate in revenue?

As a result, Dataquest believes that any forecasts for carrier or line revenue associated with multimedia—as opposed to straight teleconferencing, or voice mail, for instance—is subject to such variance as a result of definitions or computational algorithms as to be misleading. Also, the trade-off between premises-based solutions, such as local ATM switching, and services, like frame relay or SMDS, are not clear enough to predict the impact on future revenue.

That does not mean the traffic will not be there. Given the data intensive nature of multimedia applications, particularly ones with video, the amount of data being shunted over the public telephone plant will easily more than double during the next five years. Determining how that translates into revenue, however, is problematical, since a lot will no longer go through traditional private lines.

To this end, the forecast for multimedia telecommunications in this report is for the primarily definable market in LANs and LAN internetworking hardware and software, including FDDI. Central office switching, Centrex, PBX add-ons, T1 and T3 equipment and services, and the portion of data services attributable to multimedia are not realistically quantifiable. There will be growth in network services and equipment as a result of increased bandwidth demand and changing traffic characteristics coming from multimedia applications, but that demand will surface as a general increase in backbone networking.

Here are some other general notes on the forecast:

- The shipment of multimedia PCs/workstations will be associated with commensurate shipments of LAN components, while the shipment of upgrade kits, nine times out of ten, will not, since the PCs and workstations being upgraded will already be serviced by LANs. In the forecasts for LANs related to multimedia, this has been taken into account, and the LAN and FDDI forecast has been built from the MPC forecast and estimations of the number of nodes per LAN and average configurations.
- Because of the complexity of multimedia applications and the bandwidth and switching demands placed on the LAN by multimedia applications, Dataquest has forecast LAN supporting multimedia machines to be more highly configured, with 25 percent to 40 percent higher average system prices than the average LAN.
- Counted in the LAN configurations are network interface cards, network operating systems, intelligent hub ports, and routers. Cabling, installation, and repeaters or bridges were not counted.
- Other than in average system prices, Dataquest saw no reason that LANs supporting multimedia PCs and workstations would exhibit different node-to-LAN or PCs-per-LAN ratios than the market as a whole.
- The growth in LANs supporting multimedia PCs and workstations is derived from two countervailing trends: 1) the increased percentage of PCs and workstations connected to LANs; 2) falling component prices and an increase over time of the number of nodes on a LAN.
- Most of the networking revenue in the early period of the forecast period will come from Ethernet and token-ring LANs. By the end of the forecast period, FDDI LANs will become increasingly important, however.

Other exotic wide bandwidth equipment, such as SONET and asynchronous transfer method (ATM) switches and broadband ISDN services will come on stream during the forecast period and will be market enables, but their impact on the market will not be multimedia-specific. They have not been added into the quantitative market forecast. Similarly, ISDN services, frame relay services and equipment, and other value-added wide area networking services have not been added.

- Also note that hybrid electronic messaging systems that link voice mail and e-mail or fax are included. While these systems may evolve into true multimedia messaging systems, Dataquest felt there are sufficient unknowns in the likely development of the technology and its use to preclude forecasting.

- A separate category of desktop video conferencing was considered, but since most such applications today are based primarily on the addition of low-cost video cards to PCs and the use of authoring and communications software, Dataquest felt the forecast coverage in other line items covered the category. Standard video phones, such as the AT&T VideoPhone 2500, was not considered a multimedia device.
- One final clarification: The figures show networks supporting the multimedia-capable PCs and workstations but make no assumptions as to how many of those devices are actually engaged in multimedia applications.

Table 7-5 shows year-by-year shipments and revenue of LANs and FDDI networks supporting multimedia.

This FDDI revenue growth tracks Dataquest's general forecast for FDDI. Note that the number of networks is radically different—since the FDDI networks are expected to have many more nodes per network than a single LAN. (Internetworked LANs are counted as the total of interconnected LANs). Figure 7-10 shows not only the dramatic growth in multimedia networking from 1991 to 1996—from $10 million to more than $1 billion in factory revenue—but also the rapid expected growth of the FDDI portion of that revenue.

Figure 7-11 shows the rapid increase in multimedia networks, of which FDDI networks do not count for much in terms of units until 1995. Note that each LAN and FDDI network includes the amortized portion of any routers and intelligent hubs that might support the LAN or FDDI net. Thus, the addition of ATM switches into hubs is more or less accounted for as substitutable technology. The forecast does *not* include, however, any major buildup in market demand as a result of new switching technology.

In short, the forecasts assume that multimedia networking will continue to follow the market rather than lead it on into the latter half of the decade.

Vendor Profiles

The number of vendors having a major role in this supply-drive market for multimedia telecommunications is legion. Major players include all of the long distance carriers and international PTTs, the local Bell operating companies and their research surrogate, Bellcore, as well as the systems vendors, voice mail vendors, e-mail vendors, LAN and hub vendors, and software vendors.

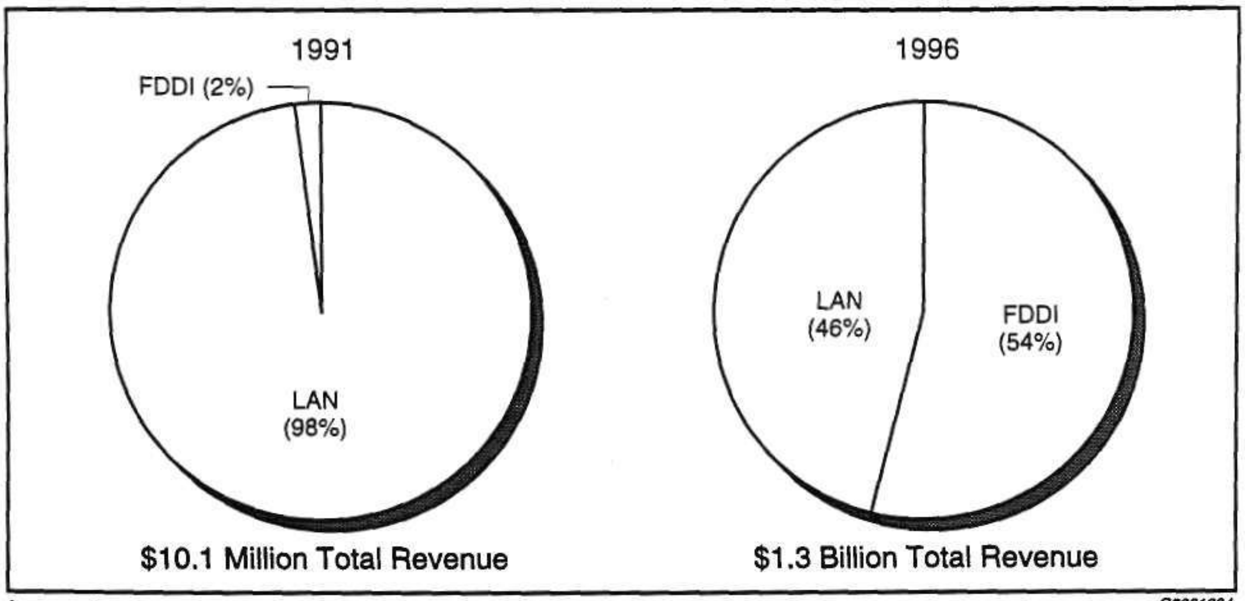
Many of them, in fact, play multiple roles—AT&T, for instance, is a provider of ISDN, of videophones, of superservers, of LANs, of imaging systems, of central office switches that support video switching, and of research and future product and service for all the broadband services. In order to provide a rich and varied cross section of all this interdependent vendor activity, vendors are profiled by specific product or strategy thrusts in the bullet points below. If specific product thrusts are previously covered in this chapter, such as the AT&T VideoPhone 2500, Lotus CD/Networker, CLI Cameo Personal Video System, or Starlight Networks system, they are not mentioned.

Table 7-5
The Worldwide Multimedia Telecommunications Market

	1991	1992	1993	1994	1995	1996
Number of Multimedia LANs	3,150	11,540	48,560	87,710	147,730	226,090
Multimedia LAN Factory Revenue ($K)	9,934	35,079	154,459	297,411	529,758	855,743
Number of Multimedia FDDI Networks	NA	20	420	2,210	8,760	24,320
Multimedia FDDI Factory Revenue ($K)	169	1,754	20,080	68,404	227,796	462,100
Total Multimedia Networks	3,152	11,565	48,975	89,912	156,491	250,409
Total Multimedia Networks Factory Revenue ($K)	10,103	36,833	174,538	365,815	757,554	1,317,844

Source: Dataquest (November 1992)

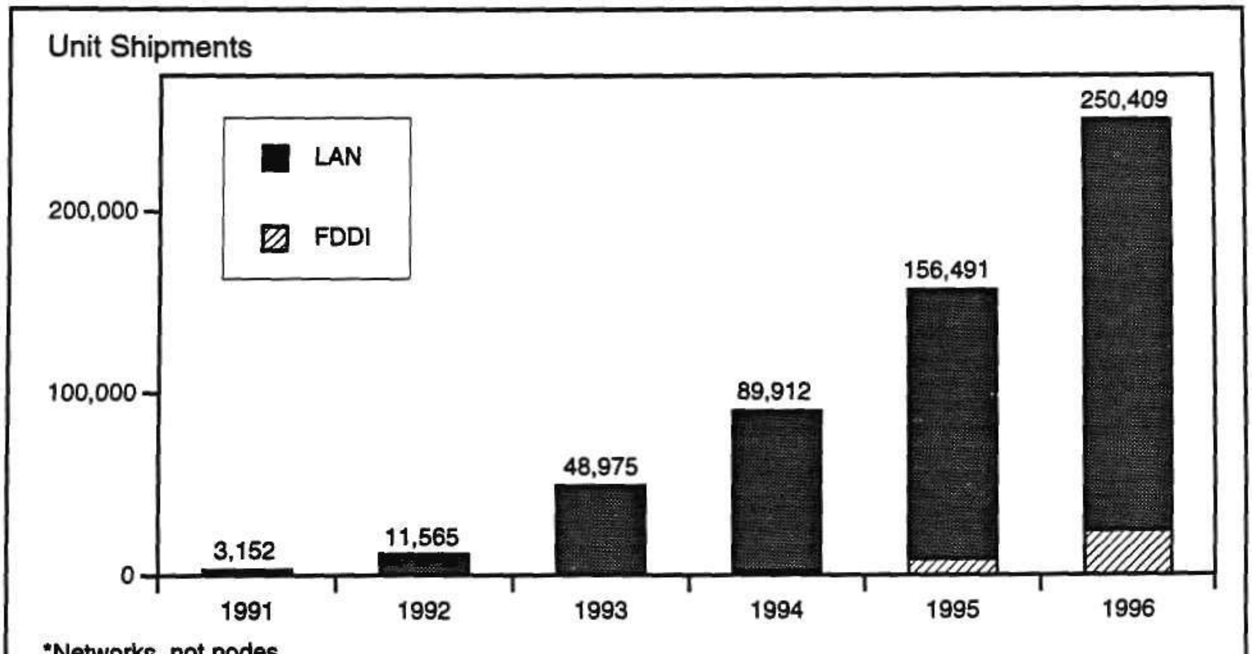
Figure 7-10
Multimedia Telecommunications by Network Type, Worldwide Factory Revenue



Source: Dataquest (November 1992)

G2001204

Figure 7-11
Growth in Multimedia Networking, Worldwide Unit Shipments*



*Networks, not nodes

Source: Dataquest (November 1992)

G2001205

The following paragraphs provide details of some important recent multimedia thrusts by major players in this market.

- Adaptive Corporation announced last summer an ATM switch, called ATMX, with a 1.2 Gbps back plane and 15 interface slots, each with six 100 Mbps ports for attaching workstations and routers over fiber-optic lines. The switch can handle 90 ports. Adaptive, a subsidiary of Network Equipment Technologies, unveiled the system after beta testing at Bear Sterns, and Company. The system can also take input from intelligent hubs, routers, token ring, Ethernet, or FDDI LANs through a bridge/router with an ATM interface. The advantage of ATMX is that it allows users to scale LANs to large size without segmenting them with bridges or routers, which can tend to slow down throughput. For administrative purposes, ATMX users can segment their LANs into virtual LANs using software. A basic ATMX costs $45,000 in entry-level configuration, including power supply, chassis, switching module, and one six-port attachment module. Additional cards cost $26,000. Workstation adapter cards can cost $4,500. Immediate advantage of ATMX will be to increase workstation performance on congested LANs; but TM switching, as previously noted, will be useful for multimedia traffic.

- Ameritech, in conjunction with IBM and Prodigy Services Inc., has launched an ISDN trial at a high school in Illinois testing multimedia applications. Students at the high school will use the ISDN lines to download data from Prodigy for access to information services. Some will also use ISDN in their home to tap into school computers and access or upload multimedia files of voice data, graphics, and video. The companies are involved in the trial essentially as market research to test the pricing thresholds and feature desirability. The high school itself has been outfitted with IBM PS/1s and PS/2s, ISDN telephones, laser disk players, e-mail software, printers, and file servers linked by Novell networks.

- AT&T, through its subsidiary NCR, introduced this summer a series of intelligent hubs that offer LAN bridging and routing, as well as hubbing functions and that AT&T said would evolve into ATM switches for local area networks. The company has said it expects to be offering ATM switching on the hub within three years, with switching at gigabits speeds designed to support bandwidth on demand for multimedia applications that integrate voice, data, and video. AT&T admitted that it had formed an internal task force across business units to determine a strategy from migrating customers to ATM.

- AT&T and Bell Atlantic have begun a trial for this school year and the next school year in New Jersey testing the delivery of interactive voice data and full motion video to a number of schools. The system will test technology called Asymmetrical Digital Subscriber Line or ADSL, for transmitting compressed video signals on the public network. The information can go over normal telephone lines. The trial will test the feasibility of delivering multimedia information to homes and to schools; if it is successful and demand were to increase, Telco would have to upgrade the physical point to fiber.

- AT&T, through its AT&T Microelectronics Unit, has introduced a chip set, the AVP1000, that handles the three major multimedia decompression and transmission standards, to wit MPEG, JPEG, Px64. The chip set uses advanced digital signal processing and video code technology. The chip set also comes with a system controller and signal synchronization circuits. Along with the chip set, AT&T announced the BCOS operating system, or virtual caching operating system. BCOS resides under control of a host operating system, such as MS-DOS, creating a platform for the chip set processors to work with the host computer system. At announcement of the chip set at COMDEX this spring, a number of vendors said they would incorporate the chip set and BCOS into their future systems, chief among them, Apple Computer. The Apple decision is somewhat counter to its joint relationship with IBM and the company Kaleida, which is developing multimedia systems. IBM has been working with Texas Instruments and Software House Intermetrics to develop a multimedia system called Mwave. Other competitive chip set designers include Analog Devices and Motorola. At announcement, AT&T said the underlying technology—compression algorithms and circuit design—is the same one being used in a project AT&T is collaborating with Zenith on HDTV.

- Bytex, a maker of LAN and intelligent hub equipment, recently revealed it's working with PictureTel and CLI to add video to installed token ring networks. Bytex is planning to develop a system that uses its auto configuration software to allow users to be "cut and pasted" on and off a physical token ring that is dedicated to video. The development would be a precursor to ATM switching.

- Shortly after the announcement of Microsoft Windows 3.1, Compaq Computer, Microsoft, and Analog Devices announced a joint hardware and software development effort to bring business-oriented audio to personal computing. Business Audio entails a fusion of object linking and embedding (OLE) technology with various audio application programming interfaces (APIs) with Windows 3.1. It will be built on a Compaq platform using an Analog Devices SoundPort chip. The hardware platform will be capable of recording or playing PC quality sound, telephone/workstation quality sound, and CD quality sound in mono or stereo. The expect initial application of Business Audio will be voice annotation within Windows 3.1 for spreadsheets, compound documents, and e-mail. Users will be able to leave audio notes within files on their systems, which can be played back by clicking on an audio icon. The companies were careful to distinguish Business Audio from multimedia that relies more on CD ROM technology than Business Audio.

- The Department of Defense (DOD) this summer announced funding of a major three-year project to test ATM technology under heavy application loads. A number of vendor, academic, and government organizations joint in a consortium, called the Multi Dimensional Applications and Gigabit Internetwork Consortium, under the project. The application tested will be terrain visualization, which involves data collection by the Earth Resources Observations Systems Data Center in Sioux Falls, South Dakota, and transmission to various Army and academic centers. The backbone network will transfer over ATM sonnet links at 2.4 Gbps. Vendors involved in testing interoperability between LAN and LAN ATM include Digital Equipment Corporation, Sprint, and Northern Telecom. The tests will determine protocols required to set up long distance circuits for LAN internetworking across distances, for the management allocation and ATM bandwidth among different devices, troubleshooting and repair, and packet transmission reliability, as well as general interoperability of ATM links with various LAN and WAN equipment. The test will also be useful for Sprint, which has already announced plan to develop an ATM public network service.

- One of the most widely watched multimedia experiments is GTE's Cerritos project. Begun in 1988 among the community of Cerritos, California, the project is experimenting with multimedia communication over different types of digital fiber-optic cable. Services being implemented in Cerritos include video on demand, video television, home shopping television, fiber tone service, and fiber-optic local-exchange network services. Sent over the fiber cables to houses are not only cable video programs and the video on demand programming, but also AM, FM, and normal television reception. In addition, video phone communication using phone with attached cameras is also being tested.

- Lannet Data Communications announced a high-speed switching hub last August that can handle up to 128 Ethernet segments. Announced as an upgrade for its LET-36 hub and available early in 1993, the system will support multimedia applications including video desktop through the use of framed switching technology, it will route traffic throughout 1.28 Gbps back plane. It will be one of the first, if not the first, use of cell relay switching on a hub. The trade-off for not being full ATM is that the switch will work with 10 Base T Ethernet networks without the requirement for expensive upgrades. The switching capability will cost about $1,000 per port.

- Microsoft has finally begun selling its "rosebud" software that is essentially multimedia and audio clip art. For $79.95, users of the program can call up classic film lines such as Mae West's "Come up and see me some time," along with some 19,000 movie reviews and video stills. The software reflects personal efforts by Microsoft founder Bill Gates to obtain rights to the music and video artwork in the program.

- Northern Telecom introduced a multimedia application package for PCs this summer that works over telephone lines called visual interactive technologies (VISIT). The software permits video conferencing, data transfer, and screen shine between desktop computers over standard 56 Kbps switched or PBX lines. The software provides, if only choppy, black-and-white video images, which Northern Telecom thought was a reasonable trade-off to the requirement to obtain ISDN or switched 64 Kbps lines. VISIT requires no change to PBX or LAN infrastructures to install. It consists of a compression/decompression board, a miniature camera, and applications and communications software. The first release is for Apple Macintosh computers, the second was a version for IBM-compatible

PCs. It also includes an access device for connecting the PC with the switched telephone services. Although the system only supports point-to-point communications, its screen sharing technology should be of interest. The system competes with CLI Cameo Personal Video System, which requires ISDN lines. Color versions will be available before the end of the year. Also available before the end of the year, according to Northern Telecom, will be the capability of having a Macintosh talk to an IBM PC using the VISIT system. Pricing for the desktop video conferencing version of VISIT is between $3,000 and $3,500. Another version of the software was also announced that enables users to access voice mail and telephone features, i.e., setting the PC up to be a phone management system. This is bundled with the video conferencing system but is available standalone for $100.

- Pacific Bell, IBM, and Northern Telecom announced this year a joint venture for testing multimedia carrier delivered application over ISDN. Initial tests will include IBM's Person-to-Person/2 desktop conferencing system, Northern Telecom's DMS 100 Supernode digital telephone exchange switch, and Pacific Bell's ISDN Centrex service, with the application Centrex-base video conferencing. Later phases of the project will test transmission over higher bandwidth media, such as frame relay and ATM networks. The trials will test not only point-to-point but point-to-multipoint multimedia communications. The real intent of the test is market research to determine what features multimedia users desire, how they should best be delivered, and what pricing thresholds exist. ISDN testing will come in 1992; ATM testing, late in 1993. Applications testing will include not only person-to-person video, but also shared CD-ROM delivery from information repositories. Pacific Bell has said, however, that tariffed multimedia services based on ATM will not be available until 1994 or later.

- Starting in November 1992, a group of vendors has come together calling themselves the Packet Video Consortium. Driven by interest from academic centers and Internet members, the intent of the Packet Video Consortium is to develop standards for packet delivery of video. The issues addressed by the Consortium's efforts would be prioritization of video packets, development of a transport layer for real-time multimedia communications, and development of a multicast protocol to allow simultaneous transmission to multiple locations. The driving force behind the Packet Video Consortium has been the Internet Engineering Task Force and the MCNC Center for Communication, which is a consortium of universities in North Carolina. Vendors that will probably join the consortium include Digital Equipment Corporation, CLI Corp., IBM Corporation, Sun Microsystems, and BBN. Some groundbreaking work has already been done by potential members. Digital, for instance, has demonstrated a prototype of its DECspin multimedia workstation, running live video over internet during the Siggraph 92 show. The Internet Engineering Task Force has broadcast live to users running Sun Microsystems' SPARC stations equipped with Sun videopix cards and BBN software. MCNC has been testing video conferences over the Internet using CLI, Codecs, IBM RS6000 workstations.

- Sprint learned this year that the Department of Energy (DOE) has awarded it a five-year, $50 million contract to develop ATM services under its National Research and Education Network (NRN) Program. This will allow Sprint to accelerate its original ATM deployment schedule into commercial use by 1993. Initially, the network will provide transmission of 45 Mbps, but eventually it will go up to 155 Mbps and 622 Mbps. Tied into the network will be test sites in California, New Mexico, Texas, Tennessee, and Illinois. The award is the first step in the development of the controversial gigabit speed NRN network, which is to be something like a high-speed upgrade to the vast lower-speed internet. Partners with Sprint in the award were Cisco Systems (ATM routers), TRW (ATM switches), and Digital Equipment Corporation (management software). The DOE decision to go with ATM meant that it leapfrogged a possible migration to SMDS.
- VideoTelecom, introduced this year its MediaMax Systems, which integrate video conferencing with facsimile, computer screen sharing, and document conferencing. VideoTelecom, one of the major suppliers of video conferencing systems, has also begun delivering H.261 upgrades to its existing video conferencing systems.
- Sun Microsystems, Apple Computer, Bellcore, and Xerox have collaborated on technical document discussing issues of ATM compatibility in a LAN environment. The document, called "network compatible ATM for local network applications," addresses standards issues and builds on experience from Xerox, Sun, and Apple experience with their own developing ATM networks. The intent of the work is to ensure that there is interoperability between computing ATM products when the switches and services come on the market in 1992, 1993, and 1994.

Dataquest Analysis

Dataquest's view of multimedia telecommunications has been embedded in the analysis in the previous sections and in the data and graphics provided, but can be summarized as follows:

- The market for multimedia telecommunications will follow the market for multimedia PCs until the latter half of the decade, when new broadband networking technologies come on stream and act as a market enabler.
- In addition to new broadband networking technologies, the market will require standards for mixed-media communications interoperability before telecommunications can be an enabling technology.
- The market for multimedia telecommunications is supply-driven, with scores of players involved, from the large telephone companies to small, point product equipment vendors.
- There are conflicting and confusing telecommunications alternatives—frame relay versus SMDS, ATM versus FDDI—that will make developing a network architecture to support multimedia applications a nontrivial exercise.

- The most significant immediate relief to the problem of insufficient bandwidth for multimedia communications will come from compression technology.
- A number of multimedia applications that involve telecommunications will evolve out of existing single media applications, such as voice mail, store-and-forward fax, e-mail, and desktop video conferencing.
- The issues of network design and engineering, management, control and fault isolation, and support and maintenance for multimedia telecommunications are still muddy.

In short, there is a lot happening, and much of it is happening fast, but the problems are significant. It will take time, money, and development efforts in a number of communications areas to make multimedia networking a reality.

Chapter 8
The Impact of Emerging Technologies on Multimedia

Introduction

Technology is at an exciting crossroads where many futuristic concepts are quickly becoming everyday reality. Devices that only a few years ago were considered "science fiction" are now available on the shelves of consumer electronics stores and are visible in public places.

Who would have imagined in 1970, for example, when watches had hands and showed the time of day, that in 1992 you would be able to purchase for less than $50 a digital watch that not only performs a host of time-keeping functions, but that also stores appointments and rings an alarm to remind you of them, contains a telephone directory of more than 100 numbers, and even emits digital tones to dial the telephone for you? Or, in the days when a letter took a week to get across the United States, who could have envisioned sending digital images via facsimile, much less carrying a pint-size, cellular fax machine in your briefcase that can send faxes via wireless communications? Or, not too very long ago, when telecommunications were tightly bound by terrestrial wiring, would you ever have thought it possible to be sitting on an airplane at 30,000 feet, lift a telephone receiver from the seat back in front of you, and casually call home to see what is for dinner? And remember the days before ATMs when you had to make it to the bank by 3:00 p.m., Monday through Friday, to cash a check—otherwise you were out of luck? It is a dizzying prospect indeed, to ponder how much faster such advances will occur during the rest of the decade and into the 21st century, spurred by ever-advancing technology coupled with miniaturization.

There are a number of new and emerging technologies that are destined to have an impact on multimedia systems development, or will rely heavily on multimedia technologies to move forward and grow. These include the following:

- Computer conferencing
- Document imaging
- High-definition television
- Personal digital assistants
- Speech recognition and synthesis

- Wireless communications
- Virtual reality
- Convergence of consumer electronics and computing

This section presents an overview of these technologies. Note that we provide market size estimates and forecasts where available, but because many of these areas are so new, we have not sized all of these markets. In all descriptions, we provide a conceptual analysis of the impacts that we believe these technologies will have on multimedia, or vice versa.

Computer Conferencing

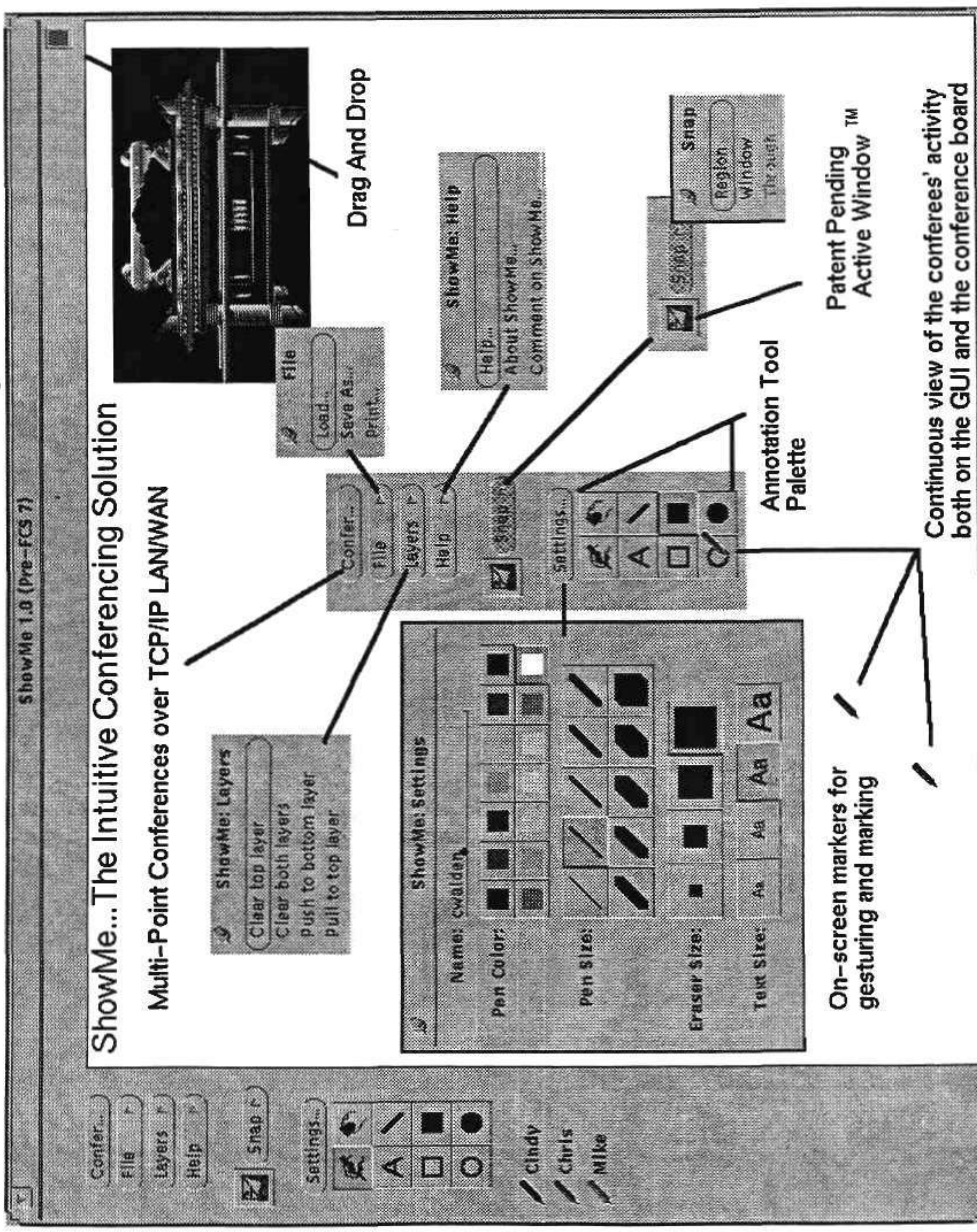
Computer conferencing is a term that describes a new class of software products that enable people to conduct meetings and share information via live, interactive, workstation-based conference sessions. In a computer conferencing environment, any number of users on a network can log into a conference session and participate interactively through sharing data and image files, through voice communications, by making pen annotations to data presented on screen, and, in some environments, by updating data and image files real time. Changes made by one participant display instantly on the workstations screens of all conference participants (see Figure 8-1).

Computer conferencing has it roots in some of the early message-sending features available on mainframe systems, and more recently in electronic mail systems and online bulletin boards found on public and private computer networks. Through these tools, users can send messages and files back and forth, post bulletins, and browse through information notices and want-ads. The limiting factor is that these communications are one-way, making simultaneous collaboration impossible.

Today's computer conferencing software offers a much more robust medium than its predecessors for bringing people together in a dynamic, information-sharing environment. An example of a typical conference session might link together engineers from several remote locations to discuss a CAD design. The computer conferencing software would display the design simultaneously on all workstations and allow the engineers to discuss it through voice communications (telephone, at this point). The conferencing software provides markup and redlining tools to annotate the drawing. As one engineer makes a suggested modification to the drawing, all conference participants see the change. Signature tools facilitate the review and approval cycle.

This is only one example of the way this type of software is being used in business and technical environments. Almost any meeting—and in fact many business telephone conversations—could be

Figure 8-1
ShowMe's Intuitive Conferencing Solution



Source: Sun Technology Enterprises

conducted much more effectively using computer conferencing. Vendors see opportunities for computer conferencing tools in scores of applications, as follows:

- Engineering—Product design and approval
- Manufacturing—Product production and troubleshooting
- CASE—Project collaboration
- Medical—Diagnostics and remote consultation with patients
- Finance—Spreadsheets, documents, customer communications
- Real estate—Development and site management; architectural drawings and facilities design
- Sales and Marketing—Sales meetings and presentations
- Government—Inter- and intra-agency communications
- General office—Workgroup and corporate communications

Various factors have driven the development of computer conferencing software, including the following:

- Globalization of companies—Many companies are now global enterprises with people at physically distant sites trying to work together on a project. Telephone communications—even conference calls—often prove inadequate when people need to sit down together to sketch out a design, critique a product, or solve a problem.
- Economics—It has become too expensive both in terms of time and money to send people to remote locations to participate in meetings. Many times, a person needs to be several places on the same day. Computer conferencing allows him or her to stay the office, but still participate in all of the meetings.
- More powerful desktop computers and operating systems—Many people now have access to desktop workstations running operating systems (especially UNIX) robust enough to handle computer conferencing.
- Improvements in LAN and WAN communications—Local and wide area networks have joined people together in environments capable of supporting the interactive, back-and-forth communications necessary for computer conferencing.

Several computer conferencing products have appeared on the scene during the past 18 months, and many start-ups as well as giant corporations are working on products for this market.

- The first to market may have been a product called CAD Conferencing that was introduced by Intergraph Corporation (Huntsville, Alabama) in May 1991 (developed for Intergraph by DataBeam of Lexington, Kentucky). This runs on Intergraph's series 300, 3000, and 6000 workstations and displays both vector and scanned images, which can be annotated or modified by conference participants. As the name implies, CAD Conferencing is targeted at engineers and provides markup, signature approval, image manipulation (pan, scroll, and zoom), and color coding and high-lighting features.

- Shared X from Hewlett-Packard (Cupertino, California) enables users running in the X Windows desktop environment (on devices ranging from HP UNIX workstations to X terminals) to simultaneously access, view, and revise documents and drawings.
- Another computer conferencing product recently introduced is ShowMe from Sun Technology Enterprises, a division of Sun Microsystems Inc. (Mt. View, California). ShowMe runs on Sun SPARCstations under Solaris 1.0 and takes advantage of Sun's Open Look graphical user environment. It supports both scanned images and computer files in a "conference board" environment where participants can write and draw on displayed documents using colored pens.
- InSoft Inc. (Grantham, Pennsylvania) bills its Communique software as "real-time multimedia workgroup communications conferencing with graphics, audio, video, and text." The most advanced of the products mentioned here, Communique not only provides the ability to view and markup scanned images and data files, but through optional hardware enables the integration of video and audio data types to provide a conferencing environment more like face-to-face communications. Communique runs on Sun SPARC hardware and is available in English, French, and German language versions.
- Lotus Development Corporation (Cambridge, Massachusetts) recently announced an agreement with PictureTel Corporation (Peabody, Massachusetts), a manufacturer of video conferencing systems. Lotus plans to incorporate PictureTel's desktop teleconferencing capabilities into its Lotus Notes groupware software. The enhancement will enable Lotus Notes users to conduct live video conferences with each other directly on their computer screens.

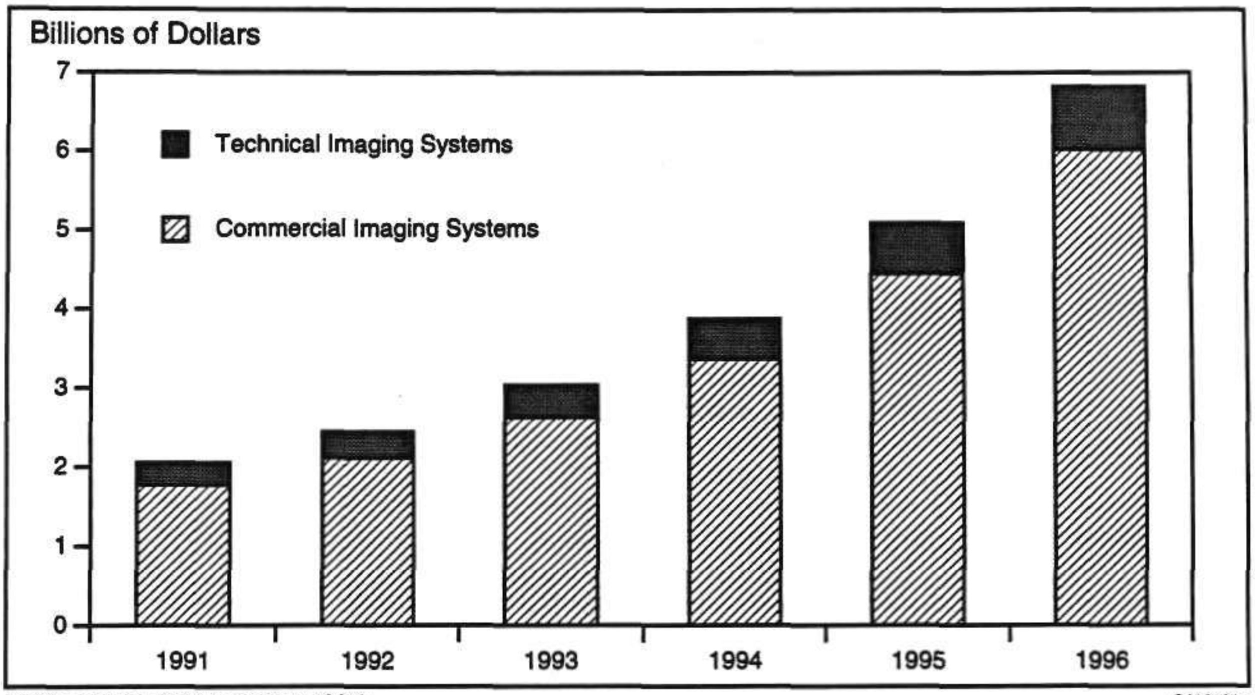
From a general productivity perspective, we believe that computer conferencing is the wave of the future. It allows people to quickly and inexpensively get together to get a job done—powerful medicine in a business world struggling to get products out the door before competitors and cut costs at the same time.

From a multimedia perspective, we expect that developments in multimedia video and audio hardware and communications will enable computer conferencing to fulfill its true destiny—to provide real-time, face-to-face communications such as are now available through expensive teleconferencing equipment. As workstations evolve during the decade to include video cameras, microphones, and speakers, the workstation will become a video production studio for workstation conferencing sessions. On-screen windows will display real-time video images of conference participants, and their voices will be captured by microphones embedded in the workstation. Conferencing software will undoubtedly become more specialized, providing tools specific to a person's job (graphics and CAD tools for designers and engineers; word processing and spreadsheets for white collar workers; diagnostic tools for doctors, and so on). In the future, it is conceivable much face-to-face business will be conducted in a very interactive, positive way without people ever physically meeting each other.

Document Imaging

Document imaging systems have become very popular during the past few years as a means to manage the high volume of paper in offices and to help automate the flow of information around an organization. Early pioneers in the document imaging business include both image system suppliers like FileNet Corporation (Costa Mesa, California), Plexus Software (Sunnyvale, California—previously known as Plexus Computers), and Wang Laboratories (Lowell, Massachusetts), as well as providers of optical equipment and micrographic and/or optical media such as 3M Corporation (St. Paul, Minnesota) and the Eastman Kodak Company (Rochester, New York). Today, the document imaging universe is populated by scores of software companies, all major computer companies are in the business, and hundreds of VARs and integrators are busy installing custom systems. Document imaging has grown rapidly into a multibillion dollar business opportunity. IBM alone is expected to exceed the $1 billion mark in sales of document imaging-related software, hardware, and services in 1992. (Figure 8-2 presents Dataquest's forecasts for the overall growth of the document image management systems market).

Figure 8-2
Worldwide Document Imaging Market Revenue Growth Forecast



Source: Dataquest (November 1992) G2001813

From the multimedia perspective, Document imaging systems deal with a very low-level data type—scanned or bit-mapped images. These systems use scanners to capture digital images of drawings or documents. Once captured, the images are indexed, filed off on optical disk, and available for retrieval at image-enabled workstations. The great thing about imaging systems is that they virtually never lose documents, multiple individuals may review the same document simultaneously at different workstations, and they provide very space-efficient storage for up to millions and millions of pieces of paper in optical jukeboxes. In addition, specialized application software enables the user to put the images to work. Images can be collected into electronic folders, folders can be routed throughout an organization using work flow software, OCR software converts image data into ASCII text so that full-text searches may be run through image databases to find information quickly, and hand-print or recognition software reads handwritten data from forms and automatically inserts them into the system's database.

At the core of the document image software is an image database that files and manages the images. Most systems are built on popular database structures such as Oracle, Informix, or Sybase. Some are built on proprietary databases optimized for managing scanned images. There is a growing tendency to base document image systems on object-oriented databases that have the capacity to recognize, store, and manage a variety of data types besides scanned images. Plexus' Extended Data Processing (XDP) software is a good example of document imaging software that is able to handle a variety of data types including text, data, scanned images, vector graphics, animation, voice and sound objects, and full-motion video. Plexus built its software on the Informix database and designed the product as a system for managing scanned bit maps, but with an eye toward a future where it would need to include multiple data types.

That future is getting here quickly. While full-blown multimedia computing has not *quite* reached the document imaging world, we did see a few glimmers of it on the show floor at the annual Association for Information and Image Management (AIIM) conference held in June of this year. We predict that momentum will build quickly once current document imaging users start to visualize applications that could really benefit from access to multiple data types.

At the AIIM show, FileNet displayed a little multimedia demo called "Passport to the Future," which the company said it pulled together in a couple of weeks, just to have something catchy for the show. This involved creating a multimedia "passport," such as may be used to identify travelers in the world of the future. This incorporated pen computing to record the traveler's signature (using a tablet and stylus), freeze-frame video image capture to record his photograph, a "voice print" to verify his voice, scanned images of the person's "travel documents," and database access to complete the traveler's profile. FileNet stressed that the ability to incorporate and manage all of these data types exists in its system today—and suggested that a few of its forward-thinking customers are thinking of ways to incorporate freeze-frame video and voice annotation into their current document imaging installations.

Other companies paid homage to multimedia at AIIM. Wang demonstrated its interest in the technology with "Images in the Future," a set of APIs for incorporating full-motion video into some of its Microsoft Windows-based applications. Wang envisions many uses for this in areas including training and manufacturing applications. IBM also showed its multimedia offerings with a display of the UltiMedia PC and some applications featuring integrated video, images, and sound. And Digital featured an information kiosk combining touch screen technology to navigate through and access audio and video information clips on Digital's imaging systems and software products.

How soon will multimedia find its way into document imaging systems? The answer is that it already has. As the early adopters of document imaging systems begin to refine their systems to make them easier-to-use containers of a company's information repository, we expect that multimedia will impact these systems in two ways:

- By providing graphical and navigational tools for interacting with the imaging system
- By providing access to a wide variety of data types that comprise a company's stored information collection

We believe that integration of multimedia into document imaging systems will proceed in tandem with multimedia systems development. And, of course, many of the networking and image compression issues discussed previously in this report will impact the speed with which multimedia will enter the document imaging mainstream.

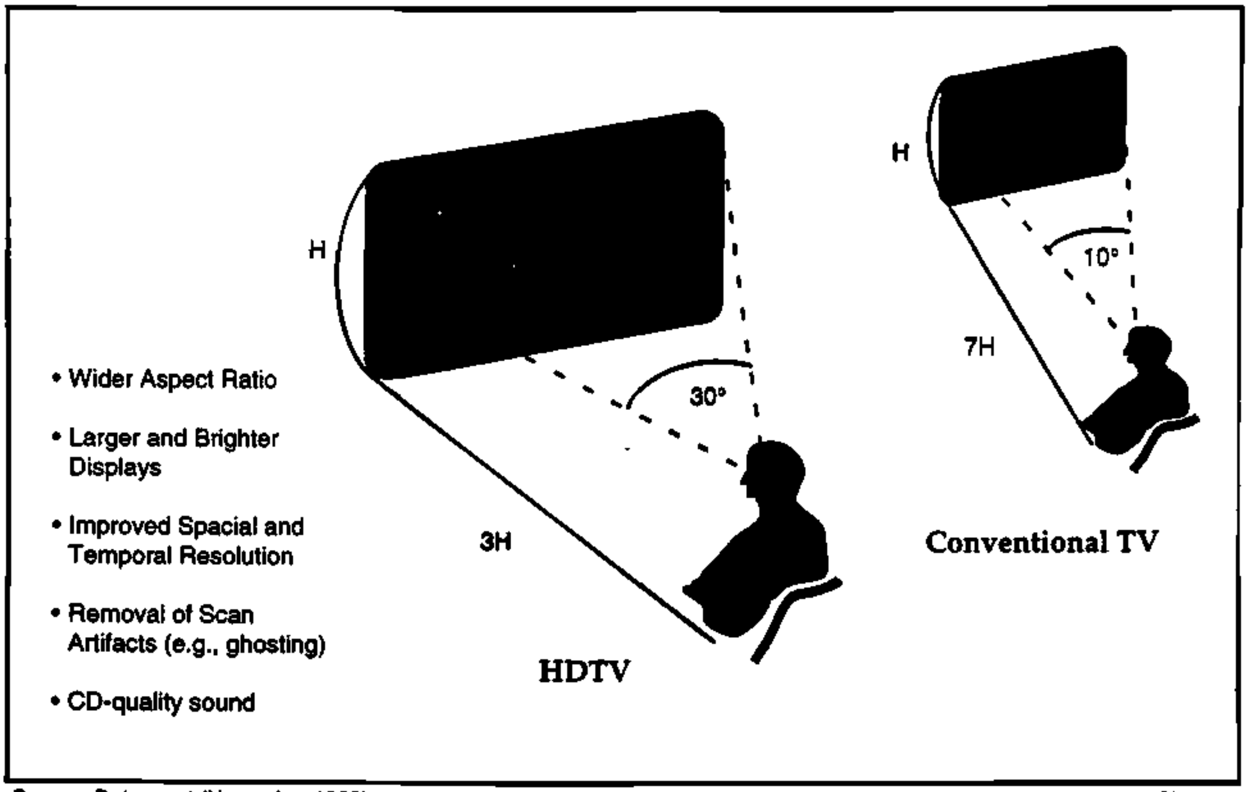
High-Definition Television

Development of high-definition television, or HDTV, began in Japan more than 20 years ago as a means of improving TV image quality above that offered by the specifications set down by the National Television Systems Committee (NTSC standard). To enhance these specifications (then the standard for both United States and Japanese TV manufacturing), HDTV proposed the following (see Figure 8-3):

- A wider aspect ratio (16:9 rather than 4:3) for TV receivers
- Larger and brighter displays
- Better spatial (number of lines on screen) and temporal (frame rate) resolution
- Removal of scan artifacts (for example, ghosting and snow)
- CD-quality audio sound

The result was a massive development effort, estimated at about $1 billion, and spearheaded by the Japanese government, quasi-governmental agencies such as the Ministry of International Trade and Industry (MITI), and Nippon Hoso Kyokai (NHK), the Japan Broadcasting Corporation. This development effort produced an analog broadcast system, designed primarily for Direct Broadcast Satellite

Figure 8-3
Optimum Viewing and Listening Conditions, HDTV versus NTSC Standard



Source: Dataquest (November 1992) G2001814

(DBS) transmission, for reception on TV sets built around the 16:9 aspect ratio, and capable of displaying 1,125 interlaced lines. This system, known as the MUSE (Multiple Sub-Nyquist Sampling Encoding) bandwidth compression scheme for HDTV broadcasting via satellite, was proposed to the United States as the next standard. Due to extreme pressure from both American and European companies, the Federal Communications Commission (FCC) did not immediately accept the proposal, but instead opened a formal "competition" for reviewing all proposals relating to HDTV.

The Europeans, in an attempt to protect their domestic studio and consumer equipment manufacturers, claimed that serious technical problems existed in the down-conversion of 60Hz 1125-line HDTV to 50Hz 625-line PAL and flatly impeded adoption of MUSE. They instead developed and adopted their own competing standard, also based on analog transmission and DBS transmission, which is said to be compatible with future digital standards. This is known as the Multiplexed Analog Component (MAC) and has several variations including HD-MAC and D2-MAC.

In the United States, the HDTV chronology followed a similar pattern. The Advanced Television Systems Committee (ATSC) was formed by five television industry organizations, which approved basic parameters for HDTV production and broadcast standards. In 1988, the Defense Advanced Research Projects Agency (DARPA) offered $30 million in grants for HDTV development and eventually awarded research funding to five companies researching display technologies, including: Newco, Photonics, Projectavision, Raychem, and Texas Instruments; and to three groups including: the David Sarnoff Research Center, Sun Microsystems, and Texas Instruments; Adams Russell Electronics and MIT; and Qualcomm. Since then, HDTV products have been announced by U.S. concerns including General Instruments, the Advanced Television Research Consortium, and Zenith, among others, and research and development efforts continue.

From the consumer perspective, we believe that there is a considerable market opportunity for HDTV in the United States:

- Approximately 160 million TV sets are currently in use in the United States.
- An estimated 52 million homes (60 percent of the total market) subscribe to cable TV
- Approximately 10 million TV sets are sold in the United States each year, and one quarter of these have a screen display 25 inches or larger, verifying the premise that there is a large market for wide-screen television

From a development point of view, opportunities also abound for makers of components including the following:

- Displays including CRTs, LCDs, plasma, and electroluminescent screens
- Receivers and tuners
- Video compression and decompression
- Power supplies
- D/A converters
- CCD linear arrays
- Audio componentry
- DSP chips

Unfortunately, besides the major standards barriers described previously, there are a number of other obstacles that inhibit the growth of this market. These include the following:

- The prohibitively high price of HDTV technology (currently running approximately $9,000 for a 50-inch home HDTV setup, or around $5,000 for a 25-inch system)
- Squabbles for ownership of HDTV transmission rights among broadcast stations, broadcast satellites, cable franchises, and motion picture studios

- The role that the government will play both in terms of subsidizing HDTV development and through FCC endorsement
- Development of alliances and key partnerships among HDTV industry participants

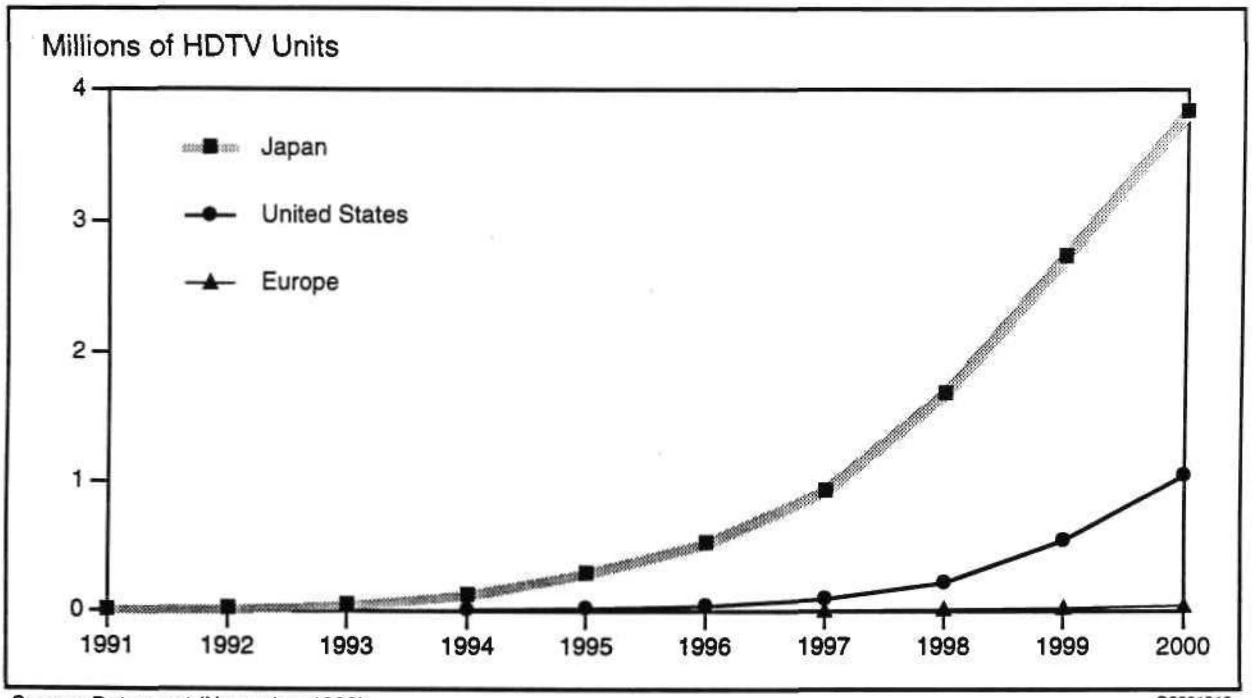
Today finds HDTV standards in a state of fluidity with new proposals coming from every quarter as no system is yet in widespread use. Figure 8-4 presents some tentative forecasts for the growth of this market by geographic segments based on the following assumptions:

- United States—Testing of various HDTV proposals is on schedule, although some broadcasters believe that there will be a 6- to 12-month delay to accommodate new or modified systems. The proposed schedule calls for a complete standard by the second quarter of 1993. The FCC is expected to decide before the middle of 1993 on a single standard, opening the door to a rush market development and competitor alliances.
- Europe—The Europeans propose to have the HD-MAC standard being broadcast by 1997 with the interim D2-MAC standard being used previous to this. The broadcasters do not necessarily support this view, although it is heavily supported by the manufacturers.
- Japan—Today, scores of Japanese companies are involved in HDTV (now called Hi-Vision) research and production. Leading manufacturers include Fujitsu, JVC, Matsushita, NEC, Sharp, and Sony. In addition, a public service corporation called the Hi-Vision Promotion Center was established in 1988 to promote wider use of Hi-Vision technology in industry and by government organizations. The center is sponsored by more than 20 Japanese electronics firms. These sponsors see Hi-Vision largely as a consumer market and are thus working to bring down the costs of the componentry involved with HDTV production and increase awareness of the uses of the technology. NHK is now broadcasting eight hours per day of MUSE using a single channel of a satellite. This is not enough programming to stimulate the market, and it will be 1997 before the BS-4 satellite provides up to eight channels of MUSE broadcasting. The prospect of the more advanced U.S. system leaping ahead of the Japanese system has led to careful examination by the Japanese of switching to digital signal.

The principal limiting factors of HDTV market penetration will be source material availability (programming) and consumer HDTV set costs. With motivated vertical companies like Sony (Columbia Pictures) and Matsushita (MCA) ready to roll, source material creation is not expected to be a problem. On the other hand, costs are expected to limit HDTV penetration, especially until the 16:9 CRT and projection systems become more cost-effective. The cost of an HDTV set in the United States is expected to decline throughout the decade, probably reaching the $1,500 range by the year 2000 (see Figure 8-5).

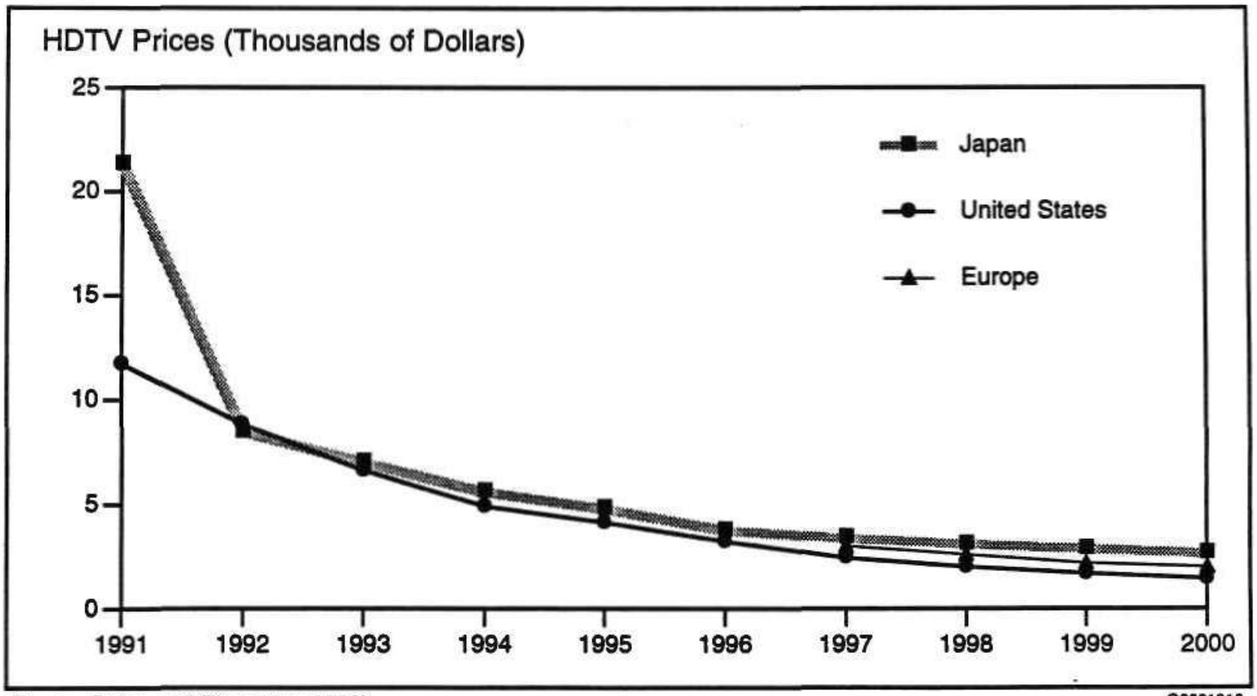
HDTV is not a multimedia technology, per se. We believe, however, that after the dust settles and standards emerge, HDTV research done in the areas of high-resolution displays and high-quality sound will directly impact these components of multimedia computing systems.

Figure 8-4
Worldwide HDTV Adoption through the Year 2000



Source: Dataquest (November 1992)
G2001815

Figure 8-5
Declining HDTV Average Selling Prices



Source: Dataquest (November 1992)
G2001816

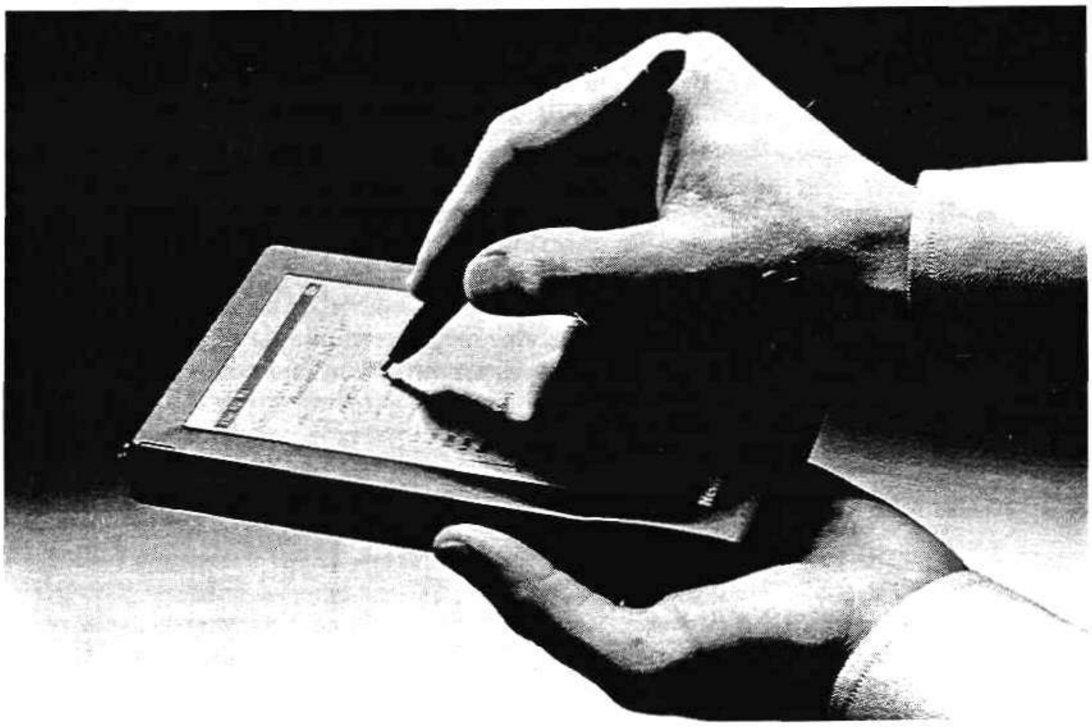
Through our PCs and workstations, we will be able to access not only computer data but also broadcast data. Many of us will have access to "personal new shows" compiled for us on the fly from both textual and video-based news wires and news feeds. PCs will have to be able to provide the audio and video quality we have come to expect as TV consumers. HDTV research will be at the forefront of enabling display and sound technologies for multimedia workstations.

Personal Digital Assistants

At the Consumer Electronics Show (CES) held in Chicago, Illinois in May of this year, Apple Computer provided the world with a first look at a hand-held computer product—the Newton—the likes of which is destined to revolutionize both the world of hand-held computing and the consumer electronics industry.

Visually, Newton can be compared to the communicator used by Captain James T. Kirk in the *Star Trek* series, complete with flip cover (see Figure 8-6). Newton is not that small, but it does fit comfortably in the hand, and a flip cover protects the combination screen/writing surface. Newton is designed to be used with a pen input stylus and incorporates an operating system that is tightly coupled with the hardware to provide an intelligent device. According to Apple, Newton will be available in the first quarter of 1993 and will cost less than $1,000. (Incidentally, Newton gets its name from Sir Isaac Newton who, according to legend, formulated the theory of gravity soon after he was hit on the head by an apple falling from an apple tree.)

Figure 8-6
Apple Computer's Newton Personal Digital Assistant



Source: Apple Computer Inc.

To understand how Newton will work, imagine carrying a roll of calculator paper with you wherever you go. This roll is never-ending and as you write on it, "pieces" can be "torn off" and saved. Newton's software is able to recognize and interpret the writing on the pieces. Alternately, output can become a document that can be faxed or sent to another Newton or computer for transmission to its final destination. The Newton is the first member of a family of such products and it makes use of an infrared link to move information between it and other computers. Future Newtons will likely use alternate forms of communications including wireless (RF) devices that will be either built-in or attachable.

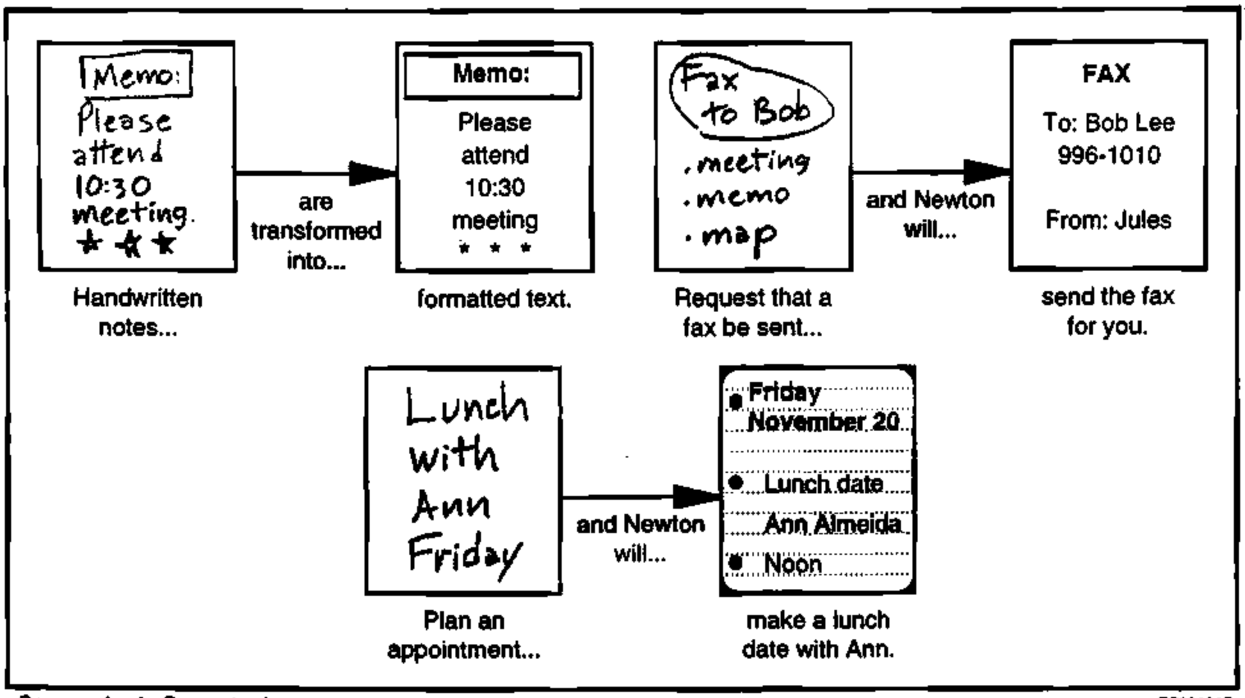
In truth, Newton extends the paradigm that began with the introduction of the HP 95LX from Hewlett-Packard. The HP 95LX has been a success in the market partly because it makes use of a series of applications contained in the basic system and it provides the user with a solutions-oriented hand-held device that includes Personal Information Management (PIM) capabilities. We expect Newton to extend this concept even further.

The real excitement of Newton is in the software. At present, Apple is demonstrating the principles of the operating system and associated hardware using the power of a Macintosh, but we have to believe that the company feels confident it will be able to retain all of the functionality and speed when Newton's tethers are loosed and it runs on its own.

The only word for the operating system is "smart." The writing recognition actions that the machine takes when it recognizes words are almost uncanny. Typical of the actions Apple demonstrated at CES are the following: You write, "Lunch with Andy next Tuesday," on the screen. The text is recognized and, based on Newton's best understanding of the words, it takes actions (see Figure 8-7). In this case, Newton would open the daybook and insert a lunch appointment with Andy on next Tuesday . Newton "knows" the date of next Tuesday, and "assumes" that lunch happens between noon and 1:00 p.m. The only thing that might puzzle Newton is exactly which "Andy" you mean. If there is more than one in your database, you are presented with choices. Selecting the proper "Andy" completes the transaction and your calendar is updated. Write, "Call Linda Tomorrow," and Newton will put this note in your daybook—complete with Linda's number. In this case, you might get multiple numbers: office, home, mobile phone, and fax. However, if you had written, "Fax Linda," the only number that would be showing would be her fax number. Besides the entry, Newton will provide you with a dialing icon so that with a touch of the pen, you can have Newton dial the proper number for you.

The basic, first Newton includes the display/writing screen, a built-in infrared communication link, a PCMCIA compatible slot for PC cards (RAM, ROM, flash, modem and more), and the basic personal information manager functions one would expect in such a device (notepad, scheduling, telephone and address database). It even provides a graphics utility that is "smart" enough to recognize that the

Figure 8-7
Newton's Intelligent Software Acts as a Personal Assistant



Source: Apple Computer Inc.

G2001817

shape you just drew on the screen is a circle, and it replaces your crude attempt with a well-formed and completely round circle.

Newton is being codeveloped with Sharp Electronics, and Apple has authorized its partner to sell their own version of Newton. Apple has further stated that it may, in some cases, license the technology to other vendors. Apple wants Newton to become the pervasive hand-held system during the next few years. By licensing the technology, Apple believes that it can create a bigger market in which to gain market share and also keep others from encroaching on this type of product.

Part of Apple's strategy, it appears, is to use Sharp and several other licensees to meet the initial demand for Newton so they do not lose sales to "non-Newton" hardware. Even if a user buys a licensed Newton clone from Sharp or another vendor, Apple has not lost prospective customers, although, for the most part, non-Newton hardware vendors have. As Newton matures over time, Apple still has the opportunity to convert a user from a non-Apple Newton to an Apple Newton with advances in technology and enhancements to the product. In addition, even if the non-Apple Newton user never buys an Apple Newton, Apple still benefits by collecting licensing and royalty fees.

Apple's game plan, then, must be to get Newton to market when promised (early 1993), and to handle (through licensees such as Sharp) the pent-up demand from those individuals eagerly awaiting the product. Although this type of game plan might be compared to the Sun SPARC licensing idea, we see it very differently. First, Apple has stated that it will only license a "few" companies to build and/or market Newton. Second, the market for the Newton is ten orders of magnitude larger than that for workstation products. Last, Apple knows that some of its licensed partners have far better access to the consumer channel than they do and, therefore, will pave the way for additional Macintosh sales.

The CES event was a look into the not-too-distant future, and it signals the start of the war—not for the desktops of corporate America, but for the pockets and palms of the world. Within weeks of Apple's Newton announcement, Tandy, Casio, and GeoWorks announced plans for a PIM product alliance, and Day Runner and Texas Instruments announced a "cooperative development agreement" to create a similar product. Perhaps the most significant announcement, however, was the news that AT&T Microelectronics and GO Corporation plan to develop a personal communications platform. At the base of this alliance is the coupling of GO's PenPoint mobile operating system and the Hobbit microprocessor from AT&T. In a nutshell, GO has optimized a version of its PenPoint operating system for both the Hobbit architecture and communications applications. AT&T has developed a series of low-powered microprocessors that work with digital signal processors (DSPs) and other technologies required for communications-oriented devices.

While personal digital assistants and today's multimedia computing platforms are currently distant cousins, there are implications to consider. Data generated by PDAs may eventually need to find its way into multimedia systems and could represent yet another data type that multimedia software will have to be able to interpret and integrate. It is also likely that PDAs will eventually incorporate multimedia technology elements including color graphics, the ability to display video images, and the ability to accept and transmit voice and sound. Tiny 2.5-inch (or smaller) CD-ROMs such as those used in Sony's DiskMan could also become a factor in PDA products. Through the integration of CD-ROM technology, the PDA could become not only a traveling organizer and communicator, but also a palm-top reference tool and bookshelf.

Speech Recognition and Synthesis

Ever since Dave's conversations with HAL (and HAL's famous reply, "I'm sorry Dave...") in the film *2001: A Space Odyssey*, the popular imagination has been captivated by the notion of computer speech recognition and synthesis. How wonderful it will be to simply "speak" to your PC and have your words or data fly onto the screen. No more tedious keyboarding. How marvelous it will be when the machine can understand your spoken requests, dip into its data banks, and provide the information you need—in a soothing voice, naturally!—within a few seconds. Gone is the drudgery of research. The computer will become a willing—and almost—human servant.

Well, 2001 is only 9 years away, yet computerized speech recognition remains the most elusive of the emerging technologies described in this section. Development of computer software that can recognize the spoken word is hindered by the fact that human speech patterns are so varied and unpredictable. Recognition systems must contend with regional accents and foreign accents, varied pronunciations and mispronunciations, mumblings and fumblings, pitches and frequencies, and all of the other idiosyncrasies that human speech is heir to. Add to this the issue of vocabulary. Not everybody has the spoken vocabulary of William F. Buckley, but speech recognition systems flounder when they come up against "foreign" words. Three levels of speech recognition are possible: speaker-dependent (system is trained to understand a single individual's speech patterns); speaker-adaptive (system has been trained to recognize common idiosyncrasies of speech); and speaker-independent (system understands anyone). There is also the notion of noncontinuous speech (speaker must pause between each word so that the system can process it) versus continuous speech (speaker talks at normal speaking pace). Naturally, continuous, speaker-independent speech recognition is the most desirable—and the hardest to achieve.

The problem of training systems to understand human speech is being addressed on several research fronts, including: training systems to recognize 1,000 keywords pronounced a variety of ways; wordspotting, a system that recognizes only certain important words in the context of a spoken sentence; neural networking, which teaches itself as it listens; and using a camera to focus on and read the speaker's lips. All in all, it is a very complex technical problem to solve. But it will eventually be cracked because speaker-independent recognition systems will form the basis of very lucrative commercial products.

Scores of researchers and development labs are grappling with the problem of speech recognition and some have offered prototype or commercial products to illustrate what is possible:

- AT&T's Voice Activated Dialer can be trained to respond to up to 62 different names or phrases and automatically dial the appropriate telephone number, providing "hands-free" dialing for its Mobile Cellular Telephone 3030 customers.
- Toshiba is developing a voice synthesis/voice recognition system for taking orders at fast food drive-through restaurants
- MIT has developed a prototype conversational system called Voyager that is capable of interactively answering questions about the local area including sites, hotels, restaurants, and other attractions.
- IBM has prototyped a voice-activated office word processor called Tangora, which understands a vocabulary of 20,000 of the words most frequently found in office correspondences.
- A joint project between Fuji and Xerox is working to develop a Japanese-language speech recognition word processor. This will be particularly useful in Japan because of the difficulty that many people have dealing with entering kanji's 7,000 characters by keyboard.

- Kurzweil Applied Intelligence, Dragon Systems, and IBM, among others, have developed automatic speech recognition systems for handicapped people, especially for hands-impaired individuals.
- Apple recently demonstrated its speaker-independent voice recognition system—code-named Casper—running on a Macintosh Quadra 900 enhanced with a digital signal processor and microphone. Casper has a vocabulary of more than 100,000 words and is able to recognize a wide range of voices through a sampling algorithm that sifts through hundreds of accents, tones, and pitches to interpret the spoken word. Casper will eventually become the voice extension available on Apple products.

Practical applications for speech recognition technologies abound. Consider the following examples:

- Providing live operator assistance and information services for countries where touch-tone telephone penetration is small (for example, only 5 percent of telephones in Spain are touch-tone) is expensive. Telephone companies look to speech recognition as a solution to this problem.
- Speech-to-text products, particularly for people who are keyboard-illiterate or who are involved in "hands-busy, eye-busy" applications, would be very useful in applications ranging from brokerage houses to medicine to manufacturing.
- Security systems that recognize "voice prints" of authorized individuals provide foolproof security.
- Automatic language translation systems that recognize the spoken word will save thousands of laborious human translation hours.
- Voice may well be the next computer interface as voice-activated computers navigate quickly by responding to voice commands.

Speech recognition capability has splintered into high, medium, and low functionality. On the high end (cost $10K to $100K per site) are the telephone company systems with "almost natural" capabilities. These systems are heavily software oriented. Midrange systems include standalone attachments and software that connect to PBXs and other premise equipment ($5K to $10K). These systems are capable of continuous speech as well but they may trade off user independence or vocabulary size. On the low end are the add-in board/software products ($200 to $3K) that offer isolated word, limited vocabulary capability, and require the user to train it. During the next few years we can expect the more sophisticated capabilities to migrate to the lower price points.

Speech synthesis is the other, simpler, side of the coin. Here, voice synthesizers, coupled with software, accomplish the task of translating the computerized word into the spoken word. Today's text-to-speech processors are still somewhat scratchy and harsh, but they at least produce intelligible spoken words. And advances are being made quickly to smooth out the rough edges.

Text-to-speech products have a number of practical applications, particularly for the new breed of mobile professionals that do more work out of a briefcase than out of an office. Text-to-speech systems that translate electronic mail and fax messages to speech are already a boon for helping traveling employees sift through their electronic in-boxes by telephone. Text-to-speech systems are also being used extensively by telephone companies to provide information and directory assistance from dynamic databases. Read-to-me programs for visually-impaired individuals that translate computer information to speech provide another example of how useful this technology can be.

From a multimedia perspective, speech recognition and synthesis are complementary technologies that add further dimensions to the multimedia systems already under development. We believe that speech recognition capabilities will be imbedded in most PCs and workstations by the end of the decade. This will facilitate new ways to navigate through the system's databases and to interact with the computer. Speech synthesis technologies will enable computer systems to respond to our information requests in much more human fashion and pave the way for the talking personal digital assistant.

Wireless Communications

The advance of mobile and wireless communication, both within local area network and wide area network environments, will pose some unique and difficult problems for multimedia computing. All of the problems and market inhibitors mentioned in the "Multimedia Telecommunications" chapter of this report hold true for mobile or wireless communication, with additional issues raised by network addressing, physical interfacing, and network management devices that are not in a continual fixed place. Network managers and designers are already discovering difficulties, for instance, simply designing LANs that support both desktop and mobile laptop or notebook computers. The interface cards from notebook and laptop computers to LANs generally tend to slow signals down from the computers to LANs and conversely can create contention and traffic problems on the LAN itself. The issues of network addressing, LAN segmentation, and routing are made more difficult in a mobile setting.

Most likely, the initial accommodation of mobile systems connected into multimedia settings will be through desktop units that transfer information to and from laptop/notebook computers, which, of their accord, will not have the on-board storage and display capabilities or speed to handle multimedia data.

Another problem of wireless communication in the LAN environment will be one also of bandwidth. Current infrared or radio signal LANs are not as wide in bandwidth as FDDI or even token ring LANs, and there are issues of propagation interference and a compatibility with wire systems. The advantage of broadcast availability using wireless technologies is somewhat offset by the requirement to provide receivers and transmitters at each workstation.

In the wide area network setting, the issue will probably be one of bandwidth. The new wireless, long distance data networks (example, ARDIS) are typically low-speed, low-bandwidth networks designed for remote data entry. As a result, it is hard to believe that wireless networks will spring up with sufficient bandwidth to handle either backbone multimedia networking or workstation to backbone access. It is possible to use satellite networks for backbone networks, but that will be transparent to multimedia telecommunications.

In short, the advantages that wireless communications bring to local area and wide area networking and remote computing are not necessarily advantages to multimedia telecommunications. This is an issue of bandwidth, network design, and requirement for access.

Virtual Reality

Virtual Reality is the name commonly given to a new technology that integrates sensor-based data of human movement with computer models and simulations. To experience virtual reality, the user must don specially-wired, motion sensor-based clothing that can include everything from gloves, goggles, masks, and headsets, to whole body suits. This equipment is attached to a computer system(s) that runs the virtual software and perform the calculations necessary to create and maintain the "virtual world." The virtual system replaces the user's everyday world with a universe that is populated with creatures, creations, flora, and fauna generated entirely by computer. As the user moves about in this virtual space and experiences it through the goggles or mask, the system monitors his movements through the sensors in his gloves or suit, and responds as if he is actually present in and touching his surroundings.

Dr. Thomas Furness, founder and director of the Human Interface Technology (HIT) Laboratory at the University of Washington in Seattle, Washington, is credited with developing the first virtual systems. He says that his research team's early experiences with virtual reality were both exhilarating and frightening. However, his ongoing research in virtual reality over the years has resulted in "a paradigm shift" representing whole new ways not only to use computers, but to experience the universe.

Virtual worlds can be entertaining, practical, or both. On the entertainment side, virtual reality will no doubt give rise to whole new concepts in arcade, competitive, and practice games. Those who enjoy the excitement of playing a combat flight game, for example, can imagine how the challenge and thrill would be amplified by actually entering a cockpit, zooming around in virtual space with alien missiles exploding all around, and fighting back with lasers blasting full, virtual force. On the practical side, virtual flight simulation systems offer pilots valuable cockpit experience without ever leaving the ground, and at a fraction of the cost of going live in a real flight simulator or airplane. Other virtual games allow players to practice and test their skills against competitors of various competencies. These include highly realistic games of virtual tennis, racquetball, golf, football, and ice hockey, for example. Virtual surfing, waterskiing, and snowskiing allow users to hone their skills in these sports without ever getting wet or cold.

On the practical side, virtual software for creative professionals including artists and designers will enable these people to test out ideas before actually "going live." Virtual design software products have applications in just about any field where a product must be conceived and modeled prior to production—from designing automobiles and airplanes to houses and buildings. Virtual software for architects, for example, enables the architect to create virtual spaces, then enter and move about inside of them to see how the buildings look and feel. Virtual design software also provides the new luxury of being able to share a "vision" with a client prior to actually building the structure or product, thereby alleviating any confusion or disappointment about how the final object or space will look.

In the world of medicine as well, virtual reality has important applications. In the future, doctors may be able to take a voyage inside of a patient's body to help diagnose an illness or prepare for a surgical procedure. By combining medical imaging hardware such as ultrasound scanners and magnetic resonance imaging equipment with virtual software and hardware to view and navigate, a physician could explore a patient's interior spaces without even touching him.

The only limit to thinking of applications for virtual reality is one's imagination. However, most applications are just that—imaginings. Most virtual reality research is going on in academic research centers, government labs, and think tanks. Our research indicates that a number of government projects are under way, particularly in the area of flight simulation and training. Japanese electronics firms are also reportedly spending millions of dollars on virtual research. And a handful of companies are involved in developing the hardware gear and software used in virtual systems. Overall, though, the market is quite embryonic, and most U.S. companies are hesitant to jump into a field that is so new and ill-defined.

Given the slow speed with which virtual technologies are emerging, we believe that multimedia computing will eventually have to include additional data types represented by the analog input from virtual reality sensors—but probably not before the end of this decade. From a multimedia point of view, all of the issues related to the storage, manipulation, and communications of complex video, audio, and data types would hold true for integration with virtual reality systems. In fact, they may be even more exacerbated in light of the fact that there are likely to be few standards developed in advance of the market for virtual reality and there will be tremendous conversion and interoperability issues. The immediate problem in the multimedia setting would be the input of signals from the multimedia user back into the system and the integration of that information with multimedia data files and databases. In addition, there would be additional problems simply handling the physical interfaces of the headsets, gloves, and goggles.

For the immediate future, meaning the next six years, virtual reality and multimedia will evolve on separate courses. Only after that, once there is a defined real market for virtual reality, will it become an issue. By then, the widespread use of object technology *may* (as opposed to should) make it a little bit easier to integrate virtual reality into the multimedia mainstream.

The Convergence of the Computer Industry and Consumer Electronics

In the popular imagination, computers and consumer electronics devices are two distinct and very different classes of products. Computers are information tools used in work (and increasingly in home) environments to get a job done. Though some computers are used for playing games, the vast majority of the work we use them for is serious—number crunching, writing and publishing, information distribution, database management, and graphic arts. Consumer electronics equipment, on the other hand, falls into the category of entertainment devices. These are machines like VCRs, compact disc players, and compact disc interactive (CD-I) players that provide movies, music, and games for us to enjoy in our leisure time.

When we look at multimedia computing, however, it becomes clear that many crossover points exist between computer platforms and suppliers, and their counterparts in the world of consumer electronics. We believe that a fair amount of cross-pollination is occurring that will drive multimedia developments on both sides of the spectrum.

For one thing, through a series of deliberate acquisitions and investments, both American and Japanese electronics companies have acquired vast riches of multimedia "content." Matsushita owns Universal (MCA); Sony has invested in Columbia Pictures; Toshiba and IBM have large stakes in Time-Warner. These entertainment and publishing conglomerates own store houses of film, photo, video, music, and text archives—copyrighted resources that provide the raw material (content) for multimedia CD-ROM titles, applications, games, and programs. One of the biggest issues in developing multimedia programming is access to the content needed to create it. These companies have solved that problem by owning the content.

The evolution of CD technology is another example of how consumer electronics has fed advances in computing. Consumers were introduced to the huge storage capacity, superior quality, and multimedia capabilities of optical technology first through laser disks and CDs. The dazzling quality of movies and music delivered through these media was like nothing people had ever experienced at home. Next, Philips introduced CD-I, which combines CD-quality audio and video with interactivity, and delivers it through a medium most consumers can relate to—the TV set. This product has been embraced by the home market for playing info-tainment titles ranging from games to reference and education programs. Now, the move to CD-ROM has begun in the home. Kodak's Photo-CD is a dual-mode CD player that can read and play both Kodak's own Photo-CD disk format as well as standard CD-ROM disks. Besides being offered as a standalone product for home photo enthusiasts, the Photo-CD drive has been incorporated into Apple's new Performa multimedia workstations that are targeted through price, distribution, and configuration directly at the home consumer market. Another newcomer on the scene is Sony's Discman, a pocket-size CD player for tiny 2.5-inch CD-ROM disks. While just recently announced, products such as this may break more ground in the use of miniature CDs for display and even storage of multimedia data on hand-held devices. The bottom line is that many multimedia-capable optical and CD technologies were originally developed for consumer products, but are now migrating to multimedia computing systems.

In addition to CD technologies, multimedia PC manufacturers are also taking advantage of some of the same compression technologies, peripheral technologies (especially high-resolution and color display), and chip and board technologies originally developed for and used in consumer products. From a software perspective, there is already a crossover between the video games and computer games market, with some of the same games that play on both 8-bit and 16-bit video game systems now available for 32-bit IBM and Apple computers. Business applications are being enhanced with multimedia content and interfaces, an embryonic phenomenon that we believe will explode onto the scene during the next three years.

All in all, while it is likely that consumer and computer multimedia systems, applications, and vendors will remain distinct at least in the short term (because of the vastly different distribution channels, the traditionally computer versus consumer electronics-orientation of most players, and the difference in software development customization and installation requirements), it is evident that both will proceed along parallel development paths and feed ideas and product enhancements over the fence to each other throughout the decade. We believe that by the end of the decade, many multimedia consumer and computer products will have merged. It is highly likely that most homes will use multimedia workstations to watch TV, pay bills, order goods and services, make telephone calls and send messages, access information data banks, keep track of appointments, and manage personal information.

Dataquest Perspective

This is a time of enormous flux in the development of computer systems and software. Leading edge research that is considered to be on the fringes of technology today—like virtual reality—will evolve and be productized into commonplace systems during the next decade.

Multimedia will drive the development of certain new technologies, particularly in the areas of video display and compression, audio input and output, workstations, storage, and applications. Many of the emerging technologies discussed in this chapter, however, will evolve along separate paths, but eventually will be folded into multimedia computing systems that will be commonplace on the desktops, in the briefcases, and in the pockets of us all.

Appendix A
Index

A

B

D

G

H

I

J

K

L

M

N

O

Q

R

S

T

U

W

X

Y

Z

Dataquest®
a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Offices in
Costa Mesa, Munich,
Paris, and Seoul

Representative Agencies in
Bangkok, Hong Kong,
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Focus Report

Semiconductor Application Markets *Worldwide*

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Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

List of Figures

List of Tables

Chapter 1
Introduction to Personal Information and Communications Devices

Overview

This report on personal information and communications devices (PICDs) is a collection of *Dataquest Perspective* articles that focus on what promises to be a market with a high growth potential. In an attempt to provide a balanced perspective, we have included articles from the Semiconductor Application Markets and the Personal Computers groups.

Definition: PICDs

PICDs (pronounced PicDees) describe small form factor personal computers that rely heavily on communication and use a pen-centric operating system and a pen as the primary input device. PICDs are meant to be portable and self-sufficient for extended periods.

Introduction

PICDs—What Are They?

There appears to be no consensus for a name that properly describes future small-size portable PCs: Apple calls such devices PDAs (personal digital assistants) and AT&T calls them personal communicators. Of course, other names—palmtop, subnotebook, and companion—all more or less describe similar products. Both Apple and AT&T are attempting to describe a new device that, even though it is an evolutionary computer product, may in fact combine into one appliance the capabilities now found in our telephone, fax, PC, and daytimer. It is envisioned that products with all or part of these capabilities will appeal to both mobile professionals as well as consumers who thus far have not really embraced PCs.

The Roots

Thanks to advances in semiconductor technology, we have shrunk the desktop PC down to a size that fits in our palm. A product from Hewlett-Packard, the HP 95LX, is a good example of a PICD. It operates on two AA-size batteries, runs DOS and Lotus 1-2-3 (both embedded), and has 1MB of main memory. It is a significant achievement, even though most likely it will seem ancient history in 10 years' time. Until now we have used our computers to "compute"—that is, they calculate things for us and thus can be considered "overgrown calculators." Sociologists, however, tell us that the need to calculate is secondary for humans; the need to communicate is undeniably more necessary. So why all this fuss with the overgrown calculators? For one thing, computers help us do much more than calculate. They help us communicate, they manage our information, and to some extent they entertain us. Common to both Apple's and AT&T's vision is the need to easily manage information and communication.

Chapters 1 through 5 of this report will describe overall portable computing needs and discuss Apple's Newton, GO's operating system, and the recent AT&T-GO alliance. Chapters 6 through 10 present a portable computer forecast, a discussion of the elements that make up today's hand-held PC, and future trends in MPUs, storage, and communication.

Project analysts: Nicolas Samaras
Andrew Seybold

Chapter 2
Portable Computing Today

Present standards in portable computers include the full-function notebook systems, soon-to-be released subnotebook (companion) PCs, hand-held DOS-compatible systems such as the HP 95LX, and hand-held organizers.

Each form factor will soon be available with either keyboard input (as they are now) or pen-based input devices. Each will continue to be important, but it is the movement toward sub-$1,000 hand-held machines that will enjoy the fastest growth over the next few years. This product group is where many innovations and new designs will be found. Until mid-1993, pen-based systems will be implemented by large companies and organizations in vertical markets with little or no retail sales of a horizontal nature available for start-up companies. It is important to note that the end-user community will view this area of subnotebook and hand-held computers not so much as computers but more as appliances.

The Need for Communication

As the trend evolves for smaller and lighter portable computers, the one shortfall hindering acceptance of these systems is in the area of communication. Notebook computers became popular after the capabilities of desktop systems were incorporated: an Intel 386SX processor, VGA compatibility, backlit screens, large hard disks, and better battery life.

One reason for the fast market growth of fully functional notebook systems is that a user can now duplicate the desktop on a notebook (operating system, applications, and file storage). This is a mandatory requirement because there is a lack of easy-to-use communications links among the worlds of portable computers, desktops, and networked systems. Moving data between platforms using a product such as Traveling Software's LapLink is not easily accomplished by a computer nonexpert. Programs such as LapLink assume that the user knows exactly which files need to be moved, where they are located on the desktop system, and where they should be located on the portable. Once moved, data need to be translated to the format of the receiving application. This usually requires reformatting. Further, when applications are moved from one platform to another, video drivers sometimes need to be changed and parameters for communications and printing need to be reset.

Subnotebooks

Many hardware vendors are designing subnotebook or companion PC products that will soon come to market. These units will have a smaller form factor, and for the most part will not include an internal floppy drive. Some will follow the Phoenix Technology reference model and, at first, be based upon CPUs with less power than the Intel 386-based notebooks.

Other vendors, however, will move directly to this form factor with a 386-based system, again, with no internal floppy drive. Instead, these machines will rely on communications links to transfer data to and from remote computing platforms. This will be accomplished by way of wired modem, infrared, and soon, RF communications links.

We believe that these links will be a viable form of communication, but they will represent no more than a transport layer for the data that must be moved across them. For the most part, we have seen no real evidence to date that software companies really understand the requirement for true ease of use in data communication for this class (subnotebook and smaller) of computers. End users will not tolerate the arcane data transfer software applications now available, nor will they tolerate having to know which programs and files need to be moved from one system to another.

On-board operating systems and applications will be used extensively in these recipient machines. The Phoenix-Lotus model will become a standard, but many such machines will rely instead on MS-DOS 5.0 and Windows 3.1 in ROM for their operating environment. Additional applications will either be part of this on-board suite of programs or will be available to the user by way of Personal Computer Memory Card International Association (PCMCIA) cards. And here again, the built-in communications links we have seen do not address ease-of-use issues. They will not be easier for end users to figure out and make work. Consequently, acceptance of such units will be delayed until these communications issues are appropriately addressed.

Hand-Held Computers

In response to the demand for ubiquitous, carry-everywhere computers, we will see a large number of diverse entries during the course of the next two or three years.

The first "true" entrant into the hand-held market was the HP 95LX. This machine has been successful for HP not just because it is DOS-compatible; it is a financial modeling tool first, a personal information manager (PIM) second, and a DOS-compatible system last. However, even more important than DOS compatibility is its ability to move data from the hand-held platform to the desktop and back again. Fully 75 percent of all HP 95LX systems are connected to desktop systems at one time or another. Other units, such as the Sharp Wizard, Casio Boss, and PSION hand-helds that are not DOS-compatible have also been successful, but many have ended up in a desk drawer after a few months of attempted use. These machines only partially meet the requirements of the mobile computerist. Until recently, moving data between these hand-helds and the desktops has been a difficult operation.

The Next-Generation Hand-Held Systems

The industry is on the verge of a major change in how it views hand-held computing. Many vendors have discovered that being DOS-compatible is not an important selling point in the hand-held world. What is important is the ability to move data quickly and easily back and forth between the hand-held platform and the desktop world.

Recognition of the relative importance of communication as compared to DOS compatibility has led to many new designs, some based on pen input and some still making use of a keyboard for data entry. We expect to see announcements of many other new technologies within the next six months. The resulting products will forever change end-user expectations of hand-held computing.

As one example, Apple announced a technology concept at Consumer Electronics Show (CES) in Chicago on May 31 that we believe will change the perception of hand-held computing for all time. The new hand-held, called Newton, is a total departure from what we have known in the world of hand-held computers (see Chapter 3) This unit is the first of what is supposed to be a series of products that include a built-in infrared communications link. This link is being designed to permit instantaneous and easy communication not only between like units, but also between Newton and both Intel and Macintosh desktop systems.

One feature is the ability to transmit and receive business cards from one Newton to another with a single keystroke. Other communications features include the use of in and out boxes for storing items to be sent and received once connection is established. This connection, which is made automatically once a Newton comes into the range of an infrared transmitter/receiver, will then intelligently handle all communication into and out of the unit with no additional end-user intervention required. It is our belief that the first communications links built into Newton will not be as easy for the user community to operate. Products of this ilk have begun to use in and out boxes for remote communication, but all we have seen so far still require the end user to format the document for the type of output: fax, word, or e-mail, among others. Wide acceptance of this type of unit will only occur once remote communications links are automatic and can take care of document and file formatting. The end user will not have to be concerned with it.

Formatting, merging, and reconciliation should be able to be preconfigured by the end user in the second generation of these products. The user should also be able to change the configuration simply by selecting from menus. An example of this type of preconfiguration might be as follows: The end user purchases a hand-held machine from Dell Computer. The system installed on the desk will be an Intel-based processor system running Windows 3.1, Excel, Word for

Windows, and PackRat, and will be connected to a LAN running CC:Mail. The network will have a fax server installed, as well as several different HP and PostScript-compatible printers. The end user will turn on the hand-held device and select setup (most software is already installed in ROM and the balance is available through PCMCIA cards). The Menu Selector will ask the user to indicate the types of programs and/or devices with which the companion unit will communicate. The user selects Excel, Word, CC:Mail, MCI Mail, and several printers from the menu, chooses the type of connection to be used most of the time (infrared, wireless, or direct connect) and then will move to the record and field mapping section of the setup. Here the user will spend only a few minutes determining which fields used in the local applications will map to which fields on the desktop and network systems. Once this is done, the information is stored and may be updated at any time either in sections or completely.

As part of the setup, the user may also choose to invoke "filters" for the data to be automatically received. These filters might include the types of e-mail to be downloaded (priority, or from whom, among others). It will be possible for the user to receive a listing of all mail and documents waiting on the system and then to point and click on the ones to download. Upon connecting to the desktop system, the two systems will "talk" to each other, exchanging the data placed in the in and out baskets of each. Messages received can then be reviewed and answered without having to close the message and open a word processor.

Calendar, To-Do, and Phone Messages

The premise of these systems is that once information has been entered, it never needs to be recorded again. If a secretary enters a new appointment and several phone messages in a desktop-based calendar, they are then placed in the out box, waiting for the portable device to connect to the system.

Once the portable system is connected to the "base station" (a term we will use for desktop PCs and/or networks—each portable will be assumed to have a main base station but be connectable to any number of substations by any number of different means), information will be automatically transferred to the portable system and information stored in the portable will be sent to the base station as well. The system should be user-selectable to provide the following features when a connection is made:

- Place the new information in the proper format in the proper file (appointments in the calendar, phone messages in the to-do list, among others, checking for duplications and overlaps in the process)
- Build an "incoming review file" from all of the sources

This review file would be used as follows: The user could open this file and read through the new incoming information, review each entry (or make mental note of it), and then choose to have it stored in the appropriate section of the portable, answer it, or take some other action as it is being reviewed. We believe that this type of "new" file is important in this environment because in a truly automatic transfer of multiple kinds of data, a user might not be aware of new information that has been sent. If, as in most systems we have seen, the data are merely placed into the calendar or to-do list with no notification, it is possible that it will be missed by a user that does not take the time to review all of the files each time input is downloaded. Fully automatic data transfer is important, but we believe that notification and review are equally as important. Such a feature would also be valuable for use in the one-way paging marketplace.

We have been working with the Motorola EMBARC paging system for the past few months. One shortcoming of this system is that the user has to download a new appointment transmitted to the pager and then move it to the proper area for storage. Automating this process so that the end user receives notification of the incoming message, reviews it for content, and then, with only a single keystroke or pen motion, stores it in the appropriate place for future reference would be a major enhancement.

"Act-Upon" Software

One requirement for mobile computer systems will be the ability to create, edit, mark up, and otherwise work with diverse types of information. Such categories are calendar, to-do, phone, fax, word processor, spreadsheet, and database.

The idea of act-upon software is that each type of document or file can be created in the portable computer, and then sent to the base station for final formatting and distribution action, instead of having to burden the portable with formatting, reformatting, and storing multiple copies of a single document (for example, a letter that is to be faxed to one person, sent via MCI mail to another, printed and mailed to yet another, and stored in the native format of the base station's word processor). Act-upon software provides a way to encapsulate a document within a folder. The folder would contain the formatting information, destinations, and other information required to remotely handle the document. In this case, documents would be stored in machine-native format in the portable (suggesting also compression techniques that could be employed for memory savings). The portable user would be able to prepare a file or document for transmission by simply instructing the system to "attach" one or more headers to the document that, upon receipt by the base station, would then command the base station to format and send one or more copies of the file to one or more locations by one or more methods.

The advantages of these transmission features become obvious. Because the system does not have to transmit information in formatted form, it provides a faster transmission capability. If new formatting requirements are needed, it is only necessary to add the formatting capabilities to the header files. If a document is to be formatted in a number of different ways, it is only necessary to send the information once, accompanied by multiple headers. Address books could then be built that would identify each person and the way they can be reached. For a memo to be sent to several people, it will be possible to look up the person and attach a formatting header to the document based on the information stored in that person's file (there could be multiple ways to reach the same person, which could lend itself to automatic follow-up file transmissions—send this by fax to John Q. Public and then confirm the fax transmission by mail, among others).

The Future

It is assumed that by year-end 1992 several new hand-held computers will be available from major manufacturers with capabilities that exceed the HP 95LX in communications and personal information management. These systems will have a mix of pen and keyboard user interfaces and will include software such as is described in "The Age of Appliance Computing," by Gerry Purdy of Phoenix Technologies Ltd. (*The Outlook*, Vol. 10, No. 9) and other similar designs. Communication will be limited to RS-232 serial cables, pagers, and infrared. The hand-held PIM software will be fairly unsophisticated. Pen-based computing will be limited to pilot programs in large corporations. Hand-held computer mass storage will be limited by cost.

It is assumed that more hand-held computers will emerge with 386SX chips and more sophisticated PIM software in 1993. The new PIM software will be aware that communications applications need to be notified of changes to the data. Pen-based applications will begin to proliferate. Two-way mobile radio will become one communications option, although still expensive. Hand-held computer storage will become less of a limitation because of lower cost. In 1994, hand-held computers should be fast and cheap enough that many processing and storage options will be affordable. Hand-held PIMs will be powerful and easy to use, and will cooperate with communications applications. Limitations will be screen size and keyboard usability. Pen-based applications will be quite usable. Two-way mobile radio will become reasonably priced.

Hand-Held Computer Vendor Dependencies

One trend we see unfolding, especially with the advent of the personal digital assistants such as Newton, is that operating systems, CPUs, and applications programs will not necessarily be compatible as we move forward. If data that arrive in the proper format can be received and sent among various platforms, then compatibility becomes a nonissue. Vendors of the software in hand-held computers must develop their PIM software with facilities to share data with communications/translation applications developers so that translators and formatters will be written to move data seamlessly between diverse platforms.

Several vendors have already taken steps to provide this type of "smart" communications links. Contact Software ACT has desktop software for both the Intel and Macintosh desktop systems. It offers a separate HP 95LX version that includes data integration and a Zap-cards wireless business card exchange feature.

Goldmine, an advanced contact management software product from Elan, includes filters and import/export routines, not only to permit data to be moved intelligently to and from portables, but also to allow users to import data that already exist in another desktop software program. Traveling Software, LapLink Pro, and LapLink Mac are also moving in the proper direction. These products at present permit a user to not only move files but also to compare files between systems and then move the latest version to both systems. LapLink also provides interconnection capabilities that include direct connection and modem sessions. Adding the capability to communicate via wireless will not be a difficult task.

IntelliLink is perhaps the company—and the product—that is the farthest along. It routinely handles data translation on the fly, reconciliation, and merging. Its present product includes the communications links between the desktop and the hand-held world, but it has designed its product so that the intelligent data transfer portion can be separated from its own transport layer, giving it the advantage of being able to easily move the "smarts" of its program to any and all types of data transmission methods.

Conclusions

The good news is that the industry is beginning to recognize the need not only to move data, but to move information in an intelligent manner. The bad news is that we are still a long way from having the tools available that will make the end-user community flock to the small hardware devices that will become so pervasive, and useful, over time.

We have established the need, and end users are willing to spend the dollars. It is now time for the industry to respond with products that work.

Chapter 3
Apple's Newton

At CES, Apple provided the world with its first look at a hand-held computer product that we believe will revolutionize both hand-held computing and the consumer electronics industry.

This specific device in and of itself may not have this effect (although it could), but this class of device, with this genre of "smart" operating systems, will. The Apple product, Newton, is (will be) a hand-held device with pen input. A demonstration to analysts prior to CES focused more on the operating system than the hardware device, and what was shown at CES was not a standalone Newton, but rather a Newton that used a Macintosh as its "mother ship" to demonstrate the principles used in the conception and design of the product. Apple's preannouncement of this product, expected to be delivered sometime in early 1993 and priced at less than $1,000, has enough sizzle to get even the most staid computerist excited. Further, in keeping with the Apple tradition, it also delivers sizzle to the noncomputer user. In short, when Newton arrives next year, it will appeal to a wide audience.

Newton: What Is It?

Visually, Newton can be compared to the communicator used by Captain James Kirk on "Star Trek," complete with flip cover. Newton is not that small, but it does fit comfortably in the hand and the flip cover protects the combination screen/writing surface. Newton is designed to be used with a pen input device and incorporates an operating system that is tightly coupled to the hardware to provide an intelligent device.

To understand how Newton will work, we use the metaphor of carrying a roll of calculator paper with you wherever you go. This roll is never-ending and as you use it, "pieces" can be torn off and saved. The built-in programs can recognize and use the writing on the pieces. Alternatively, output can become a document that can be faxed or sent to another Newton or computer for transmission to its destination. The Newton is the first of a family of products; it makes use of an infrared link to move information between it and other computers. Future Newtons will likely use alternate forms of communication, including wireless (RF) devices that will be either built-in or attachable.

The Hardware

Newton's design around the ARM RISC chip itself is a departure of magnitude. It does not make use of a Motorola processor, as does the Apple Macintosh line of products, nor does it use either an Intel processor or an Intel-compatible CPU, as many popular systems do.

In truth, Newton extends the paradigm that began with the introduction of the HP 95LX. Yes, the HP 95LX is based on an Intel-compatible CPU, but this is not the main reason the product has met with great success. Rather, it is successful because it makes use of a series of applications contained in the basic system, and it provides the user with a solutions-oriented hand-held device that includes PIM capabilities. And, by the way, it is Intel- and DOS-compatible. Apple has realized that a hand-held device of this type will be attractive to users regardless of their desktop computer preference. Even those that may not use computers or are intimidated by them will be interested in this hand-held. Newton is a truly revolutionary and, in our opinion, intriguing product. The Newton design team was not hindered by having to give consideration to backward compatibility or any other limiting design considerations that might have resulted in a less than spectacular product.

It is hard not to get excited about Newton. Even though it is not "real," and even though we will have to wait for it, the concept and the marriage of hardware and software into a product such as Newton gets one's imagination going. Even if Apple's product never came to market (which is not the case), the vision behind it would have changed the expectations of hand-held computer users forever. We believe that Newton will become a "real" product under Apple's watchful eye and that it will appeal to the masses—not just the computer masses, but the masses in general.

The Software

The real excitement is in the software. At present, Apple is demonstrating the principles of the operating system and associated hardware using the power of a Macintosh. But we have to believe that Apple is confident that it will be able to retain all of the functionality and speed when Newton's tethers are loosed and it runs on its own.

The only word for the operating system is "smart." We have seen writing recognition demonstrated and have tried it. Newton is good and fast, and the action it takes when it recognizes words is almost uncanny. Typical of the actions Apple demonstrated at CES are the following: "Lunch with Isaac next Tuesday" is written on the screen. The text is recognized and Newton takes action based on its best understanding of the words. In this case, Newton would open the daybook and insert a lunch appointment with Isaac next Tuesday. Newton "knows" next Tuesday's date and "assumes" that lunch happens between noon and 1:00 p.m. The only thing that might puzzle Newton is exactly which Isaac is meant. If there is more than one in the database, choices are presented. Selecting the proper Isaac completes the transaction, and the calendar is updated. Write "call Isaac tomorrow," and Newton will put this note in your daybook—complete with Isaac's number(s). In this case, multiple numbers may be offered: office, home, mobile phone, and fax. However, if "fax Isaac" is written, the only number shown would be his fax number. Besides the entry, Newton will provide a dialing icon so that a touch of the pen can have Newton dial the proper number.

The Newton System

The basic, first Newton includes the display/writing screen, a built-in infrared communications link, a PCMCIA-compatible slot for PC cards (RAM, ROM, flash, modem, and more), and the basic PIM functions one would expect in such a device (notepad, scheduling, telephone, and address database). It even provides a graphics utility that is smart enough to recognize and replace crudely drawn circles on the screen with well formed and completely round circles.

This tight coupling of the operating system, a handful of small applications, and the hardware makes this product sizzle. The design team at Apple (or now Apple PIE) has come up with a winning combination of hardware and software. Its PDA term indicates that it understands that Newton is not simply a computer, it is a true appliance that can be used by anyone, either as a standalone device or in conjunction with existing computers. CES was a look into the not-too-distant future, and it signals the start of the war—not for the desktops of the world, but for the pockets and palms of the world.

The repercussion of unveiling the product concept at this time is that it will hurry along companies developing similar products. Several companies are rumored to be developing products that will use the AT&T "Hobbit" RISC processor, and some will use Intel or Intel-compatible processors. Several companies that were fairly far along in their own next-generation version of the HP 95LX have scrapped their current prototypes and design criteria and are starting anew, this time targeting Newton as their competition. Others are sticking to their guns and working on implementations of their own vision of hand-held computers, believing (and rightfully so) that the large market potential for these products will support not only multiple designs, but multiple paradigms as well.

Newton is being codeveloped with Sharp Electronics, which will be able to sell its own version. Apple has stated that it may, in some cases, license the technology to other vendors. Its motivation is for Newton to become the pervasive hand-held system over the next few years. By licensing the technology, Apple believes that it can create a bigger market in which to gain market share, and it can also keep others from encroaching on this type of product. It is not clear exactly how Apple will license this technology, or even exactly what it will license. We know only of its stated desire to do so.

Can Newton and/or Newton derivatives become the largest selling of the hand-held systems? Maybe, but, like everyone else, Apple is not working in a vacuum. Because it has preannounced its concepts and even demonstrated its smart operating system, it may be setting itself up for more, stiffer competition than it realizes. Apple is not alone in developing smart hand-held devices. We have heard about a number of these devices that either are on about the same schedule as Newton, somewhat ahead of Newton, or will be ready within a few months. The market, however, is large enough to provide a number of vendors with opportunities in the range of millions of units per year. Although a million sales of sub-$1,000 units may not be as profitable on a per-unit basis as 100,000 more expensive units, the volume possible with these products in itself will provide greater overall profit for each model. Obviously, Apple believes that Newton is unique and is so far ahead of the competition that it was not at RISC (pun intended) with this early announcement of the product.

From what we have seen, this may not be the case. Further, now that there is a known target looming on the horizon, other vendors may jump on the bandwagon and try to have their products available during the same period. Newton is a model to follow, imitate, and improve upon. Newton and its licensees may not have quite the open field they believe they will have. Part of Apple's strategy, it appears to us, is to use Sharp and several other licensees to meet the initial demand for Newton so it does not lose sales to non-Newton hardware. Even if a user buys a licensed Newton clone from Sharp or another vendor, Apple has not lost prospective customers, although, for the most part, non-Newton hardware vendors have. As Newton matures, Apple still will have the opportunity to convert a user from a non-Apple Newton to an Apple Newton with advances in technology and enhancements to the product. In addition, even if the non-Apple Newton user never buys an Apple Newton, Apple still benefits by collecting licensing and royalty fees.

Apple's game plan, then, must be to get Newton to market when promised (early 1993), and to handle (through licensees such as Sharp) the pent-up demand from those eagerly awaiting the product. Although this type of game plan might be compared to the SunSPARC licensing idea, we see it differently. First, Apple has stated that it will only license a "few" companies to build and/or market Newton. Second, the market for the Newton is 10 orders of magnitude larger than that for workstation products. Last, Apple knows that some of its licensed partners have far better access to the consumer channel than it does and therefore will pave the way for additional Macintosh sales.

Macintosh Sales?

As stated earlier, Newton will appeal both to existing computer users and to noncomputer users. Over time, the noncomputer user will be compelled to have a base station available for his or her Newton so that it can provide services not available using a standalone Newton without connectivity. Even when the wireless models become available, the user will not be able to take advantage of some of the true power of the system without a base station or home port for the Newton.

The standalone user will soon come to realize that Newton really shines when teamed with a base station. This will provide opportunities for many different types of vendors: e-mail providers, communications providers, and desktop and portable computer vendors. A noncomputer user of a Newton, having mastered it and now ready to move into a connected world, makes a real (and much less expensive to find) Macintosh prospect. If the communications links are well established, the Macintosh will be the logical choice of the consumer that is soon to become a computer owner.

Missing "Links"

Missing are the links between the Newton and the rest of the world. In Newton, Apple has created a device that will work well in a standalone environment, but it will be more powerful and usable in conjunction with a base station or mother ship.

Without an umbilical cord of some kind (wired, infrared, or wireless), Newton at best is a much improved Sharp Wizard or Casio Boss. It provides the same functions as these and other electronic daybooks, and it goes a little further with its built-in dialing feature. It will be more fun and easier to use than a Wizard, and it will also be more expensive. When connected to the outside world, Newton becomes something much greater than the sum of the parts. Outside world connections give Newton availability to services it cannot provide on its own, provides reams of information it is not capable of storing all at once, and enables it to become a much more powerful work tool.

This electronic umbilical cord is both the strongest and the weakest link in the Newton chain. If the software running over this link is properly planned and implemented, the value of Newton rises substantially. However, if the state of the communications software art does not move ahead rapidly, Newton will be little more than a flash in the pan, ready to be replaced by any one of a score of new integrated hardware and software devices that may handle the communications issues in a better way. It is too early to tell if the design team and the rest of Apple really understands how dependent Newton will be on communication and how important it is to the success of the product. As we get more and more information from Apple over the next nine months, we will find out exactly how important systems integration is to the father of Newton, and how much it really understands. Although Apple has indicated that it realizes that communication is a key element in the PDA strategy, it has not yet been willing to discuss ideas and/or plans. Several companies are known to be working with Apple in this regard, with communications products planned for introduction shortly after Newton is available for sale early next year.

Sales Projections

According to a number of different sources, Apple's first Newton is expected to sell from 200,000 units to more than 1 million units in the first year. Apple has not commented on the figures nor has it indicated how involved its partner, Sharp Electronics, will be with the

Apple version of the product versus its own offering. Inconsistent sales projections across the various industry organizations have more to do with individual perceptions of the value of PDA-type products within the end-user community than any other factor.

The most bullish estimate comes from SRI International, while the most conservative estimates are from companies that generally watch the workstation and PC desktop markets and have little if any experience in consumer electronics areas. Further, without any real experience with this type of product, it is not possible to predict how successful it will be, and the demographics of the user community are difficult to determine. The two final issues that cloud the sales forecasts have to do with plant capacities and available communications interfaces.

It is safe to say that Apple and its partners will do well with this first PDA offering. However, they will not run away with the market, nor will they succeed in their stated objective of Newt (the Newton operating system) becoming the pervasive hand-held OS. There are too many highly qualified and highly skilled competitors lurking around the world and too many different approaches to solving the end users' problems and meeting their needs. Apple announced first, but another vendor may actually ship first. In either event, the size of the hand-held organizer/PDA/hand-held computer market is large enough to support many different players and offer the end-user community many choices. Newton has sizzle, it is functional, and it answers the needs of millions of people who want to be better organized no matter where they are, but it is not yet available. Between now and when Newton will be available, another product with more sizzle and more functionality could be introduced or, playing Apple's own game, shown well before it is ready to be brought to market.

Apple has captured everyone's imagination. Now it needs to produce Newton to capture pocketbooks as well. In the meantime, we too are captivated by Newton's promise. We see a hundred ways in which it could help make our lives easier each day. The concept is brilliant, it sizzles, and it is inventive. We trust Apple and look forward to it being able to deliver on its promise. If it cannot deliver, or if the PDA is delayed for any length of time, Apple's image will become tarnished, and the blow to its credibility will be difficult to overcome. It may not have bet the farm on Newton, but Apple has certainly bet John Sculley's reputation and ability to lead the rest of the computer industry into the age of consumer computing.

Newton: The Name

The name Newton is singularly appropriate because of Sir Isaac's involvement with an apple. He formulated the theory of gravity after an apple fell from a tree onto his head.

It is possible that today's Newton, or this family of products, will influence the industry to develop a new form of computing that is not computing at all but the adaptation of computing devices for the masses. Newton may hit the computer industry over the head just as the apple did Sir Isaac!

Chapter 4
Here Comes GO: PenPoint 1.0 Is Now Available

Pen-based computing has finally arrived! Or at least that is what the folks at GO Corporation would like us to believe. GO announced the availability of PenPoint 1.0 in April, its operating system for pen-based computer systems.

Just a week earlier, at COMDEX/Spring, Microsoft was on the floor with Windows for Pens, and GRiD, CIC, and Momenta have all had pen operating systems on the market for some time. So why is GO's announcement considered to be the "true" start of pen-based computing?

First of all, GO's operating system has been designed from the ground up with the aim of being more than just pen-aware. It is fully designed to specifically take advantage of the pen as an input device. In addition, it has been hyped by the independent software vendor (ISV) community and the press as being one of two major operating systems that will become pervasive in the world of pen computing. (Microsoft's Windows for Pens is the other.) And finally, the GO announcement marks the beginning of the battle for the pen user.

The end-user community has been waiting for GO's offering (as well as Microsoft's) in order to see the differences between the two systems and how ISVs will provide software for these platforms.

Hardware and software vendors have been waiting for GO's PenPoint 1.0 to begin shipping because once it becomes available, these vendors can start shipping their products in volume. Additionally, these vendors have been waiting for PenPoint 1.0 to launch so that they can ship products that take full advantage of the pen, not just products that show its promise.

Pen-Based Computing: The Elements

This is the first time in the history of computing that all of the elements needed to create a computing environment—the hardware, the operating system, and the applications—have come together at the same time. It is also the first time in history when an operating system is pushing for state-of-the-art hardware.

GO's development efforts started in 1988, well before today's powerful CPUs were available. During the last four years, the improvements and enhancements that have been made to GO's first operating system model have been possible because of the increased speed and performance of the processors, and because of the increase in the amount of memory available in a system and the decrease in its cost. PenPoint 1.0 has been optimized for the world of 32-bit processors. It is a preemptive multitasking, general-purpose operating system uniquely suited for pen computing.

The preemptive multitasking abilities built into PenPoint are important: They let users' work take priority, even while background tasks such as handwriting recognition and communications are in process.

The system uses virtual memory that enables the system to make use of a hard disk as an extension of RAM, permitting more applications and larger documents to be open at the same time. This gives users the ability to switch between tasks more quickly.

Help for users is provided in three different ways: context-sensitive help, a help notebook, and quick-start tutorials. To use context-sensitive help the user needs only to draw a question mark on the item. The help notebook provides more complete topic-based help information, and the quick-start tutorials permit users to become conversant with the system in only a few minutes—typically 10 minutes or less.

PenPoint 1.0 Features

Handwriting Recognition

GO's handwriting recognition engine, GOWrite, includes features that GO claims permit excellent "walk-up" accuracy (no training or practice), robust recognition, tolerance for sloppiness and sharp handwriting variation, trainability, and broad coverage. GOWrite recognizes more than 25 punctuation characters and a wide variety of writing styles by using a database of more than 700,000 handwriting and gesturing samples.

Look and Feel

The first view of PenPoint is a Table of Contents page, with tabs along the side and some small icons at the bottom. The entire metaphor of the system is unlike any other type of desktop computing environment in widespread use. An application is never launched, and documents are not loaded on top of the application. In PenPoint, the applications are resident, but not visible. Instead there are pages in a notebook, with each page created by the application that controls it.

Easy to Learn

Learning to use PenPoint is easy. There are only a few basic gestures that users need to learn. Once users learn those gestures, they can move freely around within the system, doing productive work and learning more about gestures and movements as they proceed.

Compatibility

PenPoint can read and write MS-DOS-formatted disks directly and can import and export many standard file formats such as RTF and TIFF. Support is also provided for Novell NetWare, AppleTalk, and native TCP/IP. In addition, several software vendors have designed and are shipping other communications-related products.

Product Specifications

The present version of PenPoint 1.0 is designed for the Intel 386 family of microprocessors, but future PenPoint versions will run on other processor types. We expect to see some very powerful RISC-based systems become available before too long.

Two applications are shipped with the OS: MiniText and MiniNote. MiniText is a simple text-editing and word processing application, and MiniNote is a basic note-taking application that permits users to scribble notes on the screen.

Memory Configuration

GO recommends 2MB minimum memory when PenPoint is ROM-based, and 4MB if the OS is disk-based. PenPoint supports memory configurations up to 256MB of physical memory and up to 4GB of virtual memory. In addition, the OS supports IDE-based hard disks as well as silicon (solid-state) disks. The OS requires 3.5MB of disk space, and virtual memory requires an additional 4MB to 5MB of space.

File System

PenPoint 1.0 supports the MS-DOS file system. The maximum number of documents that can be opened at the same time is limited only by the amount of memory available. The maximum file and volume size as well as the maximum files per volume are unlimited, but are dependent on the amount of disk space available.

PenPoint reads and writes to floppy disks in MS-DOS 720KB, 1.44MB, and the new 2.88MB formats. It also supports an external keyboard, external disk drives, floppy drives, and even some SCSI devices, depending on the hardware vendor's implementation of the system.

Display Support

PenPoint's display support is hardware-independent. If a VGA-compatible controller is used, PenPoint displays eight shades of gray based on 3-bit planes. A 1-bit plane is used for the ink annotation layer of the PenPoint interface.

Software

The software applications shown at the announcement included Slate's Day-Timer, and LapLink Pro for PenPoint (a collaborative product from Slate and Traveling Software). The Numero spreadsheet by

PenMagic Software was also demonstrated. Ink Development showed off InkWare Photo and Notetaker. Pensoft was there with its Perspective 1.0, a very robust (PIM) based on a relational database model. Many companies demonstrated vertical market packages designed to provide pen-based solutions to a variety of function-specific users. In addition, some companies demonstrated their own connectivity ideas, like Sitka with its PenCentral connectivity options, and Photonics with its infrared transceiver connections.

Operating System Summary

PenPoint 1.0 is a robust operating system that has been specifically designed for pen interface and interaction. PenPoint 1.0 includes its own handwriting support that can be replaced if another recognition system is preferred by the user. It supports embedded document architecture (live documents can be embedded within documents). It is display-scalable (runs on any size screen from very small to very large), and it has been designed to provide a new way of working with computer documents.

PenPoint is an object-oriented operating system that uses true 32-bit architecture and supports virtual memory. It is as compatible with MS-DOS as possible while retaining its own look and feel.

Dataquest Perspective

Dataquest does not believe that the average end user will beat a path to the retail stores of the world to purchase his or her very own pen system this year, or even well into next year. Instead, Dataquest believes that those hardware companies that will be successful are ones that invest the time, effort, and money to work on pilot programs with the corporate world. The first implementations of pen computing will come in vertical markets, where fully integrated hardware and software platforms are designed to provide specific solutions to current, identifiable business problems.

Companies that are already working with their corporate clients to find ways to integrate their pen-based offerings into the corporate computerized and, more important, noncomputerized operations—companies like IBM, NCR, and GRiD—will sell hardware this year. They will not sell just one and two units, but hundreds of units. Companies that do not have contacts with the corporate world will struggle through the next 12 to 18 months.

GO's announcement marks the true start of pen computing, a beginning that will change the way most of us regard computers and the way we interact with them. It is an exciting time and one that will be marked in the history books along with the introduction of the Apple II and the IBM PC. To the venture-funding organizations of the world we offer the following advice: Have patience and do not push too hard, for if you do you can only further delay the acceptance of pen computing. Putting pressure on companies to turn a quick buck can only hurt them and the industry as a whole.

Partnering and long-term strategies are going to be very important in this market segment. But the understanding of how people work, and how to integrate this technology with work habits, is the most important factor and will give many systems vendors a real advantage over the "box" shops. Finally, Dataquest believes that hooking the end-user community is more important than ever.

Congratulations to GO and to all of the vendors that are following GO into the market. Vendors have to be careful not to get into an "ours has to be the only one" position. Vendors need to earn their place in the market by providing solutions for users and accepting the fact that users may make other choices. The industry has to keep GO versus Microsoft from becoming as debilitating as Microsoft versus IBM has become to the desktop world.

Chapter 5
GO and AT&T Ally to Embrace Personal Communications

The world of personal communications devices, or personal information processors, or what Apple Computer refers to as PDA, is heating up. Apple announced its first PDA—called Newton—at the end of May, with plans to ship in the first quarter of 1993. Tandy, Casio, and GeoWorks announced plans for an alliance on May 27, and Day Runner and Texas Instruments announced a "cooperative development agreement" on July 14. Perhaps the most significant announcement, however, is the one from AT&T Microelectronics and GO Corporation on July 13 of plans to develop a personal communications platform.

None of these announcements involves products that exist to touch and feel today, although a prototype of the Apple hardware product was shown at Apple's Las Vegas launch. The AT&T-GO announcement did not include any hardware products, nor did the announcement hint at which vendors might be developing hardware for this integrated computing platform.

Tight Integration

Although the announcement did not include any hardware for the world to marvel at, or even a demonstration of what was being introduced, the announcement may turn out to be as important as—if not more important than—the Apple Newton announcement made a month and a half earlier.

At the base of this alliance is the coupling of GO's PenPoint mobile operating system and the Hobbit microprocessor from AT&T. This was not just a "here is the hardware platform, and over here is the operating system" announcement. It was, instead, "here is a very powerful, very low-powered microprocessor, and here is the operating system that will be integrated to form a powerful, portable communications and computing platform."

The Name

AT&T has chosen to name its future hand-held devices "Personal Communicators," which will be "rich in communication and will integrate voice, data, handwriting recognition, fax, electronic mail, still images, and in the future, full-motion video. These devices will provide anytime, anywhere communication to a whole new class of business users and consumers who need to constantly stay in touch," according to AT&T.

The Meat

In a nutshell, GO has optimized a version of its PenPoint operating system for both the Hobbit architecture and communications applications. AT&T has developed a series of low-powered microprocessors that work with digital signal processors (DSPs) and other technologies required for communications-oriented devices.

Even the Hobbit chips were not announced this time around. Instead, AT&T addressed the near future and the power that its new C-language Rational Instruction Set Processor (CRISP) CPU line will bring to mobile computing and how tightly it will be integrated with the GO operating system.

For its part, GO Corporation talked about the configuration of its PenPoint operating system for the mobile communications market. Special support for mobile computing has been added to the operating system, and it now supports intermittent connections via wired and/or wireless links. In addition, the operating system permits multiple simultaneous communications links, and it can store and forward messages, files, and information when connections are established (or re-established).

Interesting, But...

AT&T and GO Corporation have fired a volley in response to Apple's Newton introduction. But if they are not showing a product, or even discussing specific products or delivery dates, then why is their alliance perhaps more important than the Newton announcement?

First the Hardware

Dataquest believes that companies such as EO (the hardware spin-off from GO), as well as several others, will announce and demonstrate their fully integrated products prior to the end of this year and that they may even ship a small quantity of their offerings by the beginning of next year.

However, both AT&T and GO acknowledge that the first hardware platforms to offer the combination of GO's PenPoint and AT&T's Hobbit processor will have a larger form factor than Apple's Newton. They discussed upcoming products in vague terms but indicated that we should expect to see larger, clipboard-size products first, followed over time by smaller and lighter units.

These units will be "very powerful" (says AT&T) and—with the proper power management—battery life should be better than acceptable. Although AT&T did not, in fact, announce the Hobbit chip except to acknowledge that it does exist, AT&T did discuss the architecture of the chip and why it is "ideally" suited for the mobile computing environment.

Designed into the chip, according to AT&T, are the following capabilities:

- Fast context switching to move quickly from one process task to another is an important feature for personal communications devices, because the processor needs to service multiple processes—for handwriting recognition and several communications connections—simultaneously.
- Fast interrupt response allows personal communications devices to quickly respond to and service interruptions (such as incoming calls) while still allowing the operating system to provide a smooth, responsive interface.
- Low bus activity makes the system bus available for DSP or other communications hardware components to send communications process-handling information and other data to memory without interference from the main processor.
- Processing headroom to handle real-time communications tasks, especially those that involve rich data types—such as graphics, voice, and video—that require tremendous amounts of processing power. Hobbit represents a leap forward in providing this processing power at a cost low enough for consumer products.
- High code density allows products to be built with smaller memory systems resulting in lower overall system cost.
- Low power dissipation is achieved through an efficient power management architecture, which is controlled by GO's PenPoint operating system.
- Stack cache optimizes function call efficiency. Instead of operating with registers that are visible to the user, the Hobbit provides a run-time stack cache. This approach minimizes the overhead associated with procedure calls, which account for 1 out of every 20 instructions (or more in C language operating systems). PenPoint's object-oriented design allows an application programmer to send a single message that will result in the automatic performance of many functions by inherited classes in the system. The Hobbit stack cache makes resulting function calls highly efficient and fast.

All of these features of the Hobbit CPU, according to AT&T, make this platform the "perfect" fit for mobile communications and computing.

Systems, in addition to the main processor, that make use of the Hobbit chip can also include other low-power chips developed by AT&T Microelectronics, including a family of DSPs that AT&T claims will add a high degree of intelligence to both the product and its communications capabilities.

The Operating System

When GO's PenPoint operating system was first announced, the potential scalability of the system was one of the primary features discussed. The use of PenPoint on a hand-held platform has been a part of GO's plans since the inception of the operating system, and while scalability is important, the other features added to PenPoint during the past year are also a vital part of the package.

Because PenPoint uses object-oriented programming to provide a tightly knit core of reusable classes from which all applications and communications services are built, all types of documents, regardless of the application, become "communications enabled." This means that a document can be sent as a fax, printed material, an electronic mail message, a pager message, or a file to a desktop computer.

The other features of the operating system that have been specifically built in for mobile computing include automatic detection of device and media attachment and detachment (the ability to dynamically load and execute protocols in response to external hardware events, such as a wireless connection being made).

The AT&T-GO Vision

The press materials addressed the ways in which personal communicators will be used and how easy it will be to make a connection and take advantage of the built-in systems communications "smarts." AT&T and GO also envision a series of Hobbit-GO-based products, varying greatly from each other but all with a common focus: mobility and communication. Some of the ideas that they presented include pocket-size cellular telephone and notepad devices and notebook-size multipurpose communicators that include both data and voice communication and interaction.

AT&T and GO believe that this combination of tightly integrated hardware and software will provide their customers (who will be designing and selling the end-user products) the ability to differentiate their products and, as a result, help prevent the price wars that are now thinning out the ranks of PC vendors.

Several statements were made both during and after the press event indicating that hardware products based on this combination of the Hobbit chip and the PenPoint operating system will be introduced by the end of this year. Certainly, there has been much speculation regarding the GO spin-off EO, which is reported to be building a product based on this architecture.

The Real Deal

The press event was held just prior to the start of the Mobile '92 trade show and was well attended. A short time was spent discussing the "real" reason that people should be excited about this announcement, but not much attention was really drawn to the total communications picture.

Both AT&T and GO talked briefly about communication, indicating that they understand the need for robust communications links. Their

joint statement regarding communication seems to sum up their approach to the importance of moving information from one point to another: "If personal communications are to be successful, they will need to work hand-in-hand with today's existing wired communications infrastructure and be poised for the emerging wireless revolutions. Together, AT&T Microelectronics and GO will work with third-party partners so that the new platform will connect to key network resources and services."

The press release also reveals plans to incorporate features to make the Hobbit-based systems "wireless ready" using any of the wireless choices that are, or will be, available. Current choices are wired, infrared, and wireless connections, with the wireless option including cellular, packet radio networks such as RAM Mobile Data and Ardis; paging networks such as SkyTel and Embarc; and future networks such as those that rely on satellites.

Missing from this discussion, however, is the fact that AT&T owns and operates the largest wired communications system in existence and is involved in many cellular systems, paging, and point-to-point networks. Dataquest believes that AT&T has not yet played its trump card in this area.

If personal communications devices are to become as important as many people in the industry believe that they will, then it is the networks (as much as the technology and magic contained within them) that will enable these devices. AT&T understands this perhaps better than any other company. During its long history of being *the* telephone company before the divestiture, and even since its breakup, AT&T has been a provider of the network used for communication, and AT&T wants to continue to use this network. When it was the only provider, it rented telephone instruments to customers to plug into its networks. When customers first developed a need for radio paging or mobile telephone service, they purchased or leased equipment from AT&T and used its network.

Shortly before and certainly after the divestiture, AT&T was faced with competition in all areas. Many other companies moved in to provide the hardware necessary to connect to their own networks, and several other companies have even emerged to challenge the supremacy of AT&T's networks. However, it is still true today that AT&T's main strength is its networks, especially now that access to information is key to corporate success. The challenge still remains the ability to move information from one place to another.

The Hook

AT&T does not just own networks, it also owns services—such as AT&T Mail—that run on top of the networks. At present, AT&T Mail competes with MCI Mail for electronic delivery of e-mail on a worldwide basis. Some companies are using either AT&T Mail or MCI Mail to virtually run and coordinate their operations.

AT&T Mail, as well as AT&T's other communications networks, can serve as the point of contact for many personal communications devices. Users would not have to make decisions about the type of communications network that they needed—access to AT&T Mail could provide a gateway to any of the other services.

Access to AT&T Mail can be accomplished by wire, direct phone connection, LAN computer systems, and other networks. Access through wireless systems is easy enough to accomplish. After all, the wireless connection is an extension of the network, running through the air instead of on a pole, but part of the network nonetheless.

If AT&T couples the power of the Hobbit with the power of PenPoint and then provides easy access to its own network, the combination is one that will give it a decided advantage in the personal information processor field. AT&T will have the opportunity to sell the chip sets, help OEMs build the products, and then sit back and collect the rent for the use of its networks from all of the Hobbit users.

Dataquest believes that AT&T will work with all of the other service providers but that its main thrust will be to provide the missing link: the communications path from the hand-held device to the desktop or network device—as an integral part of the rollout of products.

Dataquest Perspective

As with the Apple Newton announcement, the AT&T-GO press event left as many questions unanswered as it answered. The two companies did not elaborate on exactly what vendors will provide hardware, or when the products will become available, or about the type of "seamless" communication that the products will offer.

Both AT&T and GO gave the distinct impression that they intend to handle every piece of information that goes into and comes out of the personal communicator as a document of one form or another. The operation to move a document from a remote base station to a hand-held system, as it was explained, involves having the document arrive at the personal communicator and be exposed to all of the applications in residence, and then have each application alert the user as to whether it can or cannot provide a home for the document. In this way, information can be sent to and received from the personal communicator, recognized by an application, and "attached" to that application.

What AT&T and GO did not discuss or demonstrate is an understanding that communication goes way beyond the transmission and reception of documents. Much of the information that will be received by and sent from personal communications devices will not be isolated or standalone but will be a piece of a larger pie that needs to be integrated with other information that often exists in a different form.

It is not clear that AT&T and GO have taken the communications metaphor far enough yet. There is still time, and AT&T does understand how to move enormous amounts of data from anywhere to anywhere. It will be interesting to discover whether or not the combination of AT&T and GO will be able not only to move the information but also to move it smartly, seamlessly, and quickly.

Without having seen the software or the hardware, it is impossible to declare the AT&T and GO alliance a success. In some ways, Apple has set higher expectations within its potential user community because it has demonstrated its concept of mobile computing on a hardware platform that is supposed to become real in the first quarter of 1993. On the other hand, AT&T and GO have announced an alliance that, when coupled with a third-party hardware supplier, will provide a product with just as much sizzle and even "more functionality" (their words) than the Newton. If the first efforts are not quite right, then the alliance has a chance to work with hardware vendors to correct problems while continuing to work with other vendors to improve existing products.

All of these personal communications/information devices are still evolving. AT&T and GO have provided a hardware and operating system platform that hardware vendors can add value to and bring to market—and probably connect to an AT&T network.

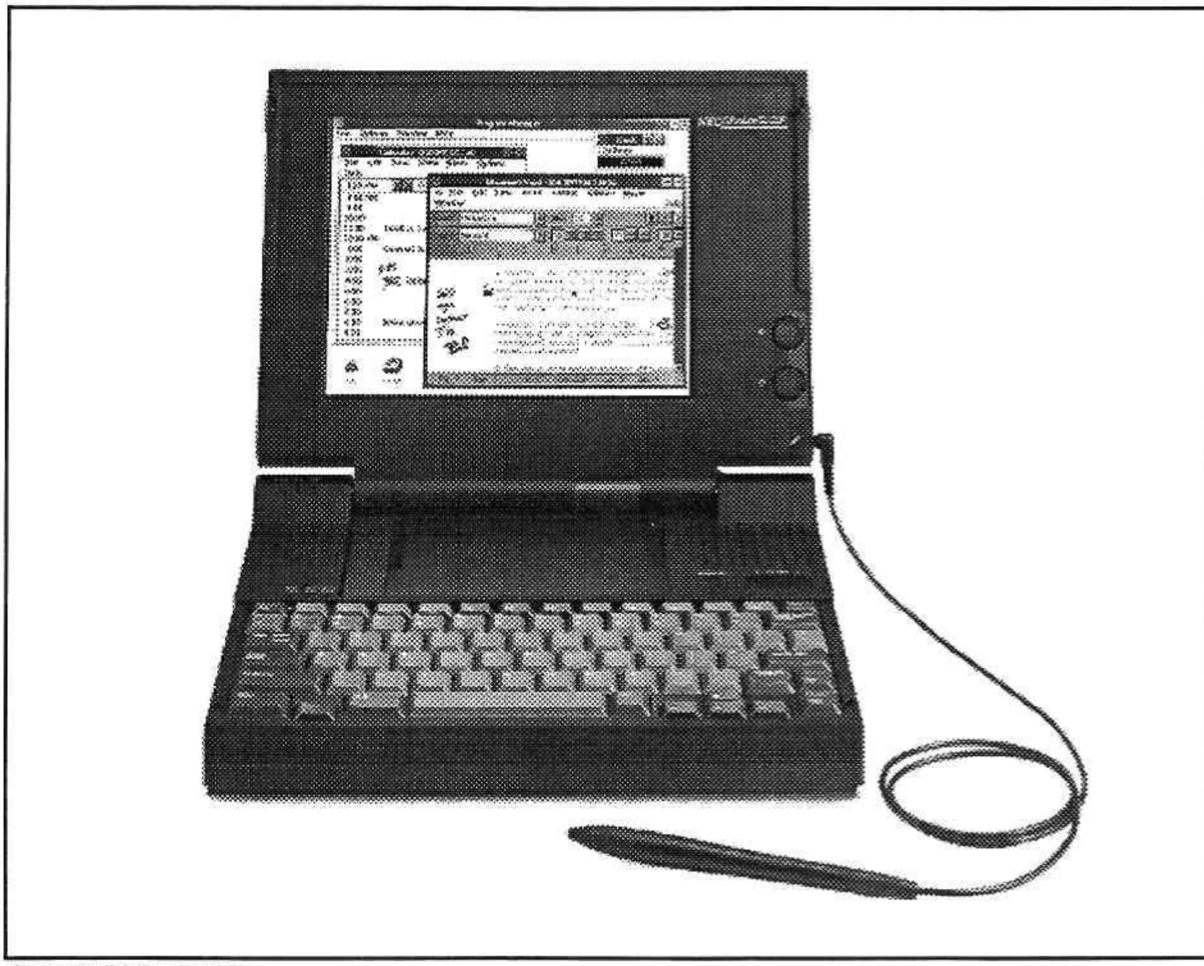
Chapter 6
Convergence to a New Form Factor

Current-generation notebook PCs are built around the 386 or 486 Intel MPU, have a 2.5-inch hard disk, a floppy, and fax/modem communication capabilities built-in. With respect to form factor, pen-based PCs today are similar to notebook PCs, and even though current-generation notebook and subnotebook PCs use a keyboard for information entry, they can easily be converted so that they run a pen-based operating system such as the Microsoft's Pen Windows using a "pen" instead of a mouse. Figures 6-1 and 6-2 show examples of pen-based systems, the IBM Thinkpad 700T and the NEC UltraLite SL/20P. The NEC model includes dual interface with both a stylus and a keyboard, and has mouse emulation via touch or stylus input.

Figure 6-1
IBM Thinkpad 700T

Source: IBM Corporation

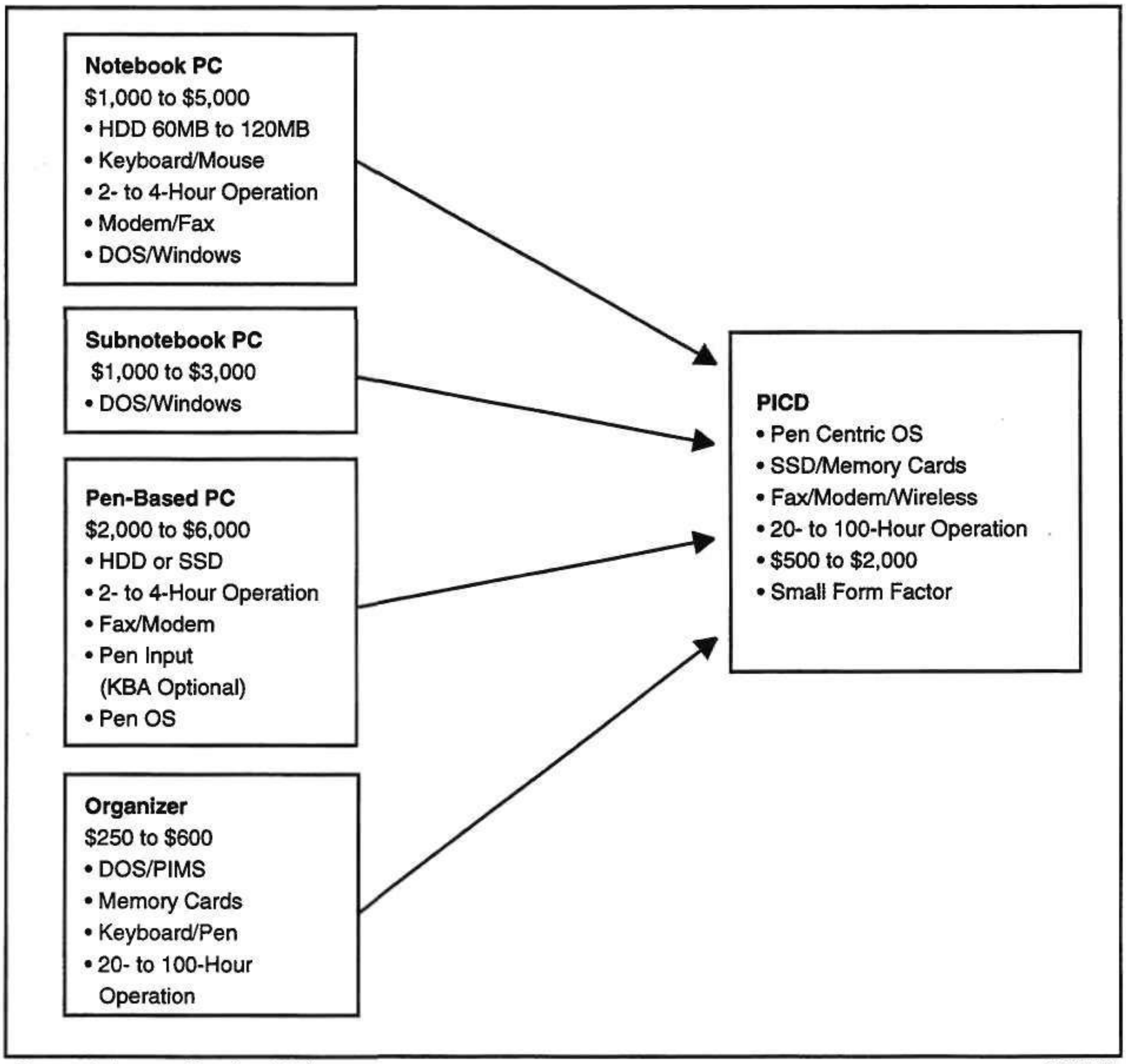
Figure 6-2
NEC UltraLite SL/20P



Source: NEC Corporation

This easy transformation of notebook PCs to pen-based PCs by simply replacing the mouse with a pen may indicate that the "pen-based PC" is not really a valid form factor, but perhaps a transient PC classification. Hand-held PCs such as the HP 95LX may acquire a pen to be used as an additional input device, and the same is true for organizers. As a matter of fact, Sony has offered one for the Japanese market, and Sharp has demonstrated a Japanese version of a pen-based organizer. All these form factors are in the process of experimenting with the use of the pen as an input device to replace or supplement the keyboard. In the process, they seem to be converging to a new form factor, as exemplified by Apple's Newton. Figure 6-3 shows that trend, which is being made possible by availability of low-power/high-performance semiconductor components and the emergence of new user-friendly and intuitive operating systems and software. Success of PICDs depends as much on the availability of new operating systems and software applications as it does on hardware.

Figure 6-3
Convergence to a New Form Factor



Source: Dataquest (October 1992) G2002266

Microprocessor Wars Revived?

For PCs, the microprocessor issue has been mute for a while now. Simply stated, the majority use X86 architecture devices, currently in the migration path along the 386/486, and soon to be P5. The major exception to this is, of course, Apple using the Motorola 68000 family of devices for its products to date. Intel in essence has been a stabilizing force when it comes to MPUs for PCs. For its immense success, it has been rewarded recently with as much as 60 to 70 percent of the profit per motherboard sold! So far most challenges mounted against Intel and the CISC camp of MPUs have failed, at least as far as PCs are concerned.

What appears to be different now is that the most significant implementations of future PICDs are not scheduled to use an Intel X86 architecture MPU. Apple's Newton will use the ARM microprocessor from VLSI, while the AT&T/GO alliance has proposed an open architecture that uses AT&T's Hobbit microprocessor. Both ARM and the Hobbit are RISCs.

Is this a RISC-CISC war again? Not really. The lines between RISC and CISC have blurred sufficiently to make this a nonissue. The reason for not using X86 MPUs may be simple: PICDs do not need to run DOS or Windows, thus there is no need for backward software compatibility. That in turn opens the door to new possibilities because, for the first time in a while, it is open MPU season for an up-and-coming PC form factor.

Why ARM or Hobbit?

The tasks that Apple is envisioning Newton performing—handwriting recognition, speech and image processing, and communication, among others—are quite taxing for a 386 class of microprocessors. And even though a 486 or P5 may have an easier time, there is the issue of power; because PICDs need to be portable, watts of power are not available to the MPU anymore. Thus, the search for a powerful yet power-nimble MPU.

The MPU players are as follows:

- VLSI Technology Inc.: ARM
- AT&T: Hobbit
- Intel/AMD/Cyrinx/Texas Instruments: X86SL
- Motorola: LSC80018
- VADEM : VG-230
- NEC/Sharp: V20 and V30
- Chips & Technologies: PC/CHIP

Operating System Suppliers for PDAs, Personal Communicators, and PICDs

Suppliers expected to offer or attempt to offer operating systems for PICDs are as follows:

- Apple
- GO
- GeoWorks
- Microsoft
- Communication Intelligence Corporation
- Others

AT&T and GO Revisit the Past (In Search of Future Profits)

We may be revisiting history here. Not long ago many good microprocessors were around for building a PC. The two most successful were the 6502 used by Apple II and the Z80 used by everybody else. There were also at least two popular operating systems, one from Digital Research running Z80 machines, and Apple's proprietary OS running Apple II. Then came the IBM PC using the Intel 8088 microprocessor and a relatively unknown operating system, DOS, from Microsoft. The rest is history.

Microsoft grew into the largest supplier of operating systems on the planet, becoming a mammoth-size company overnight. Intel was thereafter established as the king of microprocessors for PCs, which in turn established PCs as the mainstream computer business. Apple did well following its own path, and led the way with some superb products that were soon emulated. To get the horsepower needed by new products, it replaced the 6502 with a line of powerful MPUs from Motorola, the 68000.

Where are we today? Apple is proposing a new visionary line of portable products (PDA), with Newton first in line. It will use its core expertise to provide a proprietary operating system. It chose ARM, which, by the way, is a 6502 RISC derivative! AT&T is proposing an open standard architecture with Hobbit as the core MPU running GO's pen-based operating system. GO is a relative newcomer in operating systems, the way Microsoft was 10 years ago. AT&T is where Intel was before IBM's endorsement. Does AT&T want to become Intel for the MPUs of PICDs? Does GO want to become the Microsoft of the next century? There is no question that GO would love to replace Microsoft, and that AT&T would welcome the opportunity to be the Intel of PICDs.

However, at this point both companies appear focused on the short-term objective: to provide useful hardware and software for Personal Communicators and similar classes of machines. The possibility of AT&T and GO replacing Intel and Microsoft at the top may be real for the first time in years.

Overview: Semiconductor Opportunities

PICDs will most likely be configurable at the user level, for two reasons, as follows:

- It makes for flexible systems, allowing the user, for example, to pick the size of the solid-state disk (mass storage) required at the time of purchase. The same holds true for other options such as PCMCIA fax/modem, Ethernet LAN cards, memory cards, expansion memory (PCMCIA form factor), and software packages (PCMCIA ROM cards).

- The basic system is low in cost, a must for PICDs to reach high volumes. As a result, opportunities for semiconductor vendors will be found in the following areas.
  - Mass storage
    - Memory cards
    - Solid-state disks
    - Small form factor rigid disk drives
  - Communication
    - Infrared (IR)
    - Radio frequency (RF)
    - Fax
    - Modem
    - Voice
    - Cellular
  - Data compression
  - Video
  - Audio

The following discussion examines a range of semiconductor opportunities, primarily for small form factor portable PCs, by presenting pertinent market size and growth data of selected areas as well as specific examples of current implementations and future trends. (It should be noted that a good treatment of trends and semiconductor opportunities in video, audio, and compression, among others, can be found in Dataquest's Multimedia report.)

Market Overview

Table 6-1 shows the portable computer subset of the PC market forecast provided by Dataquest's PC group. It is worth noting that handheld PCs are second only to pen-based PCs in terms of unit growth, and are expected to account for 23 percent of all PCs sold by 1996. Table 6-2 shows the worldwide portable PC market forecast by product type.

Figure 6-4 is our market estimate for PICDs, whose success will depend heavily on execution. As with all new markets, this market will take time to develop. After all, it took at least 10 years for the PC market to reach its present stage of maturity. Opportunities for this market are emerging in semiconductors, systems, and software.

Table 6-1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	2,764	3,101	3,392	3,669	3,933	4,114	8.3
Notebook	1,136	1,794	2,816	4,393	6,809	9,464	52.8
Pen-Based	41	122	800	1,759	3,289	5,098	163.0
Hand-Held	238	763	2,042	3,877	6,188	7,314	98.5
Total Portable	4,179	5,780	9,050	13,698	20,219	25,990	44.1

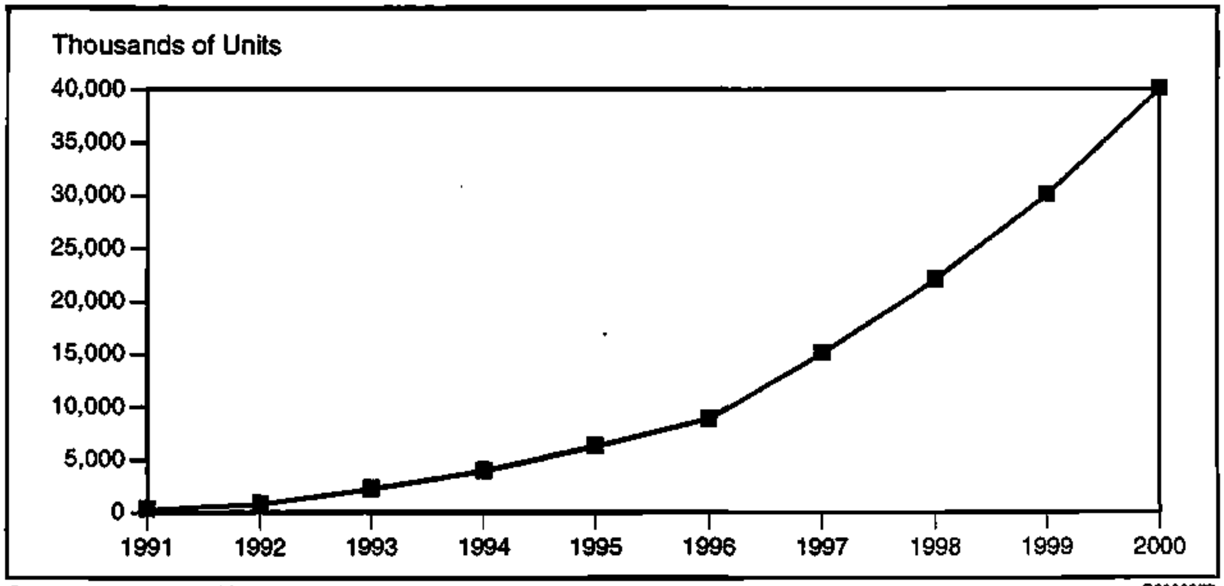
Source: Dataquest (October 1992)

Table 6-2
Worldwide PC Revenue Forecast, by Product Type (Millions of Dollars)

Type	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	4,852	5,256	5,513	5,980	5,860	5,965	4.2
NoteBook	1,795	2,857	4,369	5,798	8,238	10,410	42.1
Pen-Based	85	268	1,917	4,391	7,966	11,978	169.0
Hand-Held	86	254	653	1,193	1,832	2,083	89.2
Total	6,818	8,635	12,452	17,362	23,896	30,436	38.1

Source: Dataquest (October 1992)

Figure 6-4
Worldwide PICD Shipment Forecast (Thousands of Units)



Source: Dataquest (October 1992)

G2002277

PDA 25K 750K 1500 3m 6m

Chapter 7
Nomadic Computing and Semiconductor Opportunities for Hand-Held PCs

Portable PC terminology is confusing. Definitions change with time as technology races to fit a Cray supercomputer in a shirt pocket! In this article, Dataquest provides basic definitions and then discusses trends and semiconductor opportunities in the portable PC industry.

Definitions

A notebook PC is a desktop PC shrunk to the approximate size of 8.5 × 11 × 1.5 inches; it weighs 4 to 7 pounds.

A subnotebook PC or companion PC is basically a smaller notebook PC that typically measures 10 × 6 × 1 inches and weighs less than 3 pounds. It may use a floppy and a hard disk or silicon disk for mass storage.

A hand-held is a desktop PC shrunk to at least a size of 8.5 × 4 × 1 inches (more often 6 × 4 × 1 inches) and weighs less than 1.5 pounds. Because of size and power constraints, hand-held PCs do not use a hard disk for mass storage. Instead they rely on PCMCIA-type memory cards to fulfill this function. The memory card here performs dual functions: that of a removable mass storage device (hard disk) and of a floppy that allows for information exchange. The term palmtop is often used to indicate a similar class of machines. For our discussion we will focus on machines that support a standard operating system (OS) such as DOS.

A personal organizer is a small portable device (6 × 3 × 1 inches or smaller) typically running a proprietary OS and a small set of personal information management (PIM) utilities such as appointment calendars and phone books. Personal organizers do not run general-purpose software. They can, however, communicate with PCs for data transfers.

Why Do We Need Hand-Held PCs?

Even though portable PCs are getting smaller and lighter by the day, they are still cumbersome for many applications and users. It is true that notebook PCs have brought the computing power of the desktop to an 8 × 10 × 1-inch form factor weighing just under 5 pounds. But even though they fit in briefcases, they are still limited in a number of ways.

Portable PCs depend on expensive nonstandard rechargeable batteries that allow for just 2 to 4 hours of operation, which creates a problem: It is nice that such powerful full-fledged PCs can be taken on the road, but they tend to become temporarily useless once they run out of power. Of course they can be brought back to life when an AC outlet is found, but then, this is not much consolation inside an airplane! Another problem is the AC adaptor, which is not lightweight and takes up space. At 4 to 5 pounds (adaptor excluded), notebook PCs are still heavy for most users, who would prefer something much lighter if given a choice. More importantly these PCs are not socially accepted in meetings, while paper-based daytimers and organizers are. Portable PCs also are not very rugged, the weak points being the hard disk and to a lesser degree the LCD display. Finally, there is the cost issue: Notebook PCs still cost $1,500 to $4,000, excluding software.

Enter the hand-held PC, which is much smaller, much lighter, runs on off-the-shelf batteries (often standard AA) for up to 100 hours, fits in a shirt or vest pocket, costs a third the price of a notebook, runs most (if not all) PC application software, and easily connects with desktops.

Because the hand-held PCs run off-the-shelf software, they become almost as useful as the desktops. The key word here is almost. Some choices had to be made to downsize a desktop to a hand-held. There is no space or power to use a hard disk, which means that some alternate form of mass storage is needed. The only viable—and in the short-term, expensive—alternatives were solid-state disks and/or memory cards. The solid-state disk based on flash memory is the hard disk replacement; the memory card is the floppy.

Solid-state storage is a blessing in disguise. Because it is more expensive than the equivalent hard disk drive (HDD), it mandates that only the necessary software be built-in or carried along. This fact, limiting as it may at first glance seem, forces examination of the utility of the software carried along. Only absolutely necessary software is embedded in hand-held PCs because semiconductor mass storage is not cheap. On a per-megabyte basis a hard disk drive costs $3 to $4, whereas a flash memory disk/card may cost $50 to $75. By year's end it is expected that the cost disparity between hard disks and solid-state storage (flash) will be reduced to 5:1 as memory cards reach $25 per megabyte.

A point often missed in cost-per-megabyte discussions is that just 3MB of hard disk storage cannot be bought for $9! Even if the cost issue is ignored, hard disks cannot be used in hand-held PCs because they consume too much power and their size, even at the 1.8-inch form factor, is a problem. This may not hold true if and when low-power 1-inch HDDs become available. At that size most problems inhibiting their use in hand-helds should disappear. A 1-inch hard disk would be reasonably rugged and power nimble. For now, however, solid-state is the only alternative.

Hand-held PCs are not meant to replace the office PC; instead, they are expected to act as adjunct computers.

To the extent that hand-held PCs can effectively be used as take-along computers, their compatibility with the user's desktop PC is essential. However the ability to run all the software as the user's desktop is a questionable quality. The hand-held is more of an outgrowth from the organizer camp as opposed to the downsizing of the notebook PC. Attributes other than full compatibility are more important. For example, are the PIMs adequate and well designed? Is the hand-held small and easy to carry along and use? Is the keyboard useful for a reasonably small amount of typing? Are the batteries easy to find and do they last 50 to 100 hours? Is the display quality acceptable? How easy is it for the average user to connect the hand-held to a desktop and upload/download data? Is connectivity expensive? Successful hand-held implementations should have plenty of yes answers for this set of questions.

Who Uses Hand-Held PCs?

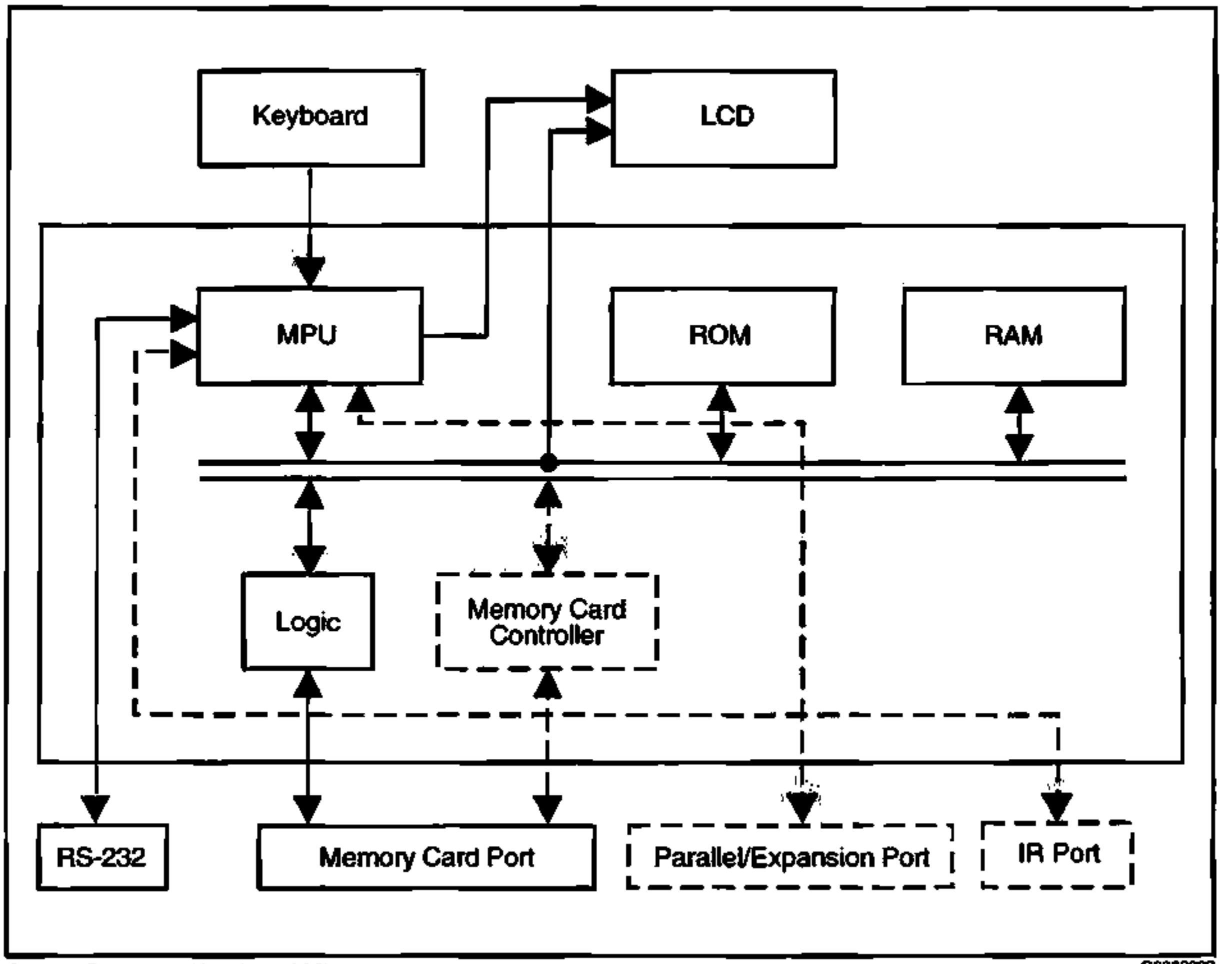
Beyond the on-the-go professional that needs something light for the road, a multitude of people use and will use these devices in a variety of environments. Weight, portability, and battery life are key features that make hand-held PCs attractive in industrial/commercial tasks on the factory floor to collect data, in shipping and receiving, for inventory and other tasks. Thus assuming that hand-helds deliver on the challenges at hand (ease of use, long battery life, and seamless connectivity), they stand to clearly dominate parts of mobile computing. Figure 7-1 shows a representative level of integration in today's hand-held PCs.

The trend in hand-helds is toward using a highly integrated MPU such as the NEC LH72001, the C&T F8680, the VADEM VG-230, or the Motorola LSC80018. The memory card port can be controlled in a number of ways. A memory card controller may be used if space and cost permit. Alternately, glue logic or even the MCU may be used for direct but less efficient control. This function will ultimately migrate to the MPU.

Table 7-1 shows hand-held unit projections based on Dataquest's Personal Computers group's forecast, which does not include personal organizers. Hand-held PC unit shipments are expected to grow at a compound annual growth rate (CAGR) of about 84 percent from 1992 to 1996. Both average selling prices and hand-held semiconductor content are expected to come down following reasonably well-defined learning curves. The total available market for semiconductor vendors is projected to grow at a healthy rate of 67.2 percent over the same period. It should be noted that the semiconductor TAM figures do not include the substantial semiconductor memory (flash, ROM, and RAM) opportunities arising from memory card sales.

Figure 7-2 shows projected hand-held PC market share for 1992 and 1996.

Figure 7-1
Hand-Held PC—Block Diagram



Source: Dataquest (October 1992)

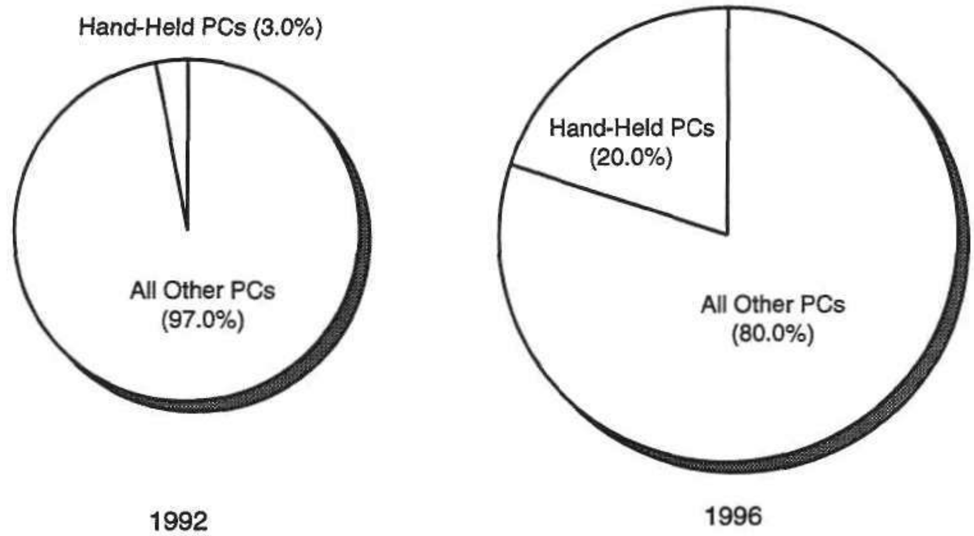
G2000099

Table 7-1
Estimated Total Available Market, Worldwide Hand-Held PCs

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Units (K)	238	763	2,042	3,877	6,188	7,314	98.45
ASP ($)	360	330	320	310	300	280	- 4.90
Semiconductor Content ($)	71	56	52	47	43	38	- 11.75
Semiconductor TAM ($M)	16.9	42.7	106.2	182.2	266.1	277.9	75.07

Source: Dataquest (October 1992)

Figure 7-2
Worldwide Hand-Held PC Market Forecast



Source: Dataquest (October 1992)

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Hand-Held PC Players

Players in the hand-held PC market, along with their status, are as follows:

- HP—In its second generation of product, HP 95LX 1MB.
- Poqet—In its second generation of product, Poqet PC.
- Sharp—About to enter the hand-held PC market with its PC-3000. Has participated in the organizer market with its Wizard product line.
- Casio—So far has offered a series of organizers (B.O.S.S. product line).
- Atari—Offers the Atari Portfolio. Sold close to 100,000 units in 1991.
- Sony—At present offers a line of hand-held PCs for the Japanese market that run a proprietary OS and accept pen input.
- PSION—Has offered a product that is similar to HP's 95LX but is based on a proprietary OS.

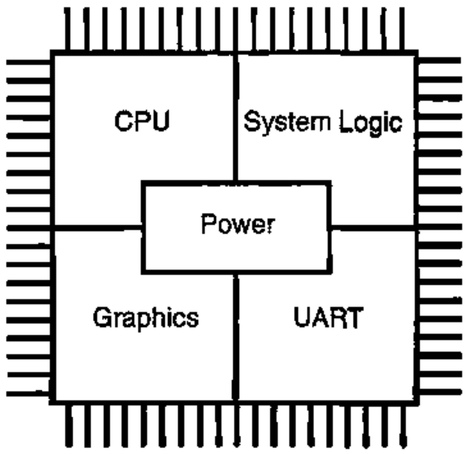
Semiconductor Opportunities and Trends

Opportunities and trends for semiconductors are described in the following paragraphs.

MPU

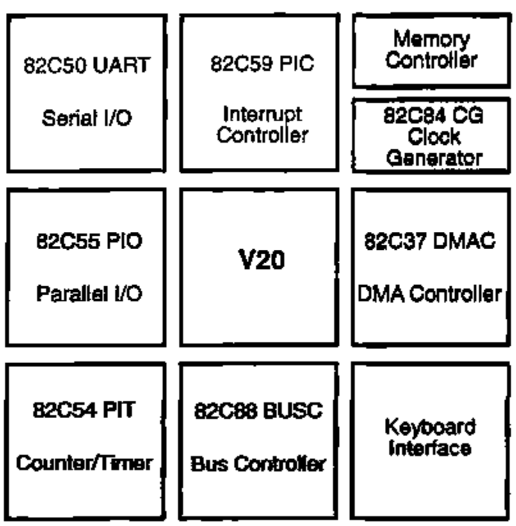
Because both space and power come at a premium, MPUs that integrate most if not all the functions needed to build a hand-held PC are now appearing to fill the gap. Figures 7-3, 7-4, and 7-5 are typical implementations. As high integration is achieved, board

Figure 7-3
Block Diagram of the Chips & Technologies F8680 (PC/CHIP)



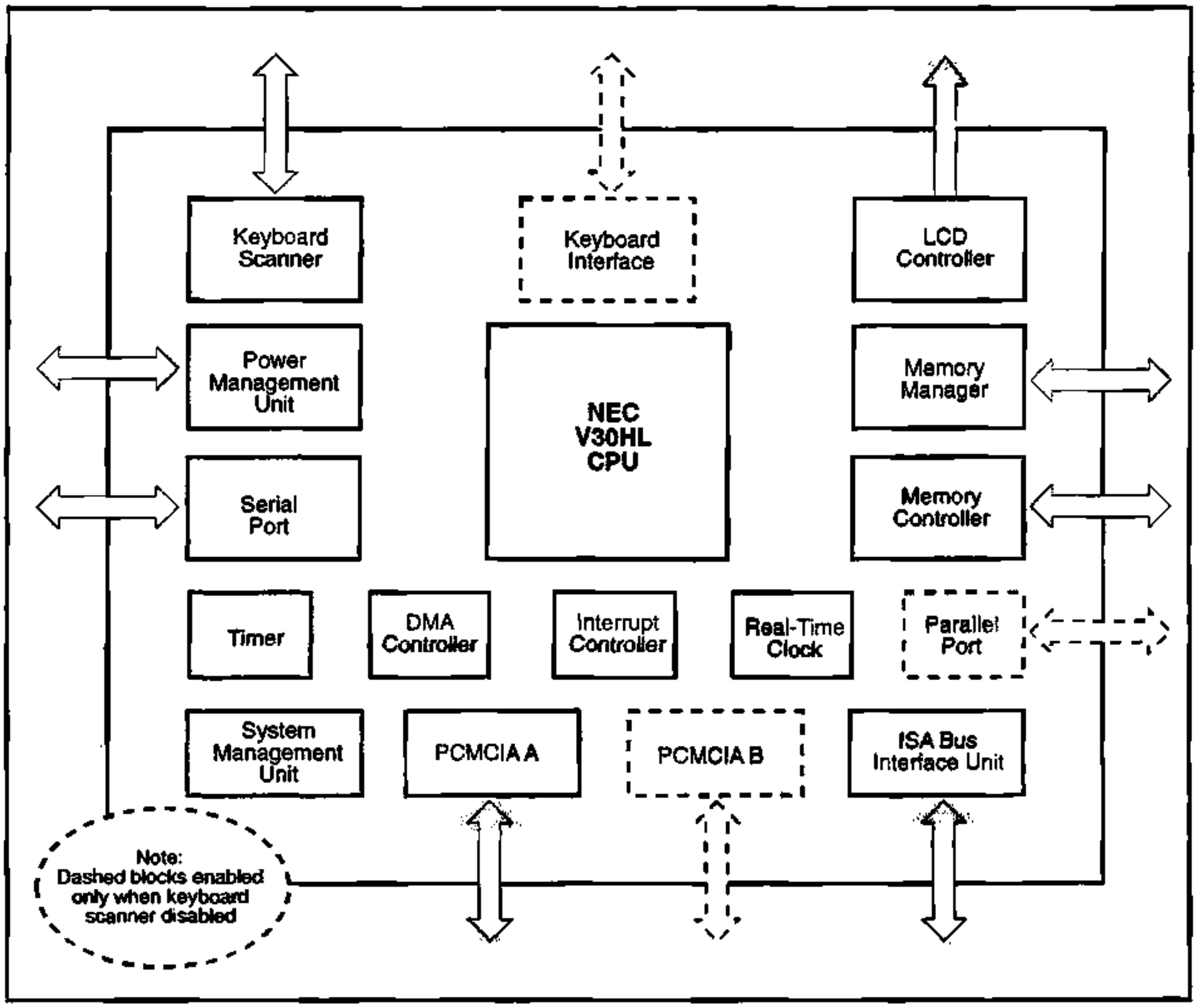
Source: Chips & Technologies Inc. G2000101

Figure 7-4
Block Diagram of the Sharp LH72001



Source: Sharp Corporation G2000102

Figure 7-5
Block Diagram of the Vadem VG-230



Source: Vadem

G2000103

space and cost will be freed for other functions such as speech and handwriting recognition, and IR and RF communications capabilities. MPU speeds will increase, primarily driven by handwriting recognition, algorithmic demands, data compression speech processing, and communications needs.

Main Memory

Today 1MB of SRAM/PSRAM (pseudo RAM) is typically used. PSRAM is preferred for cost reasons. Two 4MB, 3/5V devices do the job. If the execute-in-place (XIP) function is successfully implemented, then main memory may increase marginally to 2MB. Flash will be used in the future because of nonvolatility and low power consumption; most likely it will replace at least a part or all SRAM/PSRAM.

ROM

The 1MB typically used today most likely will be replaced by flash in the near future. In this area hand-held PCs store their operating system (for example, DOS) and programs such as Lotus 1-2-3 and PIMs. The problem with ROM is that it cannot be changed and thus the hand-held PC may be rendered obsolete in a short period. Flash memory is far more appropriate for this function. The expected memory size is 2MB to 4MB in the near term, increasing to 10MB by the end of the decade.

Mass Storage

Solid-state disks using flash memory with capacities on the order of 2MB to 5MB should be used in the near term; 10MB to 40MB should be used by 1995. Small densities should not be underestimated; by using software compression their size could be more than doubled, thus decreasing their apparent cost.

Data Compression

This function begs for eventual implementation in silicon, perhaps as part of a chip set at first, eventually to be integrated in the core MPU. Data compression is needed to offset the high cost of silicon-based memory used for mass storage.

Other Storage

Hand-held PCs will incorporate one or two PCMCIA-type ports supporting XIP. Flash and SRAM memory cards will be used as secondary storage devices. ROM memory cards will carry application software. Programming flash memory cards will become easy with the introduction of single-supply 5V devices now, and 3V in the future.

Connectivity

Connectivity is a key issue with devices such as hand-helds that tend to depend on the uploading and downloading of data to and from a desktop PC. Beyond the RS-232 type connections, infrared such as the one used by HP seems to be a very good alternative. An infrared connection with the desktop may simplify the chore of transferring data and programs between a desktop and the hand-held. In the long run, with PCMCIA ports finding their way into desktops and notebooks, the memory card will be used to transfer data between hand-held and desktop PCs.

Communication

The HP 95LX hand-held can mate with the NewsStream receiver from Motorola. It allows the user to receive e-mail over national, regional, or local paging services. Most products offer built-in terminal emulation software that allows the hand-held to be tied up to a network such as CompuServe by using a modem. Modem and or wired/wireless fax capabilities may be integrated into hand-held PCs in the near future.

Who Makes Microprocessors for Hand-Held PCs?

The NEC V20 MPU is used by the HP 95LX, the Poqet, and the Sharp Wizard series of products. It is by and large the microprocessor most commonly used in these IBM-compatible PCs.

A number of newcomer single-chip MPUs are poised to challenge this MPU. C&T introduced a single-chip highly integrated MPU, the F8680 (PC/CHIP), which also includes power management logic, a CGA-compatible LCD controller, a serial port, and IBM XT-compatible bus logic.

Newcomer VADEM will shortly introduce the VG-230, a device that incorporates the V30 MPU, a power management unit, serial port, timer, DMA and interrupt controllers, real-time clock, memory controller and manager, graphics LCD controller, and keyboard scanner.

Motorola is about to offer a highly integrated MCU, the LSC80018, to a small consortium of companies with the common goal of promoting a hand-held variant called PocSec for the Pocket Secretary. The LSC80018 features an 8-bit MCU that incorporates a graphics LCD controller, a real-time clock, an SPI, SCI, 3.5K of ROM, 448 bytes of RAM, and an 8MB MMU.

IC Peripherals for Hand-Held PCs

Table 7-2 lists memory card controller ICs, and Table 7-3 compares three hand-held computers. The Poqet has been around the longest. HP has been very well received, with sales on the order of 100,000 units for 1991. The Sharp PC-3000 is about to enter the market.

Dataquest Perspective

The need for portability must be balanced with the usefulness of a hand-held PC, which, depending on implementation, may be portable but not useful. A nagging problem in today's hand-held PCs is the human interface. A small hand-held with a tiny keyboard can fit in a pocket. Unfortunately, even the smallest amount of typing using such a keyboard becomes a chore. That makes the hand-held effectively an organizer that can be connected to a desktop PC.

Table 7-2
Memory Card Controller ICs

Intel	82365SL	Memory card controller	160-pin QFP
VLSI	VL82C107	Includes memory card Control function	128-pin QFP
Fujitsu	MB86301	Memory card controller	120-pin PQFP

Source: Dataquest (October 1992)

Table 7-3
Hand-Held PC Features

	HP95L × 1MB	Sharp PC-3000	Poqet
Size (Inches)	6.3 × 3.4 × 1.0	8.8 × 4.4 × 1.0	8.8 × 4.3 × 1.0
Weight	11oz	1.23 lbs.	1.2 lbs.
CPU/Speed	V20H at 5.37 MHz	80C88 at 10 MHz	80C88 at 7 MHz
System Memory	1MB SRAM 1MB ROM	1MB SRAM 1MB ROM	640KB SRAM 768KB ROM
Keyboard	60 + 10 FN + 10 Apps	77 + 12 FN	77 + 10 FN
Display Column/Emulation	40 × 16—MDA	80 × 25—CGA/MDA	80 × 25—CGA/MDA
Display Resolution	240 × 128	640 × 200	640 × 200
Batteries/Type	Two/AA	Three/AA	Two/AA
Memory Card Slot	1 PCMCIA-1.0	2 PCMCIA-1.0	2 PCMCIA-1.0
O/S	MS-DOS 3.22	MS-DOS 3.3	MS-DOS 3.3
Other Ports	3-wire RS-232 Infra-Red	RS-232-C Parallel I/O	RS-232-C I/O Bus (XT Comp)
Opt. Peripherals	NewsStream Receiver	1.44MB 3.5" Floppy	1.44MB 3.5" Floppy
Built-In Software	Lotus 1-2-3 Ver 2.2 Scheduler Address/Phone Book Memo Editor HP Financial Calc DataComm Filer Clock/Stopwatch To-Do list	Lotus compatible Scheduler Address/Phone Book Memo Editor Calculator LapLink File Manager Clock To-Do list	Scheduler Address/Phone Book Memo Editor Calculator File Manager Clock To-Do List

Source: Dataquest (October 1992)

On the other hand, if the minimum useful size keyboard (such as the Poqet/Sharp PC-3000) is used, the hand-held cannot fit in a pocket and its usefulness is again reduced. The solution may be a hybrid product such as the HP 95LX where the keyboard keys are enlarged to a size closer to those in the Poqet/Sharp PC-3000 (QWERTY without separate numeric keypad) and where the pen input is allowed to supplement the keyboard. Both Sharp and Sony have demonstrated products that incorporate such a pen-based input device. Even though these are not hand-held PCs that run DOS, they are a step in the right direction. Making such devices PC-compatible is rather simple.

The key to success for hand-helds may be semiconductor devices that allow for a good machine-human interface, which may be handwriting on the LCD screen, voice recognition, or a combination of both, and provide seamless connectivity. If hand-helds succeed in being easy to use, then their unit volume potential will exceed our expectations.

Chapter 8
Memory Cards

What Are Memory Cards?

A memory card is a portable semiconductor storage device that contains memory ICs. It resembles a thick credit card (3.3mm) with an edge connector at one end (see Figure 8-1).

Memory cards perform a function similar to that of a floppy disk. They store binary data.

As program or data storage media, memory cards are not new. They have been used in computer games, point-of-sale (POS) systems, photocopiers, and laser printers. More recently, electronic organizers such as the Casio BOSS and the Sharp Wizard along with palmtop PCs such as the Poqet and the HP 95LX have begun using memory cards for data storage.

Figure 8-1
Example of a Memory Card

Source: PCMCIA

The memory card form factor has not changed much over time, but the type of edge connector and the electrical/mechanical interface have. The edge connector of a memory card is the conduit that allows data to move to and from the card's memory ICs. It defines the card's capabilities. To date, we have seen cards with a variety of connectors including 38-, 40-, 50-, and 60-pin.

Memory Card Varieties

Memory cards contain mostly semiconductor memory ICs that belong to one of the following families: mask ROM, EPROM, OTP, SRAM, DRAM, EEPROM, and flash. DRAM memory cards are relative newcomers and are meant to be used as "extended/expanded" memory with no need for battery backup. SRAM cards with battery backup have been used as solid-state "floppies" in the current generation of electronic organizers. Until recently, SRAM cards (with battery backup) were the only nonvolatile memory cards. Flash memory cards today provide a promising alternative. Items such as language-translating software and dictionaries typically come in mask ROM cards, as they are the most dense and least expensive. Functionally, they are huge look-up data tables that need no change. Table 8-1 lists the various memory card alternatives.

Memory Card Standards

What inhibited memory card growth in the past was the lack of standards. In June 1989, the PCMCIA was formed in the United States, with a broad-based membership that included semiconductor companies along with software and hardware vendors. The PCMCIA's originally stated goal was to establish a standard for memory cards used with DOS-based PCs. It succeeded rather quickly as standards go. The first revision of a memory card standard was published in August 1990.

Revision 1.0 of the PCMCIA/Japan Electronic Industry Development Association (JEIDA) standard defined the following:

- The form factor—a device the size of a credit card, 3.3mm thick with a 68-pin socket connector
- The interface—parallel type bus, 8-bit/16-bit
- The address space—64Mb

Table 8-1
Memory Card Alternatives

Type	Density
ROM	128KB—16MB
EPROM/OTP	128KB—8MB
DRAM	64KB—12MB
SRAM	32KB—4MB
EEPROM	8KB—512KB
Flash	128KB—4MB

Source: Dataquest (October 1992)

The PCMCIA worked closely with the JEIDA and JEDEC. This close cooperation enabled the prompt international acceptance of the standard. Revision 2.0, as announced in September, addresses XIP (eXecute-In-Place) and I/O functions such as modems and LANs for PCMCIA bus cards. Intel Corporation also announced the Exchangeable Card Architecture (ExCA), a hardware and software implementation of the PCMCIA Revision 2.0 system interface. It is Intel's stated intention to make ExCA an industry standard so that different types of cards (memory, LAN, modem, and wireless communications) from different manufacturers will be interoperable.

Do Memory Cards Replace Hard Disks?

Strictly speaking, memory cards are not hard disk replacements. Rotating media have not been terribly successful with removable hard disks. A number of companies have tried that approach, but technology and costs kept it out of the mainstream. Thus, after a decade of using PCs, we are conditioned to think of hard disks as storage devices that belong inside the PC enclosure. This idea is a technology-dependent perception, and there is no reason why it should be so. On the other hand, memory cards, being a solid-state storage medium, are removable and portable. At a density of 20Mb, is a memory card acting like a "removable hard disk"? We believe that it is.

The Cost Issue—How Important Is It?

In 1991, the average selling price (ASP) of a 2.5-inch 40MB hard disk drive was $250.00, which translates to $6.25 per megabyte. The 3.5-inch floppy cost is close to $1.00 per megabyte. By comparison, a 1MB flash card costs approximately $300.00 or $300.00 per megabyte—a substantial disparity! Semiconductor memory certainly costs more.

The question is, "Can you put a floppy disk drive in a palmtop PC to take advantage of that cost disparity?" The answer is, "No." There is not enough power (or space). *The issue, then, is not cost.* Here the removable storage medium dictates the product's capabilities and its success or failure in the marketplace. Without a memory card, a palmtop is nothing more than an electronic organizer. It is the memory card that transforms a palmtop into a full-fledged personal computer.

Flash memory cards hold the promise of becoming the least expensive form of solid-state storage.

Cost Reduction

Flash memory cards hold the promise for becoming the least expensive form of solid-state storage. From a cell standpoint, flash rivals that of DRAM. Unlike DRAM or SRAM, it is nonvolatile, which means there is no need for battery backup. The need for bulk erasing of current-generation flash ICs creates a problem that requires clever solutions. With SRAM or DRAM cards, a single byte can be erased; EPROM-derived flash most often can be erased at the chip level (i.e., the whole chip). Recently, some vendors have announced products that allow erasure of particular memory segments. A prime example is the Intel 28F001BX 1Mb flash memory, which is segmented into areas of one 8KB, two 4KB, and one 112KB—all of which can be independently erased and programmed. EEPROM-derived flash is far more flexible at a cost premium (larger die). Flash EEPROM cells are larger than flash EPROM. Mask ROM memory cards will be the least expensive for the foreseeable future.

Data Compression ICs

Data compression ICs represent a key development for the electronic photography market and, to a lesser extent, for palmtop and pen-based PCs. Data compression ICs will be the subenabling technology devices. Without them, the future of electronic photography is in doubt. Thirty-six exposures (pictures) can be stored in a 2MB flash memory card in compressed form. If no compression were used, 40MB would be needed!

XIP

Simply stated, XIP allows a memory card to "plug-and-play." That is, once the card is plugged into the PC, program execution begins much in the way a program runs after one types in the program name and hits carriage return. That procedure is in contrast with current-generation PC architectures that need to copy the program code from secondary storage (hard disk or floppy) to main memory (DRAM) before execution. A palmtop PC with XIP capability needs just a single copy of a program, usually stored in the memory card, thus freeing up main memory.

The Players—Solid-State Disks

A number of companies are working on solid-state disk (SSD) replacement—a challenging task, to say the least. SunDisk Incorporated, located in Santa Clara, California, chose to focus primarily on hard disk replacement (solid-state disk) with a proprietary flash memory technology and architecture. The venture-capital-funded start-up launched three SSD products recently, all aimed at pen-based and palmtop PCs. The 2.5/5/10MB SSD plug-and-play subsystems come with an IDE industry-standard interface.

Toshiba announced a 4MB 5V EEPROM IC (TC58400) that is aimed at the SSD market. This device is by far the most dense EEPROM introduced to date. Architecturally, it is organized in a way that should facilitate SSD implementations. Toshiba uses a NAND cell structure that is 70 percent of its 4Mb DRAM cell; it is manufactured using a 0.7-micron double-poly CMOS process. The die size is $58.55mm^2$.

Hitachi announced a 5.25-inch form factor SSD based on 4Mb DRAM technology. This product is targeted at CAD/CAM, imaging, and graphics systems that demand a higher I/O throughput than what hard disk drives provide. The Hitachi SSD has access time of 0.35ns, incorporates an SCSI interface, and comes in 32MB or 64MB PC boards. The SSDs may be expanded to a capacity of 320MB. The data can be protected from power failures by using an optional battery-powered backup hard disk drive.

Recent Developments in Flash Memory and SSDs

AMD announced the first single-transistor cell 1Mb flash memory device that operates from a single 5V supply. The Am29F010 is by far the fastest flash memory chip with a 45ns read access time, a feature that may eliminate the need to download the flash data to SRAM in order to improve execution time. The Am29F010 is segmented into eight 16KB sectors that can be independently programmed/erased. Endurance is 100,000 cycles per sector.

Intel announced an 8Mb flash memory device and the series-2 flash memory cards based on this new flash chip. The 28F008SA can store 1MB of data or code, and by virtue of its pricing ($29.90) comes close to DRAM cost per megabyte. The device uses a 5V power supply for read operations and a 12V supply for write/erase. A 3.3V (read) version is available for portable applications. This traditional single-transistor cell-based design offers 100,000 cycles for endurance rating and 85ns access time. The memory array is segmented into 16 64KB blocks that can be independently erased/programmed. The 28F008SA is the highest-density flash memory offering to date. The series-2 memory cards are based on this new 8Mb flash memory and come in 4MB, 10MB, and 20MB densities priced at $163.50, $331.50, and $611.50, respectively. These cards are clearly aimed at mass storage applications.

AT&T entered the memory card and solid-state disk market by second-sourcing Sun Disk's IDE interface SSD subsystem and card architectures.

Microsoft announced the Flash File System (software), which supports Intel's 8Mb devices. The FFS-2 is now in beta sites and should be available later this year. Microsoft's Flash File software is a key component and necessary for solid-state disk subsystems that (unlike the SunDisk solution) will use off-the-shelf flash memory ICs.

The PCMCIA has ratified the technical content of two new standards for mass storage on memory cards. The PCMCIA-ATA (AT Attachment) specification incorporates the ATA mass storage protocol as a PCMCIA standard for mass storage on a memory card. The Auto Indexing Mass Storage (AIMS) specification is for memory cards that will be used in electronic imaging and multimedia applications.

Some Thoughts on the Future of Memory Cards and PCs

In the past, the computer was the expensive component and the storage medium (floppy disk) the inexpensive one. We've become accustomed to that oddity and do not seem to question it. However, the computer is just a machine that manipulates information. It is the information that is important and valuable, not the machine that manipulates it. So perhaps it is fitting that the information carrier, a memory card, may cost more than the computer it is attached to. In the future, we will be using platforms (palmtop PCs) that cost much less than the storage media (memory cards) they use. Imagine a $50 PC attached to a $100 memory card. At least losing the PC will not be a problem anymore!

Dataquest Perspective

Dataquest believes that memory cards represent an important enabling technology. They have the potential to transform still photography and to make the 35mm film and cameras that use it obsolete. In the process, they will change that industry and provide tremendous opportunities for growth in the consumer electronics market.

Memory cards will not eliminate rotating magnetic media any time soon. Instead, they will selectively replace them only when and where it makes sense. The bulk of the memory card growth will not come at the expense of rotating media. Growth will come from the creation of new markets. This should be good news for the semiconductor memory industry.

Ultimately, we believe, memory cards may revolutionize portable PCs by enabling them to become smaller, more rugged, lighter, faster, and perhaps user-friendly in a way that appeals to the vast majority of people who at present have no use for them. In doing so, memory cards may be the enabling technology that will make the PC of the future a true consumer item.

Chapter 9
Pen-Based PCs

This chapter looks at what are described as "pen-based" PCs. Whether the term is appropriate for a PC classification is debatable. After all, the "pen" is just a PC input device similar to the keyboard or the mouse, and we do not differentiate PCs on that basis. Having said that, we will let this argument be resolved in the future; perhaps the term pen-based will disappear. In this chapter we use this term as currently accepted.

Pen-based computers (PBCs) represent a new class of machines that quickly captured the spotlight in personal computing. These computers may evolve into something significantly different from today's PCs. It is safe to say that current advances in technology have allowed us to revisit the past, the past being the use of pen and paper as the primary form of communication.

Today's pen-based computer is a notebook PC minus the keyboard. The user interacts with the computer using a penlike device. The pen is the primary input device and as such it is no different than a mouse, except in its (familiar) ease of use. It is very difficult to sign or free-form write using a mouse, which is a pointing device.

The pen is much more. Together with the software and the hardware that drive it, the pen turns an ordinary PC into a useful, easy-to-use tool. At least, that is the expectation, which is partly derived from our familiarity with using pens and our belief that computers are useful tools. Combining the two makes sense.

The pen may or may not be connected to the computer by a cord in a pen-based system. There are basically three types of pens: The resistive type connects to the PC like a mouse; the capacitive and the electromagnetic types need no connection. There are pros and cons to any type of pen used. But the pen should not be considered by itself; the software and hardware that drive it form an entity that either works or renders the pen-based computer useless. Specific implementation is a key element in the design of pen-based systems.

The keyboard is an option; most pen-based computer manufacturers offer one because a keyboard is a far more convenient device for entering text of any length. Most people can type faster than they can write. Then again, a keyboard isn't necessary for the millions of people who never learned how to use one effectively. This is a subtle but important difference that differentiates pen-based computers from traditional PCs. A far greater number of people can use a pen than can use a keyboard. By using a pen as an input device instead of the keyboard, computer manufacturers can tap a much larger market than that served by traditional PCs.

Meeting Potential

Pen-based PCs represent a new field in computers and as such need a lot of polishing to reach their potential. The major stumbling block at present is the lack of operating systems, which in turn translates into a limited number of software packages that can run on any given hardware platform. Early hardware entries had to use operating systems developed in-house and thus limited or eliminated the possibility of using off-the-shelf software applications. So far vendors of hardware have taken one of the following approaches:

- Developed in-house proprietary operating systems (OSs) and applications—for example, spreadsheets, personal information management (PIM) software, and word processors
- Used beta-site OS for pen computers from software vendors such as Microsoft Corporation and GO Corporation to develop applications (however, this ties their hardware releases to the release of the OS; NCR Corporation is an example)
- Implemented both of the above (Momenta Corporation developed a proprietary OS that can run either off-the-shelf Windows applications or in-house-developed software such as a PIM, a word processor, and a Lotus-like spreadsheet)

Specifications

A typical pen-based computer today weighs 5 pounds and is about 8 × 11 × 1.5 in. It is able to run on batteries for three to six hours, depending on actual use and power management implementation. It is usually built around an Intel Corporation 20-MHz 386SX, 386SL microprocessor, or the newer 25-MHz 386SXL from Advanced Micro Devices Inc. (AMD). Main memory (DRAM) ranges from 2MB to 8MB for a standard configuration. The video graphic array (VGA) display is a 10-inch (diagonally measured) LCD with 640 × 580-pixel resolution and 16 to 32 shades of gray.

For mass storage the typical PBC uses a 40MB, 2.5-inch hard disk. Some PBCs use solid-state storage devices such as the 20MB solid-state disk from SunDisk Inc. or flash memory and flash cards. PBCs have no internal floppy and thus rely on communications software for uploading or downloading data. Alternately they use PCMCIA-type memory cards or docking stations for data transfers.

For communication PBCs typically offer an integrated modem/fax line, which simplifies connectivity. Some units offer modem/fax/voice capability.

The market for pen-based computers is relatively bright (see Table 9-1). Unit sales are expected to grow from 96,000 in 1991 to

Table 9-1
Worldwide Portable PC Market Forecast (Thousands of Units)

	1991	1992	1993	1994	1995	1996	CAGR (%) 1991-1996
Laptop DC	2,764	3,101	3,392	3,669	3,933	4,114	8.3
Notebook	1,136	1,794	2,816	4,393	6,809	9,464	52.8
Pen-Based	41	122	800	1,759	3,289	5,098	163.0
Hand-Held	238	763	2,042	3,877	6,188	7,314	98.5
Total Portable	4,179	5,780	9,050	13,698	20,219	25,990	44.1

Source: Dataquest (October 1992)

about 4.4 million by 1995. The compound annual growth rate (CAGR) for pen-based computers is 159.75 percent from 1991 to 1995, the highest in the portable PC market. The expected revenue also is substantial, as the average selling price is at least similar to that of a notebook PC.

Figure 9-1 represents the worldwide market forecast for pen-based computers.

Figure 9-2 shows pen-based PCs over the same period (1991 to 1995) as a percentage of the total portable computer market. At 2 percent in 1991, the market is expected to grow to 15 percent by 1995.

The semiconductor content for a typical pen-based computer retailing of a $3,000 system is about $330. Figure 9-3 shows the cost distribution on a percentage basis. DRAM represents about 36 percent of the semiconductor content (in dollars). This amount is expected to increase, driven primarily by memory-hungry pen-based OSs.

Table 9-2 shows the semiconductor cost breakdown of a current-generation pen-based computer.

Figure 9-4 shows Dataquest's total available semiconductor market estimate. Semiconductor revenue derived from PBCs will exceed $1 billion by 1994.

Major players in pen-based computing that offer hardware products include GRiD Systems Corporation, Momenta Corporation, NCR, Samsung, Sanyo Electric Co. Ltd., and Sony.

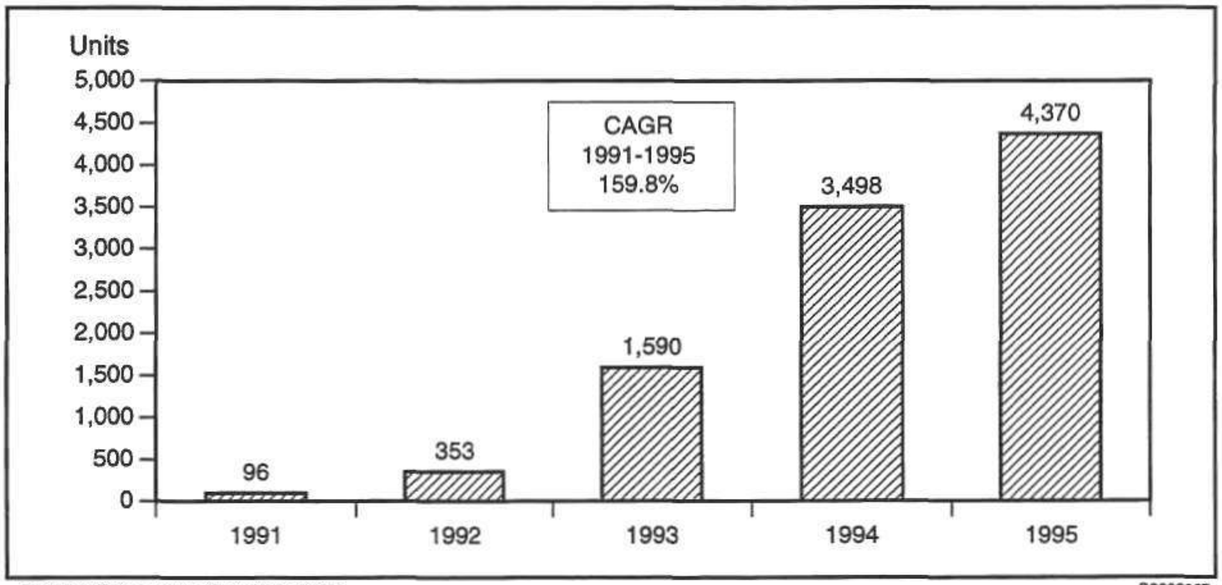
Major players in pen-based operating systems include GO Corporation (Pen Point), Microsoft (Pen Windows), and Communications Intelligence Corporation (PenDos).

Table 9-2
Semiconductor Content, Typical Pen-Based Computer

	Cost ($)
MPU	90.00
Main Memory (4MB DRAM)	120.00
System Logic	70.00
Graphics Controller	25.00
Video Buffer (PS-RAM)	8.00
Analog	10.00
Local Buffers (SRAM)	4.00
Logic	3.00
Total	330.00

Source: Dataquest (October 1992)

Figure 9-1
Worldwide Pen-Based PC Market Forecast (Thousands of Units)



Source: Dataquest (October 1992)

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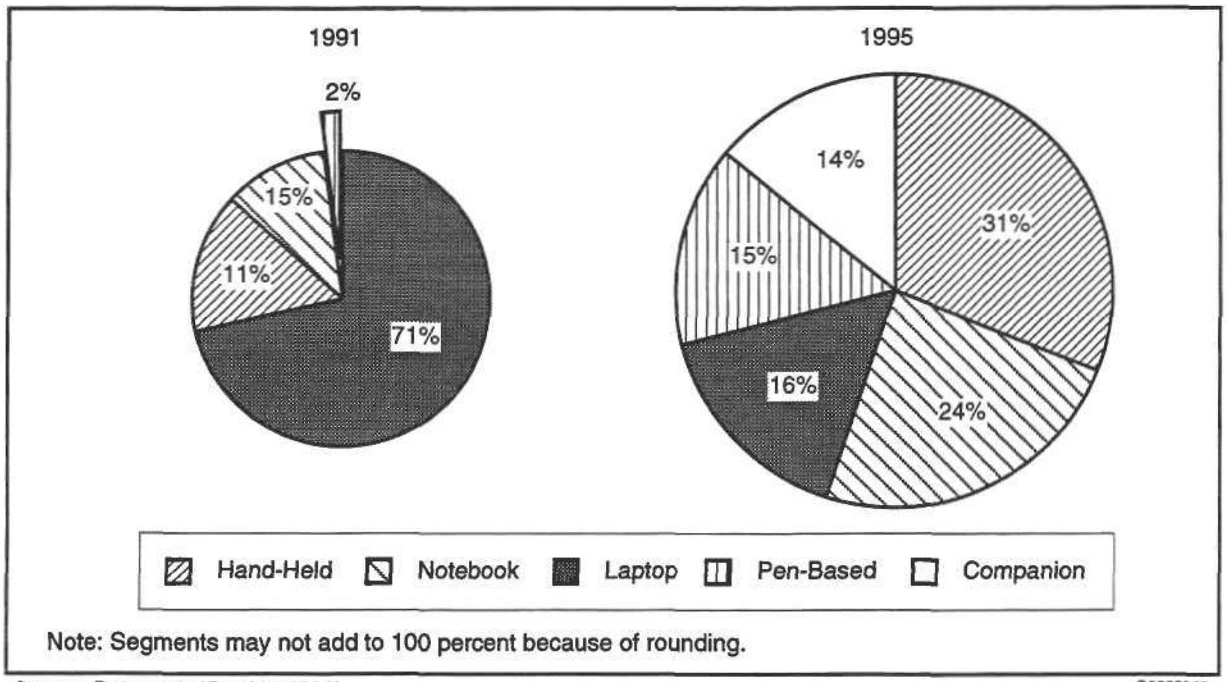
Figure 9-2
Portable PC Market, 1991 and 1995



Source: Dataquest (October 1992)

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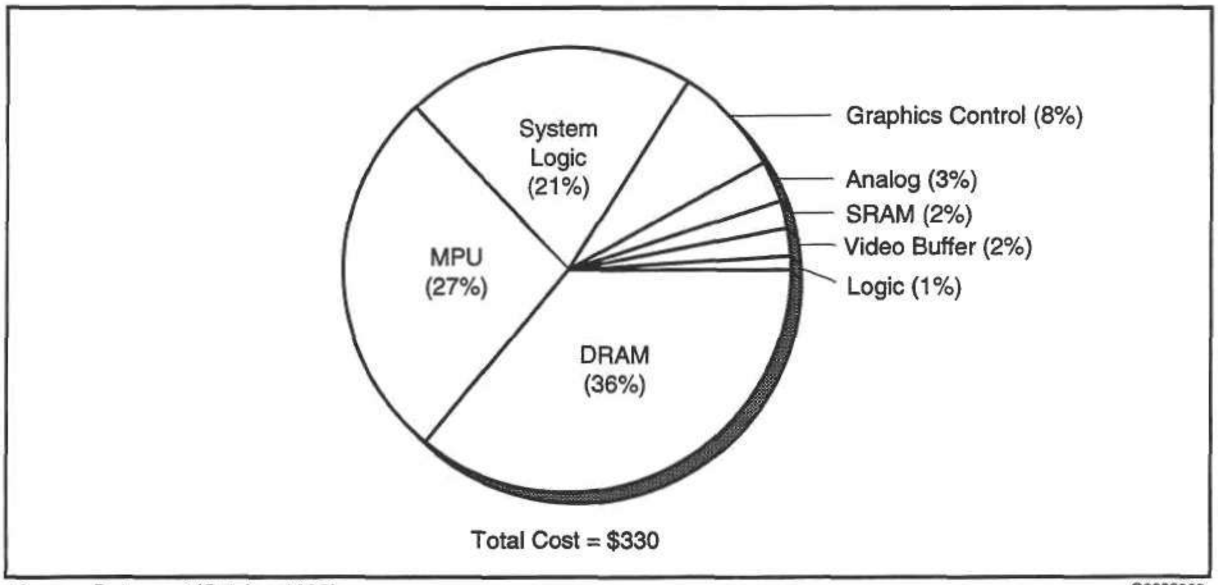
Figure 9-3
Semiconductor Content Cost for Pen-Based PCs



Source: Dataquest (October 1992)

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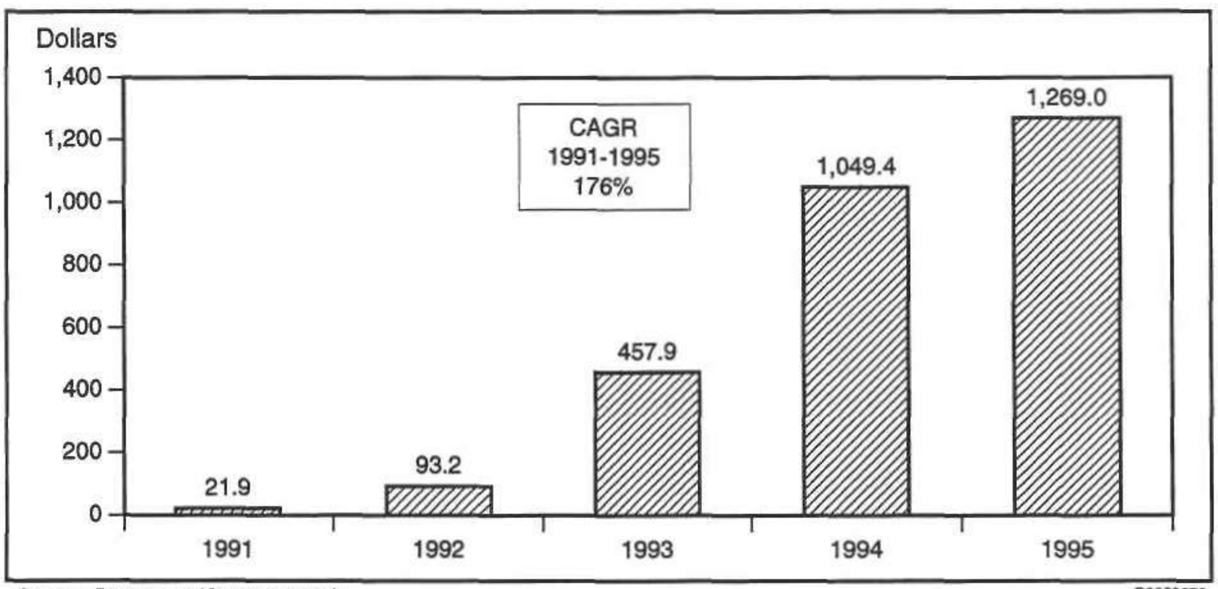
Figure 9-4
Estimated Total Available Semiconductor Market, Pen-Based Computers (Thousands of Dollars)



Source: Dataquest (October 1992)

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Who is shipping OS? Both Pen Point and Pen Windows are at a beta-site stage right now. Both products are expected to be released by the second quarter of 1992. This delay in operating system introduction has retarded the availability of pen-based computers.

Handwriting Recognition

Even though handwriting (character) recognition is desirable for a pen-based computer, at present it is not a critical item. Momenta's approach is (and rightly so) that the computer does not need to recognize everything sketched onto the screen. This position follows the logic that notes entered into a daytimer are for private use and need not be transcribed; they just need to be stored for future reference/retrieval.

Connectivity/Docking

A PBC is quite effective as a field or factory floor instrument, but it needs to download the information captured to a mainframe or a PC. That can be accomplished in a number of ways: using a PCMCIA (68-pin) port and memory cards as the transfer medium, or by using radio frequency or infrared communication. A docking station is another alternative.

With respect to communication, current-generation pen-based computers typically offer an integrated modem/fax. The addition of the fax capability is quite handy because it allows a user to receive or send a fax from any place that has a phone jack or to use a cellular phone from practically anywhere.

Applications

Pen-based systems are already used in retail stores. Customers sign for credit card purchases right on the screen of the pen-based PC, which captures the signature in a digitized form and stores it in a hard disk for after-hours phone transfer to a credit card clearing bureau. The use of a PBC instead of the regular credit card imprinter for signing for a purchase speeds up the transaction. Future off-line signature verification will be possible using a smart card (where the customer's signature stored in the smart card's nonvolatile memory is in binary form).

PBCs are very good at applications that require filling out forms. A good example is their use by public utility companies for reading electricity, water, and gas meters. Police departments use them to replace paper forms for traffic violations. In manufacturing they are used to fill out inspection reports. Banks and investment companies use PBCs to fill out standard contracts. They also are quite popular with insurance adjustors and are finding their way into real estate sales.

Dataquest Perspective

As is the case with anything new, it will take some time for pen-based systems to reach their potential. Today lack of operating systems is retarding the growth of this segment. This situation should change in

1992. From a CAGR point of view, pen-based PCs stand out. Over time the distinction between palmtops and pen-based computers may become blurred as palmtops begin to incorporate a pen as an input device. The fax communications capabilities of pen-based computers make them extremely useful to a great number of people who are on the go, substantially enhancing the total available market for pen-based systems. Dataquest believes that pen-based computers offer a significant market growth opportunity for systems manufacturers, software developers, and semiconductor vendors.

Chapter 10
Winds of Change in Mass Storage

Emerging micro rigid disk drives (micro RDDs), as exemplified by the 1.3-inch RDD recently launched by Hewlett-Packard, are challenging memory cards and solid-state disks used in hand-held PCs.

Is there any evidence to suggest changes in the mass storage industry, and what sort of changes are we seeing? The answers to the first question depends on how a disk drive, or better yet a mass storage device, is defined. If the traditional definition is expanded to include flash memory (semiconductor)-based solid-state disks (SSDs), then the answer is yes. Further confusing the issue is what one considers to be a mass storage company. For example, is Intel also a mass storage company? What about SunDisk, whose products are silicon-based?

No one is taking chances, if the Intel-Conner Peripherals joint venture is any indication. It is very unlikely that Conner feels threatened by flash memory-based SSD alternatives to RDDs for the near future. However, it early on realized the potential of the new technology and opted to capitalize on the opportunities to expand sales. Besides, the chosen route (teaming with Intel) offered the most logical and symbiotic relationship, with each company contributing strengths to the partnership: flash memory technology from Intel and subsystems storage expertise from Conner. More such alliances should be on the way in an attempt to serve the needs of the mass storage marketplace, and should come as no surprise to the participants. For companies looking at entering the market, this is food for thought.

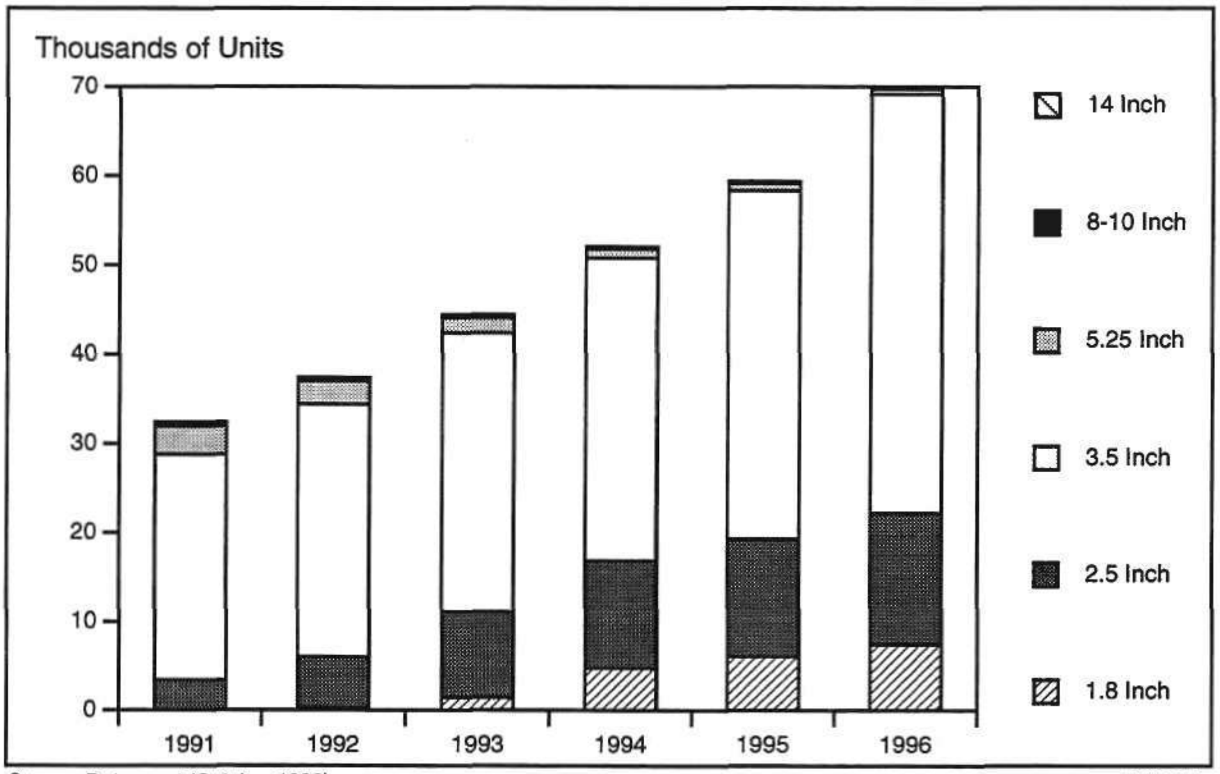
Forecast Uncertainties

The 3.5-inch hard disk drives represent the dominant form factor, at least through 1996 (see Figure 10-1). From a Semiconductor Application Markets group standpoint the wild card in this market forecast is the emergence and quick acceptance of the new small form factor hand-held computers, that is, the PICD.

As a category, PICDs describe hand-held PCs such as Apple's Newton and future HP 95LX type derivatives, as well as small pen-based machines. Will such devices be in volume production by 1996? If they are, what form of mass storage will they use? The answers may depend on one's point of view.

For PICDs to be successful, they must be small, light, easy to use (intuitive), and relatively inexpensive. They also must possess good communications capabilities. The need for portability and light weight

Figure 10-1
Worldwide RDD Market Shipments (in Thousands)



Source: Dataquest (October 1992)

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dictates the mass storage requirements. PICDs are not meant to replace desktop PCs and as a result are not required to incorporate excessive amounts of software. The bare minimum amount of mass storage is needed. Because PICDs will communicate over wireless (or wired) networks with mainframes, home, and office computers, embedding massive amounts of storage solves no problems. Indeed, it adds weight, power consumption, and cost. Forecast uncertainty results from the possibility of early PICDs' success, which may consume substantial volumes of 1.3-inch (or smaller) drives. In such a case, this forecast may be conservative because it does not fully address that new PC subcategory.

Cost Alternatives: Micro Drives versus Solid-State Storage

We know that at present semiconductor storage is a much more expensive form of mass storage than are RDDs, so why discuss the matter? The reason is that the new generation of PICDs may or may not use RDDs for mass storage, depending on the outcome of a head-on competition to satisfy the following conditions, which are seen as necessary for adopting a mass storage medium: Mass storage devices for use in PICDs must be rugged, small and lightweight, low in power consumption, and inexpensive.

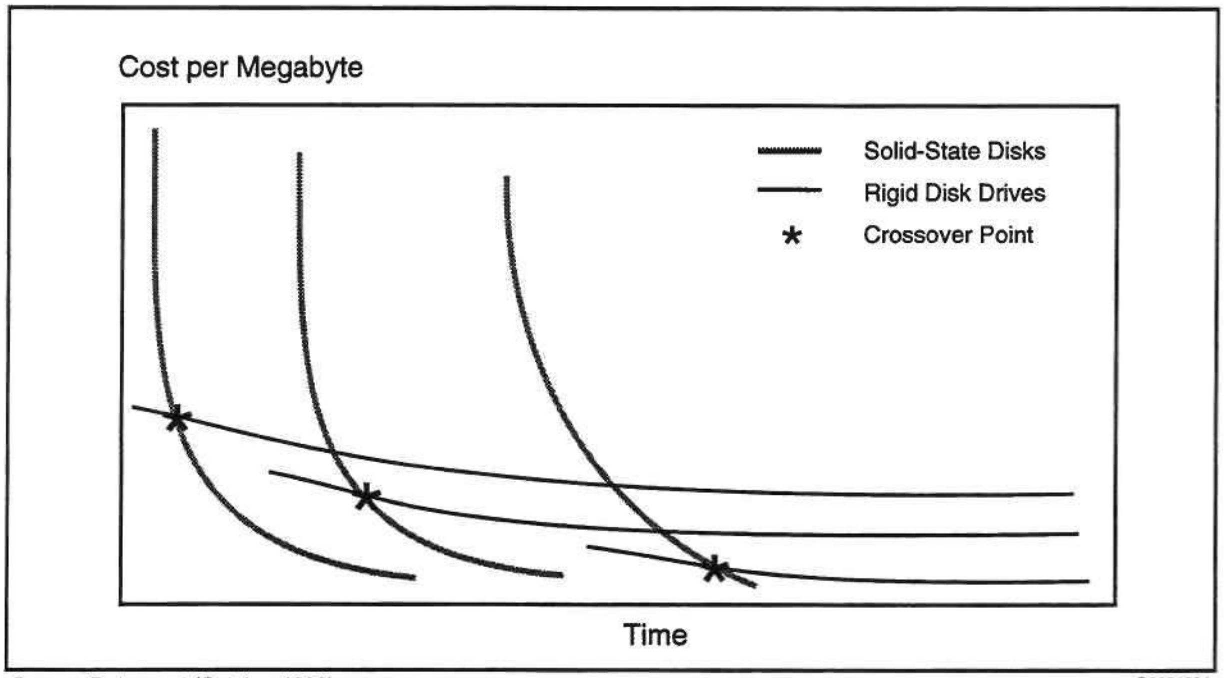
So far RDDs have not satisfied these requirements. SSDs do well with the first three, but are about five times the price of RDDs. The 1.3-inch RDDs are expected to do better addressing the conditions. But SSDs are expected to close the cost gap to 3.5 times that of the 1.8-inch drives by 1996 and perhaps to do even better when compared with 1.3-inch or smaller RDDs. Ultimately, of course, cost determines whether a particular technology gets used or not. But are we talking about the cost per megabyte or the overall system cost? This is the key question and it involves a bit of an understanding and prediction of the ways PICDs will be used.

Because PICDs are not going to replace desktop PCs but instead will be the take-along device, there is no need to duplicate the power of the desktop. Instead we need to tap into that power remotely, thus the emphasis on the communications capabilities of PICDs, which in turn dictates that only a small amount of mass storage may be needed for local processing. Thus, 10- to 20MB may suffice (effective storage of 20- to 40MB with compression). The SSD cost of the system should be $50 to $100 by 1995. It is unlikely that a 20MB, 1.8-inch drive will cost $30 (20 times $1.50), as such a cost is based on a much higher disk density. The most likely scenario is that the SSD and the HDD will cost the same for that density. If that happens, then solid-state storage will be the medium of choice, because it fares much better for the requirements delineated earlier.

So, is it time for semiconductor vendors to celebrate? RDD manufacturers offer formidable competition for anyone that ventures into the mass storage arena with SSD solutions. And so far RDD makers have been able to come up with substantial cost and technology breakthroughs whenever the requirements demanded. The infamous cost per megabyte curves for RDDs and SSDs have been drawn so as to cross over at some point, and that point has been moving forward for the past 20 years (see Figure 10-2), sparking many heated debates in the process. The real question is whether these two curves must cross. Given the preceding discussion, the answer may be no.

Figure 10-3 shows Dataquest's cost-per-megabyte estimates for flash memory-based SSDs and RDDs. The 1.8-inch drive is used for comparison because it represents the current candidate (along with the 1.3-inch) for head-on competition with solid-state storage in the emerging PICD market.

Figure 10-2
Cost per Megabyte, RDDs and Solid-State Disks



Source: Dataquest (October 1992)
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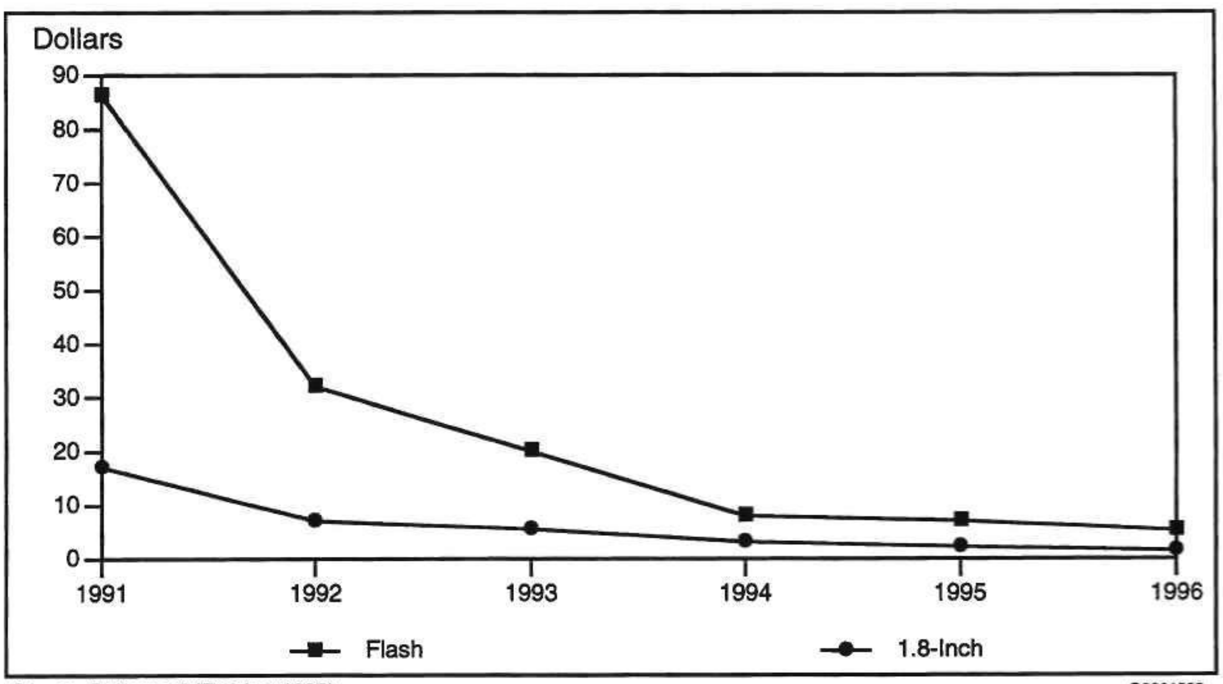
Figure 10-3
Cost per Megabyte, 1.8-Inch RDDs versus Flash Cards



Source: Dataquest (October 1992)
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a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

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