Semiconductor Application Markets *Worldwide*

Dataquest Perspective

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Semiconductor Application Markets *Worldwide*

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Dataquest Perspective

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October-December 1991 **January 31, 1992**

How to Use This Index

This is a cumulative index of key industry terms, companies, and products for all 1991 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 all 1991 issues of *Dataquest Perspective*—listing each issue number, date, and article title—is included at the end of the index.

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

Vol. 1, No. 1 October 7, 1991

Market Analysis

Market Analysis

Memory Cards: An Emerging and Potentially Explosive Market

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 1).

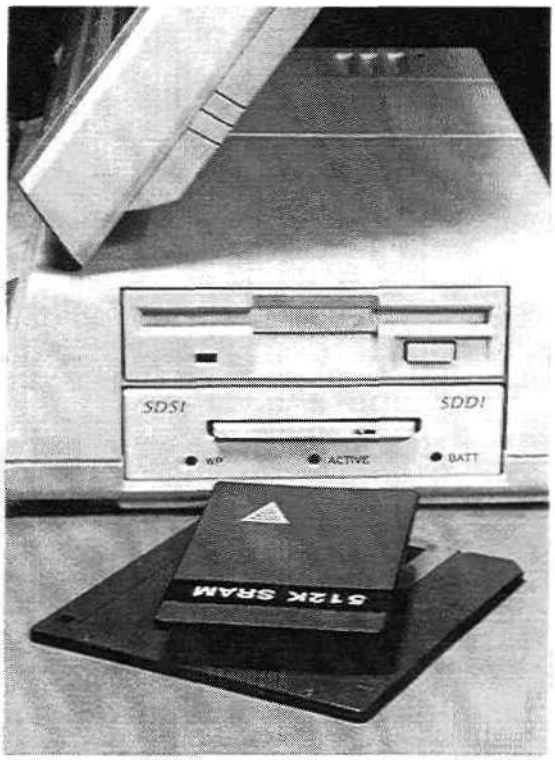
Memory cards perform a function similar to that of a floppy disk. They store binary data.

As program or data storage media, memory cards are not new; they have been around for at least 20 years. 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 Poquet and the HP 95LX have begun using memory cards for data storage. Figure 2 shows their application in portable PCs.

Figure 1
Example of Memory Card

Source: Intel Corporation

Figure 2
Memory Card Usage in a Portable PC



Source: Adtron Corporation

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 were the

Table 1
Memory Card Alternatives

Type	Density
ROM	32KB—16MB
EPROM/OTP	32KB—2MB
DRAM	64KB—12MB
SRAM	32KB—2MB
EEPROM	32KB—256KB
Flash	32KB—4MB

Source: Dataquest (October 1991)

only nonvolatile memory cards. Flash memory ICs 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 1 lists the various memory card alternatives.

Memory Card Applications

Memory card applications include the following:

- Personal computers
- Factory automation
- Instrumentation and testing
- Avionics
- POS terminals
- Musical equipment
- Medical instrumentation

On Standards

What inhibited memory card growth in the past was the lack of standards. In June 1989, the Personal Computer Memory Card Industry Association (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/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

The PCMCIA worked closely with the Japan Electronic Industry Device Association (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 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 has 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 20 years of 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, say, 20Mb, is a memory card acting like a "removable hard disk"? We believe that it is.

Memory cards have the following advantages over floppy/hard disks:

- Faster access and transfer rates
- Space, power, and weight reduction
- More ruggedness

However, they do have the following disadvantages:

- They are expensive.
- They have lower capacity.

The Cost Issue—How Important Is It?

In 1991, the average selling price (ASP) of a 2.5-inch 40MB hard disk drive is $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.

The Memory Card Market

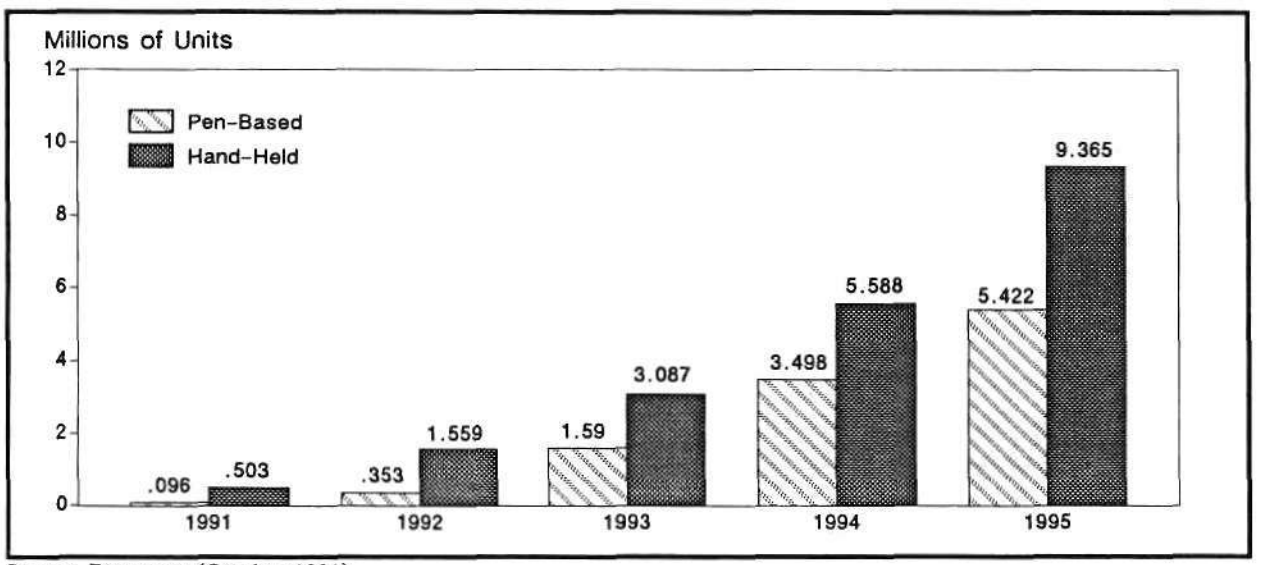
As with any emerging technology, market size projections are difficult at best. The following assumptions may be used to gauge a portion of the total available market:

- The majority of palmtop and pen-based PCs will use memory cards (80 to 95 percent).
- The ratio of 1 to 3 cards per system for 1991 will increase to 3 to 5 by 1995.
- A portion of notebook PCs will use memory cards (10 to 20 percent over the same period of time).

Figure 3 provides some useful boundary conditions. Dataquest expects worldwide shipments of pen-based PCs to grow at a compound annual growth rate (CAGR) of 174 percent, from 96,000 units in 1991 to nearly 5.5 million units in 1995. At the same time, hand-held PC shipments will grow at a 108 percent CAGR from 503,000 units in 1991 to approximately 9.4 million in 1995. Together they amount to approximately 600,000 units in 1991, growing to almost 15 million by 1995. Some simple assumptions on memory card average selling prices indicate that this could easily become a billion dollar market by 1995.

Memory cards used in non-PC applications (which may account for as high as 90 percent of total memory card shipments in 1991 and 40 to 60 percent by 1995) are not included in this discussion. Electronic still photography alone may provide an explosive market for memory cards.

Figure 3
PCs Employing Memory Cards



Source: Dataquest (October 1991)

What Are the Key Developments Needed for Memory Cards to Succeed?

Three developments are necessary for the success of memory cards. These developments and the applications where they are needed are as follows:

- Cost reduction—all applications
- Development of data-compression ICs—electronics "filmless" still photography and PCs
- XIP—palmtop PCs

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!

eXecute-in-Place (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) to main memory (DRAM) before execution. A palmtop PC with XIP capability needs just a single copy of a program, usually stored in a mask ROM memory card.

The Players—Memory Cards

Table 2 lists some of the companies active in the memory card market and their products.

Table 2
Memory Card Offerings

Intel	1MB flash cards
	4MB flash cards
Fujitsu	256KB to 1MB flash cards
	512KB to 16MB mask ROM memory cards
	128KB to 1MB OTP memory cards
	256KB to 1MB EPROM memory cards
	64KB to 2MB SRAM memory cards
Mitsubishi	256KB to 2MB flash cards
	512KB to 16MB mask ROM memory cards
	128KB to 192KB EEPROM memory cards
	64KB to 512KB SRAM memory cards
	512KB to 12MB DRAM cards
Texas Instruments	1MB to 4MB DRAM cards
	64KB to 512KB OTP cards

Source: Dataquest (October 1991)

Other companies include Datakey, DuPont, Epson, Fujisoku, ITT-Cannon, Maxell, and Oki.

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. With backing from AT&T and Western Digital, 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. SunDisk is working with Apple, GRiD, IBM, and Polaroid. The company claims a 40MB capacity on two SSD cards. Memory cards are next. Another semiconductor start-up company that uses flash memory and a proprietary serial architecture optimized for solid-state disk replacement is NexCom Technology Inc., located in Santa Clara, California. Toshiba is thought to be working on a 4Mb flash SSD as well.

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 $50.00 PC attached to a $100.00 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. ■

By Nicolas Samaras

Control Applications: The Big Part of the Iceberg

An estimated 70 percent of all semiconductors are used for control, or non-user-programmable applications. Items ranging from computer peripherals, to public telephone switching, to the family car represent such usage of semiconductors. If the semiconductor market was characterized as an iceberg floating at sea, the high profile PC and computer system markets would be the tip above the waterline and control applications would be the large portion below the water. The purpose of this article is to characterize some of the larger-volume control application opportunities.

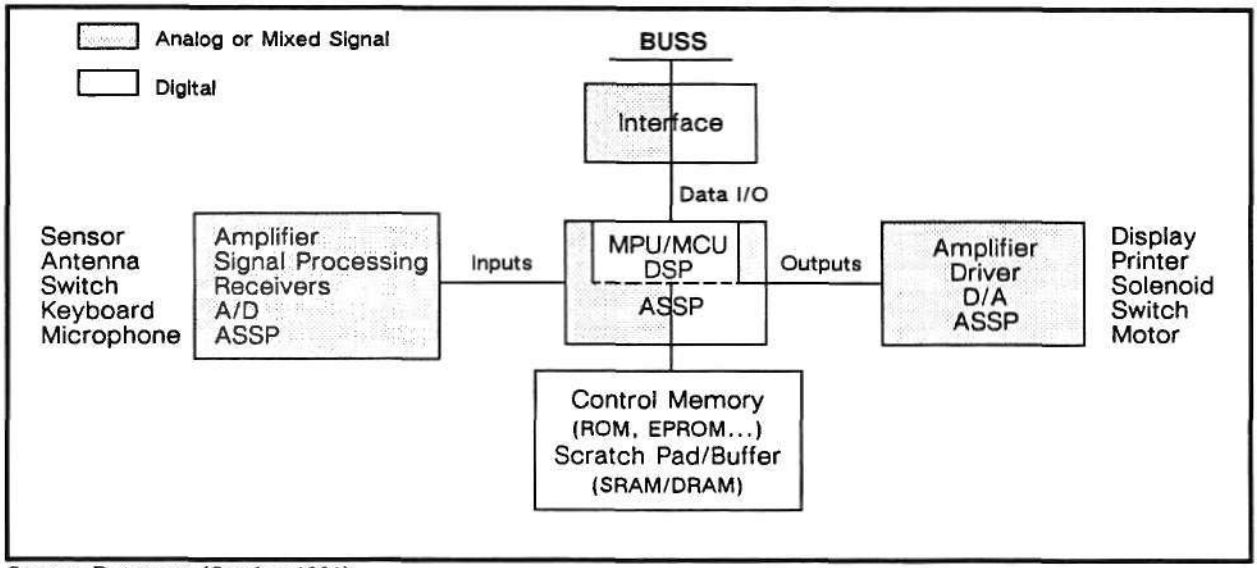
Analog World Differentiates?

There are literally thousands of different types of control applications. Almost all have to do with the management or automation of analog world events. A laser printer generating a printout; the engine control unit managing fuel, air, and spark; and even the precise movement of welding robots are examples of these events. Control applications vary depending on what kind of data, signals (sensor or actuator), or power they manage (see Figure 1). Generally, modern control applications utilize an array of functionalized and general-purpose analog circuitry for input and output and microcomponents, ASICs, ASSPs, and memory to implement the control intelligence.

High-Volume Opportunities

Most control applications never witness more than a few thousand units of production (particularly many instrumentation, factory control, and

Figure 1
Generic Control System



Source: Dataquest (October 1991)

mil/aero applications). Often these types are designed around architectural backbone standards like VME, AT, or PI bus. Some applications such as motor control (often counted as part of other applications, e.g., disk drives) involve tremendous unit potential but remain very fragmented.

Table 1 list some high-volume control applications. Cost sensitivity coupled with system feature enhancement is paramount for most of these applications. Almost all of these applications lend themselves to ASSP development where the NRE can be amortized over the volume. ASSPs help reduce board chip count and increase functional density. ASICs are often used in the first generation of a product or to support proprietary product differentiation.

Computing Power: Embedded MPUs—A Growing Alternative?

As can be concluded from Table 1, control applications can be a real fab filler. Most consumer electronic designs use either custom or 4-bit MCUs today. The trend is toward incorporating 8-bit MCUs in some consumer electronics as more features are added for product differentiation. The 8-bit MCUs are finding increased usage in audio system and various automotive control modules like the antilock braking system (ABS). Mass storage designs are beginning to move out of 8-bit MCUs into 16-bit MCUs and DSPs. Image handling (printers, digital video, HDTV, etc.), performance graphics, networking, cellular communications, and auto engine management applications are moving to 32- or 64-bit levels if they are not there already.

At the 16- and 32-bit performance levels, 16-bit MCUs, embedded 16-bit MPUs and 32-bit RISC MPUs, as well as 16- and 32-bit DSP units are competing for the designer's choice. Such 16-bit versions as the 80186, 68000, 32010, and Z8000 have been found to be extremely popular in many (embedded) control applications (see Table 2). Expect tailored variants of 32-bit RISC processors to become more popular as suppliers offer development help in the form of tools and real time software that takes advantage of RISC performance. Digital signal processors are finding greater acceptance as a new generation of user-friendly development tools (such as code debuggers) emerge.

Dataquest Perspective

Control applications represent a broad market opportunity and should be treated as such. As noted in Table 1, the high-volume applications can be very fragmented and economically difficult to target. Dataquest recommends focus as the necessary discipline when targeting one of these markets. Focus might be easy to say, but it is difficult to do. Without writing a management book, a simple recommendation is for clients to utilize their companies' relationships to identify and jointly develop compatible

Table 1
High-Volume Control Applications Worldwide

Application	Estimated Unit Volume (1991-1995) (Millions)	Semiconductor Content[1] (Dollars)	Key Design Considerations
Mass Storage			
Rigid Disk Drives	225	48	Cost reduction
Flexible Disk Drives	230	14	Cost reduction
Tape Drives	12	42	Cost reduction
Optical Disk Drives[2]	10	15-80	Cost/performance
Peripheral			
Laser Printer	40	50-200	Differentiation/cost
Fax Subsystem[3]	55	20-150	Differentiation/cost
Fax Machines	45	30-200	Cost reduction
Graphics Subsystem[3]	105	40-300	Performance/cost
X Windows Terminals	4	80-200	Differentiation/cost
Copiers	22	25-250	Differentiation/cost
Communications			
CO Switch (lines)	235	3-15	Performance/cost
LAN NICs	55	40-100	Differentiation/cost
Telephone Handsets	160	2-15	Differentiation/cost
Cellular Handsets	35	30-150	Differentiation/cost
Consumer/Auto			
VCRs	165	20-50	Differentiation/cost
Color TVs	290	18-60	Differentiation/cost
Camcorders	75	60-100	Differentiation/cost
Portable Audio	295	2-35	Differentiation/cost
Appliances (w/controls)	1,600	1-15	Differentiation/cost
Auto Engine Management	160	15-30	Cost
Auto ABS	65	15-30	Cost
Auto Stereo	240	7-25	Differentiation/cost

[1] Estimated weighted average in 1991
[2] CD-ROM to rewritable
[3] Add-in card or on motherboard
Source: Dataquest (October 1991)

Table 2
Estimated Intelligent Control Market—Worldwide (Millions of Units)

	1991	1995	CAGR (%) 1991-1995
32/64-Bit	14.4	44.0	78
16/32-Bit	16.8	33.0	18
16-Bit	49.7	268.0	52
8-Bit	681.0	1,175.0	15
4-Bit	822.0	1,200.0	10
Total	1,573.9	2,720.0	15

Source: Dataquest (October 1991)

opportunities early. Then they should prioritize funding of product development accordingly.

High-volume control applications like the ones discussed in this article offer good opportunities for products such as application-specific standard products (ASSPs). Dataquest believes that digital, analog, and mixed forms of ASSPs are an excellent way to add value and margin.■

By Gregory Sheppard

Semiconductor Opportunities in Telecommunications

Dataquest held its 1991 Telecommunications Industry conference in August. The theme of the conference (Personal & Wireless Communications: The Next Frontier) aptly describes the focus of the conference speeches and panel sessions. This article provides an analysis and summary of key semiconductor trends for telecommunications applications as gleaned from the conference.

The Applications

Semiconductors for Personal Communications Networks

The ultimate goal of a personal communications network (PCN) system is to provide every person with a low-cost pocket telephone (less than $100) that is connected to a ubiquitous digital network using low-cost microcell-based base stations. Such a pervasive digital PCN system will be compatible with existing and planned future long distance digital telecommunications networks. The goal is to provide a seamless, user-friendly network that will enable "anytime, anywhere, any person" communications.

Table 1 shows a comparison of cost/functionality for the various personal communications system types, ranging from low-cost cordless telephone systems to digital PCN systems.

PCN in the United States

The FCC has granted experimental licenses to BellSouth, Graphic Scanning, Motorola, NYNEX, and PCN America (Millicom subsidiary). Experimental licenses are pending for American Personal Communications, Ameritech, GTE, McCaw, and several others. The goal of these FCC trials is to test the technology, cost, and user-friendliness feasibility of PCN systems based on microcell-based, spread-spectrum (2-GHz) transmission using Code-Division Multiple Access algorithms. Regulatory/licensing, standards, frequency allocation, and industry structure issues are expected to be resolved for the U.S. market in the 1992/1993 time frame.

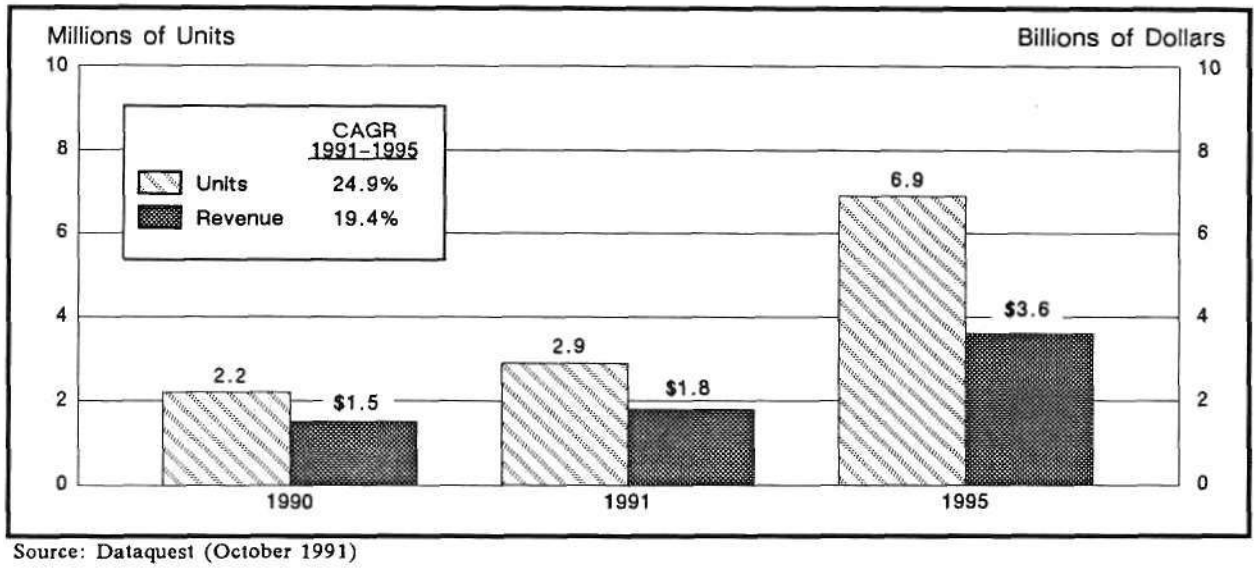
Meanwhile, the U.S. cellular telephone market is entering the analog-to-digital market transition period. Figure 1 illustrates Dataquest's estimates for the U.S. cellular telephone equipment market between 1990 and 1995. The market is expected to grow at a healthy compound annual growth rate (CAGR) of 19.4 percent, from $1.8 billion in 1991 to $3.6 billion by 1995. Dataquest expects a gradual transition from a high analog content to a high digital content in the cellular telephone equipment market by 1995. The actual digital PCN telephone market is not expected to blossom into a large, mainstream market until 1995. Beyond 1995, the digital PCN equipment market is forecast to grow rapidly to $5.4 billion by the year 2000.

Table 1
Functional Comparison of Personal Communications Devices

	CT2	Paging	Cellular	PCN
Function	Originate	Receive	Originate/receive	Originate/receive
Communications Range	200m	Metro area	>2 Miles	200M
Mobility	Limited; no handoff	High	Automobile	Pedestrian
Terminal Cost	Low ($100)	Low ($100)	High ($400-$700)	Low ($100)
Terminal Size	Small	Small	Medium/large	Small
Battery Life	High	High	Low	High
Base Station Cost	Low	Medium	Very high	Low

Source: Dataquest (October 1991)

Figure 1
Estimated U.S. Market for Cellular Telephones



Source: Dataquest (October 1991)

PCN in Europe

The Pan-European GSM digital cellular phone standard is the most well documented of the wireless PCN standards. European semiconductor companies are racing to implement the GSM standard into application-specific standard products (ASSPs) using high-density gate array/standard cells and full-custom designs. Many of these chip sets incorporate on-chip digital signal processing (DSP) cores to enable rapid A/D and D/A voice conversion.

PCN Developments

Many telecom IC companies are using application-specific integrated circuits (ASICs) (gate arrays and standard cells) in combination with programmable logic array building blocks in order to hasten time to market for the first-generation digital cellular telephone design. Dataquest anticipates that future PCN chip sets will be optimized as ASSPs using core telecom standard cells and DSP building blocks. Submicron high-performance CMOS and BiCMOS technology will enable shrinking chip counts, smaller sizes, lower power dissipation, and better performance in future-generation digital PCN systems.

The semiconductor industry believes that it can offer single-chip 0.5-micron technology CMOS/BiCMOS PCN solutions using 500K-type embedded gate arrays with optimized embedded telecom macro cells such as DSP cores, microcontrollers, ADCs, DACs, filters, cache RAM, and Codecs.

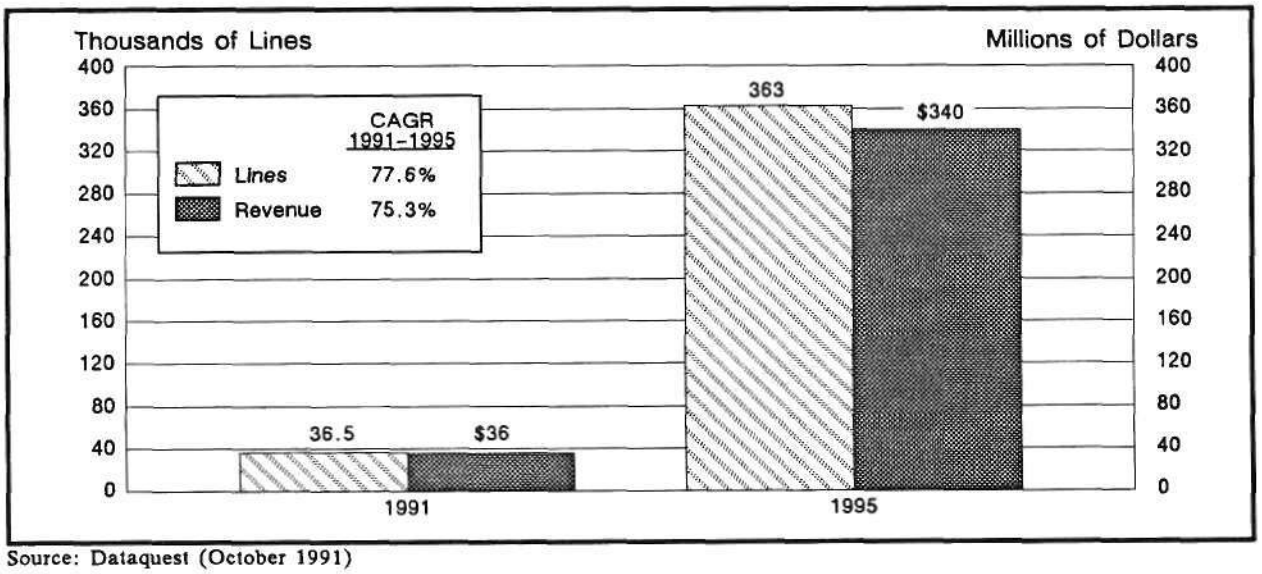
Semiconductors for Premise Telecom PBX Application

Dataquest expects wireless PBX technology to inject some life into the mature office premise PBX equipment market. Figure 2 shows Dataquest's estimate for the growth of the U.S. wireless PBX equipment market between 1991 and 1995. Wireless PBX equipment revenue is projected to grow at an astounding CAGR of 75 percent, from $36 million in 1991 to $340 million by 1995. The semiconductor market for wireless PBX pocket phones, base terminals, and network access interface cards should grow rapidly in response to the wireless PBX system growth projections.

Semiconductors for Data Communication

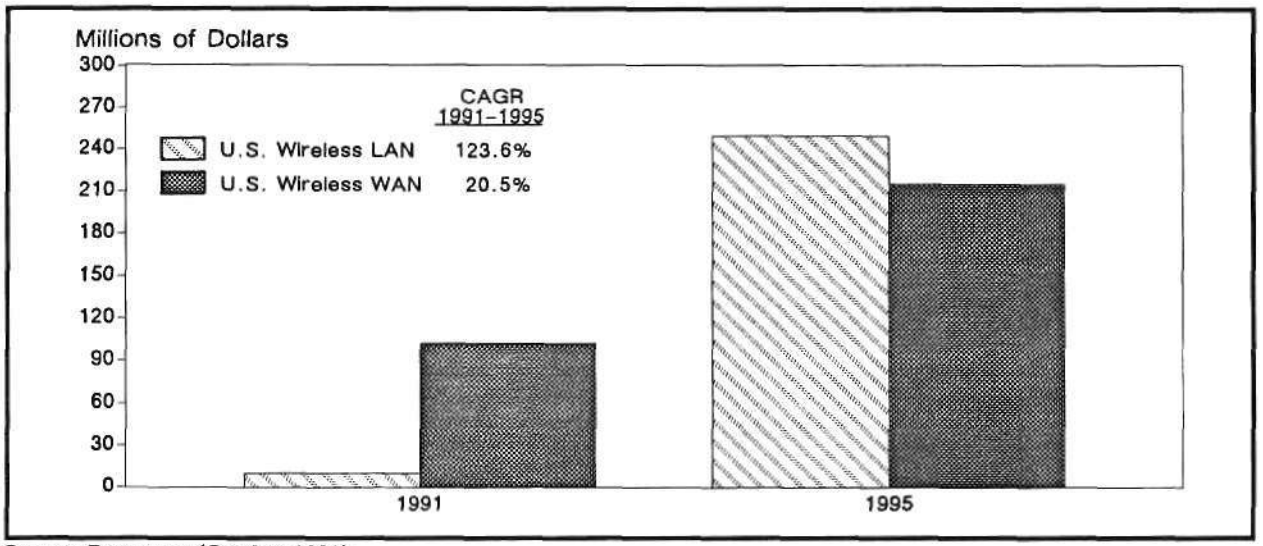
Data communication appears to be going wireless—analogous to voice communication. Much attention is focused on wireless local area networks (LANs) using RF and infrared transmisson technologies. Wireless LANs need to provide high flexibility in office configuration, low change costs, and compatibility with hardwired backbone-wired LANs and long distance wide area networks (WANs). Figure 3 shows the growth of the U.S. wireless LAN and wireless WAN markets between 1991 and 1995. The U.S. wireless LAN market, in particular, is expected

Figure 2
Estimated U.S. Wireless PBX Shipments



Source: Dataquest (October 1991)

Figure 3
Estimated U.S. Wireless LAN/WAN Equipment Markets



Source: Dataquest (October 1991)

to grow explosively at a CAGR of 124 percent, from $10 million in 1991 to $250 million by 1995. Numerous proprietary standards and protocols are emerging for wireless LAN applications using 920-MHz spread spectrum transmisson/conventional bipolar technology ICs, 18-GHz microwave transmission using high-performance gallium arsenide technology ICs, and infrared point-to-point transmission using conventional RF technology ICs.

Choice of Semiconductor Technology for Telecom Applications

Historically, telecom applications have lagged behind data-processing applications in their use of increasing very large scale integration system-on-a-chip architectures. The 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 digital cellular networks, high-speed digital data networks, and wireless transmission, a gradual segmentation of telecom semiconductor applications is occurring. High-performance CMOS technology is being universally embraced for the data compression, digital signal processing, and switching applications. Mixed-signal ASICs and ASSPs incorporating telecom core cells are being implemented in CMOS as well as BiCMOS technology, which combines the high gain/frequency sensitivity of bipolar process technologies with the integration and low-power attributes of CMOS technology. The adoption of microwave transmission standards in direct broadcast satellite communications, global positioning systems, and satellite-based global cellular telephone networks has spurred the acceptance of GaAs technology.

Dataquest Perspective

Telecommunications is shaping up to be a key semiconductor applications driver for the 1990s. The emergence of cost-effective ultralarge scale integration-level submicron chip technologies, open network systems architecture, digital cellular networks, and advanced networking software is revolutionizing the telecommunications industry. Dataquest predicts the rapid emergence of a high-volume, cost-driven, highly competitive telecommunications chip set industry that will cater to a competitive open standards-based voice, data, still-image, and interactive full-motion video communications market. Semiconductor companies that develop strong applications expertise in conjunction with influential telecommunications hardware/service companies can exploit the near-term emergence of comprehensive open standards for digital voice, data, and video communications. ■

By Krishna Shankar

Mil/Aero Outlook: Positioning for New Needs

Defense Spending Impact

In spite of the war in the Persian Gulf and instability in the USSR, spending on military hardware is expected to decline globally for the foreseeable future. Although the war did a lot to highlight the effectiveness of electronics as the eyes, ears, and brains of weapon systems, vanishing super-power tensions are affecting political thinking the most. It is most likely that defense spending in the NATO countries will stay flat in current dollar terms as that sector shrinks to be a smaller part of the respective economies. Aside from some short-term business with NATO-friendly countries like Saudi Arabia, the export of military systems to other countries is expected to be less allowed as a result of the Iraq example.

Figure 1 presents Dataquest's forecast of military and civil aerospace electronics production. We expect military electronics production to remain roughly flat over the forecast period while the smaller civilian sector continues to have double-digit growth as a result of expanding space and aviation demands.

Pockets Of Growth

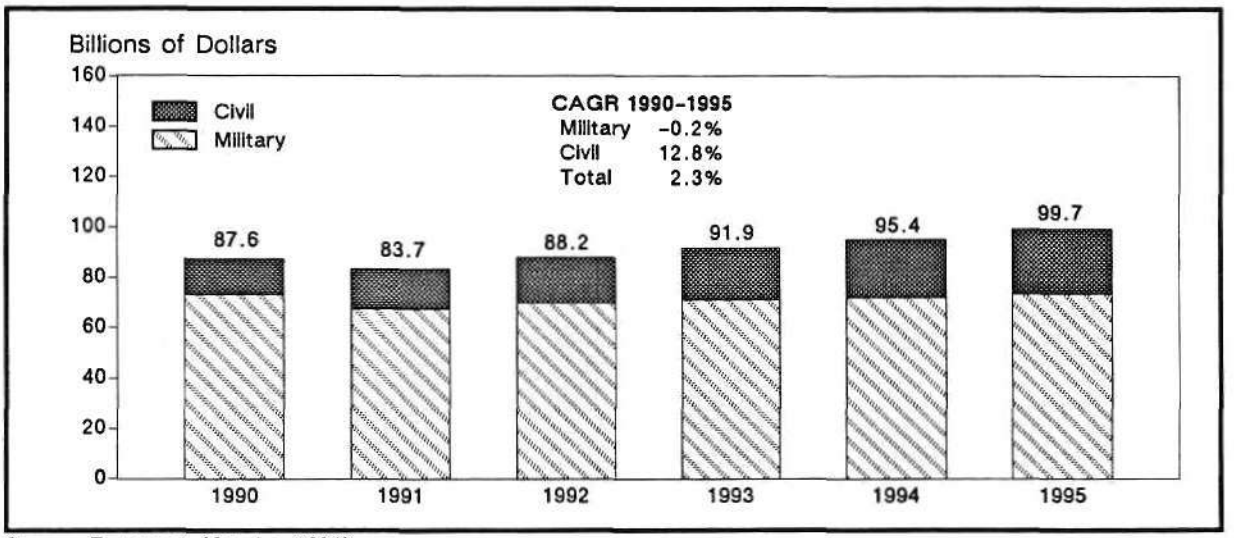
In spite of an overall flat envelope, numerous growth opportunities exist in defense electronics. Many of these opportunities will come from upgrades of existing platforms (aircraft, ships, and ground vehicles) as the production of new platforms is either slowed or discontinued. Table 1 lists some of these opportunities and some of the OEMs skilled in these technologies.

A Civil Market?

It is Dataquest's belief that the civilian space and aviation electronics sectors will witness solid growth for the bulk of the decade. Although doubt remains regarding the viability of the space station program (and its worldwide elements) there remains a multitude of government scientific and commercial communications satellite projects. The electronic content of satellite development can run as high as 60 percent, posing a significant opportunity for radiation-resistant components.

Spending by NASA (United States), ESA (Europe and Canada), and the two Japanese space agencies is expected to continue climbing significantly as earth resources and environmental monitoring programs expand. As many as 51 commercial communication satellites are expected to be delivered over the next three years, up from 39 in the previous three-year period. The need is being driven by increased demand for communication and direct-broadcast transponders. The Iridium cellular communication program promoted by Motorola could expand that number greatly, if it becomes politically feasible. The United States is expected to maintain nearly 57 percent of the satellite production, while France and the

Figure 1
Worldwide Military/Aerospace Electronic Equipment Production



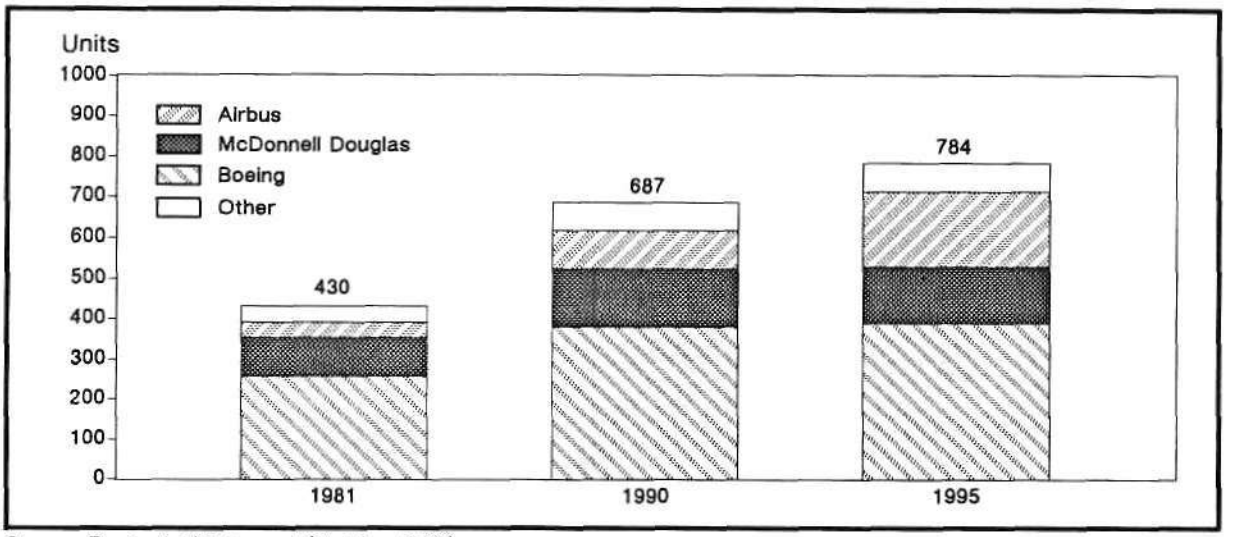
Source: Dataquest (October 1991)

Table 1
Defense Electronics Opportunities

Growth Application	Key OEMs	Notes
Rugged computers/peripherals	Miltope, Rugged Digital, Codar, Magnavox, DY-4	VME bus dominates, Futurebus+ for U.S. Navy
Space avionics/payloads	GE, Hughes, Matra, TRW, Lockheed, NEC, IBM, Honeywell, Loral	Need rad-hard ICs
U.S. army vehicle electronics (SAVA)	TI, Smiths Industries, Hughes	Based on 68020 and 1553 data comm.
Avionic processor and data comm. modules	Hughes, TI, Westinghouse, IBM, Harris, GEC, ESD	SEM-E size, i960 and R3000-based CPUs, PI bus, high-speed data bus, 1553 comm.
Antisubmarine warfare sensing systems	AT&T, IBM, GE, Thomson	Quieter subs make this a priority
Microwave/millimeter-wave front-ends	TRW, Westinghouse, GE, Lockheed, GEC, Thomson, Raytheon, Hughes	Modules for radar, comm. elec. warfare, missiles
IR tracking/imaging	Martin Marrieta, TI, Hughes, Loral, GE, FIAR	Gulf war showed effectiveness
Unmanned aerial vehicles	McDonnell Douglas, IAI, TRW, Teledyne	Market to double by 1999

Source: Dataquest (October 1991)

Figure 2
Commercial Airliner Deliveries



Source: Prudential/Dataquest (October 1991)

United Kingdom will acquire 17 and 10 percent, respectively. France, Japan, Canada, Italy, Israel, and India are cutting into the U.S. dominance of space electronics. Companies such as MBB (Germany), Alenia (Italy), Mitsubishi and NEC (Japan), and IAI (Israel) are becoming forces in space electronics.

In civil aviation electronics, substantial opportunities remain in both avionics and ground-based air traffic control systems. Figure 2 shows the dramatic growth in aircraft deliveries over the past decade. A substantial growth of 5 percent per year in passenger air miles, especially for the Pacific region, is one of the main drivers of growth. Companies such as Honeywell, Rockwell-Collins, Allied-Signal, Sextant Avionique, and GEC are the principal civilian avionics suppliers in the world.

Semiconductor Market: Slower, Maybe Profitable

The worldwide market for semiconductors used in military and civil aerospace electronics is expected to remain flat in 1991 but grow at a 5.8 percent rate from 1990 to 1995 (see Figure 3). Spending on replacement equipment for Operation Desert Storm and orders by friendly Persian Gulf states—approximately $20 billion, mostly in the United States—is generating some one-time orders mainly for mature products. Semiconductor consumption rates are expected to continue exceeding the equipment growth rate as new equipment and upgrades have more value absorbed by complex microprocessor units (MPUs), application-specific standard products (ASSPs), application-specific integrated circuits (ASICs), microwave monolithic ICs (MMICs), and memory ICs.

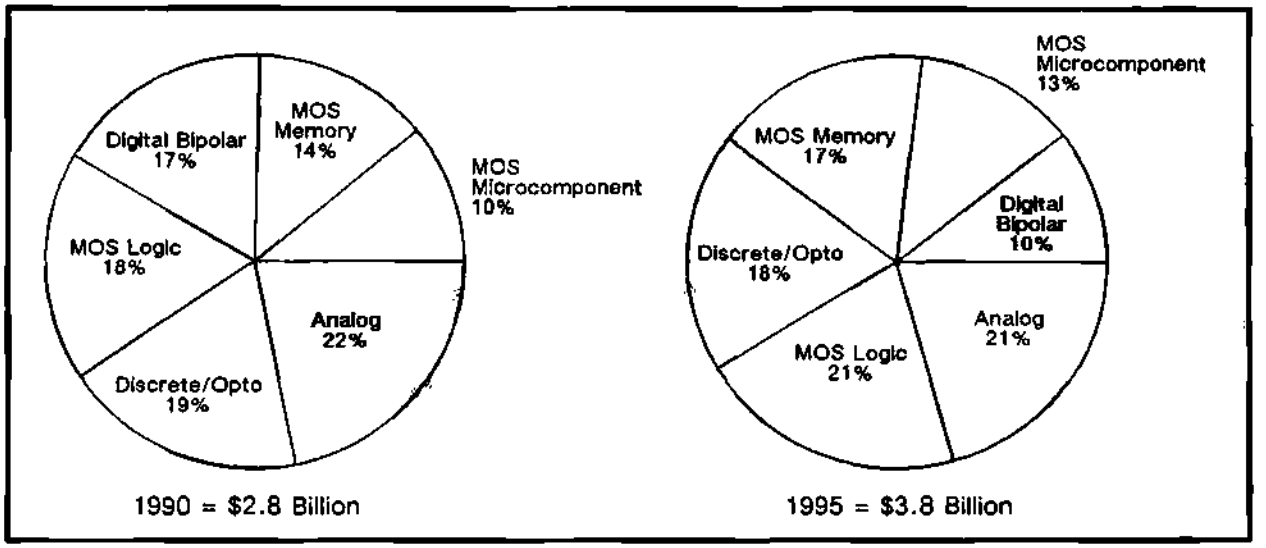
The dramatic cuts to the 1991 equipment procurement accounts in the United States, the United Kingdom, and France are cause for a bleak 1991. Some recovery is expected in 1992 as platform upgrades gain priority in spending budgets. Over the coming decade, expect the Japan/ROW market to grow larger as Japan continues developing its civilian aerospace electronics industry and countries like Taiwan and South Korea produce more of their own defense electronics.

Semiconductor Market Qualities

Earlier in this article we noted which mil/aero equipment categories are the most lucrative for semiconductor marketers and which principal OEMs are producing that equipment. In the coming years mil/aero applications will make the following requirements of semiconductor technology:

- Reduced power consumption and space, increased reliability and maintainability—These are the assumed drivers behind any upgrade or new design. Most often, this is translated into emphasis on CMOS/BiCMOS/GaAs VLSI, mixed-signal, and hybrid conversion to monolithic or multichip modules.

Figure 3
Worldwide Military/Aerospace Semiconductor Consumption by Major Product Category



Source: Dataquest (October 1991)

- Emphasis on minimizing adverse effects of radiation—Total dose, dose rate, neutron emission, and soft memory array errors lead a long list of parameters being considered by OEM designers. Enhanced bulk CMOS will continue vying with silicon on sapphire and silicon on isolator for designs.
- Testability, designability, and replaceability—These issues affect every design decision.
  - Already in the United States, VHSIC hardware definition language (VHDL) design capture is required on all new projects as platform life cycles head for multiple decades and semiconductor life cycles shrink to just a few years. A major reason is to reduce the effort in sourcing semiconductor products years after the original product has been phased out.
  - Test features such as JTAG and the TM bus, which affect chip/package design, are being required of an increasing number of programs as well.
- More digitally based, real-time control requiring extensive use of high-performance (CISC or RISC) MPUs, digital signal processors, memory, and real time software (principally Ada)
- More modularity and commonality—Emphasis is on standardizing on data communication standards (1553, HSDB), backplane buses (PI and Futurebus+), common modules (SEM-E or multichip module upgrade), and high-level language software portability.
- Greater bandwidth and sensitivity for front-end (analog environment) processing—This requirement translates into higher frequencies (exceeding 50 GHz) for RF components like MMICs and finer-resolution infrared.

Products In Demand

Table 2 lists some products that Dataquest believes will be in strong demand over the next five years. Each of these product areas can trace its demand from one or more of the above factors. It is important to note that mature standard logic, linear ICs, and MPUs usually enjoy a long phaseout period, and the opportunity for aftermarket suppliers and emulating solutions is proving to be attractive.

Dataquest Perspective

As the title of this article implies, to be a successful (profitable) supplier to the military and aerospace community, *focus* is recommended. We recommend that semiconductor companies with "design-win" class products like ASSPs, ASICs, and MPUs select a manageable list of accounts to target. As OEMs continue consolidating and reduce the length of their supplier lists, it becomes paramount for semiconductor suppliers to be responsive if they wish to remain on the list. We suggest studying which OEMs are the best positioned for growth opportunities in their respective markets. Table 1 provides one such list.

A side benefit of maintaining a strategic account focus is that a good relationship will drive the

Table 2
Key Semiconductor Products for Mil/Aero Applications in North America and Europe

Product Area	1991-1995 Market Size ($M)
Bus interface (all technologies)	790
CMOS/BiCMOS gate arrays	1,305
CMOS/BiCMOS cell-based ICs	680
(Mixed signal)	(120)
CMOS PLDs	385
(FPGAs)	(110)
Data comm. ICs (1553/SCC/HSDB, etc.)	305
Digital signal processors	170
8-bit MCU	140
16-bit MPU	245
32-bit MPU	155
SRAM	1,010
EEPROM	390
Flash memory	45
GaAs MMIC	580
Amplifiers	740
Data conversion	670
Power MOSFET	355
Rad-hard/level-S ICs	1,755

Source: Dataquest (October 1991)

decisions regarding which commercial portfolio products should be militarized and when that should happen. It is important to note commercialization trends like the conversion to standard military drawing parts or even a rugged specification; the adoption of the qualified manufacturers list should make it easier (less costly) for semiconductor companies to serve the market. However, OEM procurement organizations are increasingly wary of interlopers in the market, and sourcing preference ultimately will reside with those companies thoroughly committed to serving the unique military quality and contracting needs. ■

By Gregory Sheppard

In Future Issues

The following topics will be featured in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in digital video
- Trends in rigid disk drive applications
- T-Carrier semiconductor market opportunities

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Dataquest Perspective

Special Edition

October 28, 1991

Market Analysis

Worldwide Semiconductor Industry Forecast: Fourth Quarter 1991

Dataquest expects recovery of the U.S. economy to stimulate spending on electronics systems, spurring the worldwide semiconductor market to grow 13.5 percent in 1992, up from 9.3 percent growth in 1991, and to grow 15.7 percent in 1993.

By Terrance A. Birkholz

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The Downside and Upside to Our '92 Forecast

Semiconductor end-use markets are currently giving mixed signals concerning a recovery. Our 1992 worldwide semiconductor forecast assumes a moderate recovery in the end-use markets. However, there is both a downside and an upside to this assumption.

By Mark FitzGerald

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Market Analysis

Worldwide Semiconductor Industry Forecast: Fourth Quarter 1991

Summary

Dataquest expects the worldwide semiconductor market to grow 13.5 percent in 1992, up from 9.3 percent growth in 1991, and to further grow 15.7 percent in 1993 (see Figure 1). Recovery of the U.S. economy will stimulate worldwide systems production, which in turn will stimulate semiconductor consumption. In the short term, the cyclical upturn of the data processing market will help boost MOS memories' contribution to overall growth and help firm the foundation of microcomponent growth. In the long term, semiconductor market growth will be driven by networking the stock of data processing capability, computer-based graphics, and image-based processing, placing new demands on processing power and the associated complement of memory capacity.

Dataquest's Semiconductor Forecast Methodology

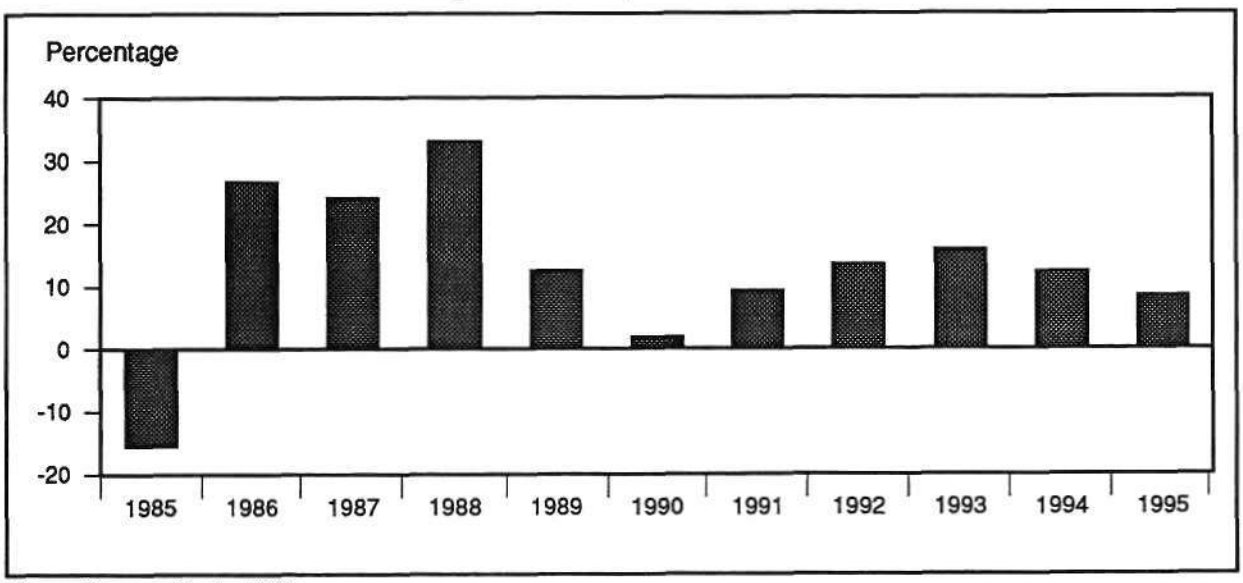
Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

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'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 compound annual growth rate (CAGR) for total semiconductors for a five-year period from a demand-side perspective.

Dataquest's worldwide Semiconductor service and its Semiconductor Equipment, Materials, and Manufacturing 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

Figure 1
Worldwide Semiconductor Consumption (Factory Revenue, Dollar-Based Annual Growth)



Source: Dataquest (October 1991)

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.

Forecast Assumptions

The worldwide economic climate is expected to improve in 1992. The Dun & Bradstreet Corporation forecasts the following outlook for the Group of Seven (G7) countries (see Figure 2):

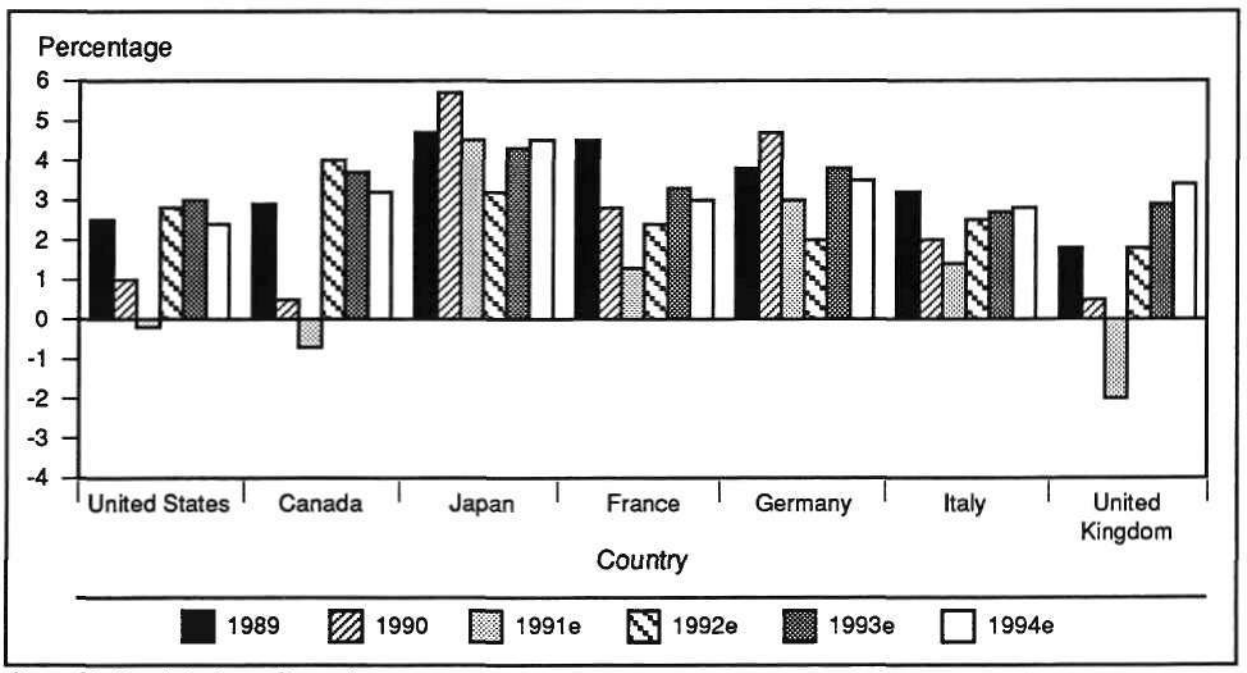
- The U.S., Canada, and U.K. economies will register negative real economic growth in 1991 but recover at rates of 2.8, 4.0, and 1.8 percent real gross national product/gross domestic product (GNP/GDP), respectively, in 1992.
- Real GNP/GDP growth is expected to accelerate in France and Italy during 1992, from 1.3 percent in 1991 to 2.4 percent and from 1.4 percent in 1991 to 2.5 percent, respectively.
- Real GNP/GDP growth is expected to decelerate in Germany and Japan during 1992, from 3.0 percent in 1991 to 2.0 percent and from 4.5 percent in 1991 to 3.2 percent, respectively. The cost burden of Germany's reunification and the rise in Japan's cost of capital are moderating these countries' short-term growth prospects. Both economies are expected to reaccelerate in 1993.

Growth in the G7 economies is expected to converge toward the countries' respective steady-state rates through 1994.

The improved economic prospects bode well for the semiconductor industry outlook, given that computers and related electronic gear represent a significant share of the G7 economies' business fixed investment.

Acceleration of worldwide systems production growth—to 9.0 percent in 1992 from 5.4 percent in 1991—will be accompanied by the

Figure 2
G7 Countries' Estimated Economic Outlook
Real GNP/GDP Growth, Local Currencies



Source: The Dun & Bradstreet Corporation

resumption of economic growth (see Figure 3), as shown by the following factors:

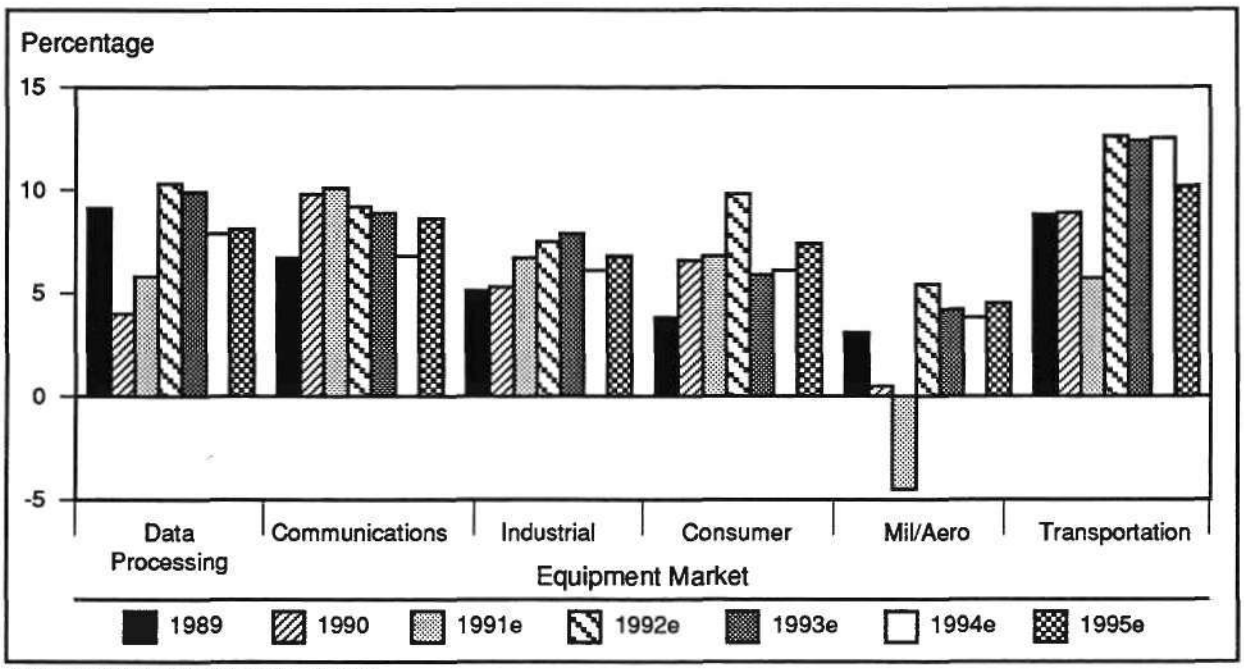
- Business conditions in the data processing and consumer markets are expected to show significant improvement as businesses and households begin to relax their budget constraints
  - Data processing up 10.3 percent in 1992 from 5.8 percent in 1991
  - Consumer up 9.8 percent in 1992 versus 6.8 percent in 1991
- Transportation electronics production growth is expected to more than double—to 12.6 percent in 1992 from 5.7 percent in 1991—spurred by increased consumer spending, combined with increasing share of electronic systems' added value to new vehicles.
- Communications and industrial electronics growth are expected to remain positive and stable. Spending on medical electronics and analytical instruments helped bolster the industrial segment from recession-induced decreased spending on measuring and controlling electronics.
- Military/civilian aerospace electronics was hit hard by Washington budget cuts in 1991, but this segment is expected to resume modest growth (at a permanently lower dollar level) as western defense agencies upgrade existing systems with more sophisticated electronics.

Semiconductor Outlook: Overview

Dataquest expects the worldwide semiconductor market to grow 9.3 percent in 1991 to $63.6 billion, up from $58.2 billion in 1990, and 12.1 percent in 1992 to $72.2 billion (see Table 1). (Note that Table 1 expresses the value and growth of the Japan and Europe markets in local currencies' terms. In addition to valuing the worldwide market assuming *current* exchange rates, the worldwide market is valued in U.S. dollars, assuming *constant* 1990 exchange rates, which removes the effects of exchange rate variation on growth.)

Our October 1991 forecast represents a downward revision to our May 1991 forecast when we forecast the market to grow 13.7 percent in 1991 and 16.6 percent in 1992. *Approximately 65 percent of the revision in 1991 and 50 percent of the revision in 1992 is accounted for by appreciation of the U.S. dollar against the Japanese yen and major European currencies since the May forecast.*

Figure 3
Worldwide Electronics Production
(Factory Revenue, Dollar-Based Annual Growth)



Source: The Dun & Bradstreet Corporation

Table 1
Worldwide Semiconductor Consumption by Region—1990-1995
(Factory Revenue in U.S. Dollars and Local Currencies)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
North America ($M)	17,386	18,483	20,728	23,888	26,758	28,816	10.6
Annual Growth (%)	-3.1	6.3	12.1	15.2	12.0	7.7	
Japan ($M)	22,508	25,544	29,524	33,341	37,208	40,232	12.3
Annual Growth (%)	-2.1	13.5	15.6	12.9	11.6	8.1	
Japan (¥B)	3,241	3,501	4,074	4,601	5,135	5,552	11.4
Annual Growth (%)	2.1	8.0	16.4	12.9	11.6	8.1	
Exchange Rate: ¥ per U.S.$1	144.00	137.06	138.00	138.00	138.00	138.00	
Europe ($M)	10,661	10,828	11,556	13,777	15,335	16,368	9.0
Annual Growth (%)	9.3	1.6	6.7	19.2	11.3	6.7	
Europe (EcuM)	8,380	8,890	9,799	11,683	13,004	13,880	10.6
Annual Growth (%)	-6.0	6.1	10.2	19.2	11.3	6.7	
Exchange Rate: Ecu per U.S.$1	0.786	0.821	0.848	0.848	0.848	0.848	
Asia/Pacific-ROW ($M)	7,670	8,792	10,405	12,532	14,486	16,246	16.2
Annual Growth (%)	17.6	14.6	18.3	20.4	15.6	12.1	
Worldwide ($M)	58,225	63,647	72,213	83,538	93,787	101,662	11.8
Annual Growth (%)	1.8	9.3	13.5	15.7	12.3	8.4	
Worldwide ($M in 1990 U.S.$1 Exchange Rates)	58,225	62,899	71,894	83,235	93,446	101,276	11.7
Annual Growth (%)	0.7	8.0	14.3	15.8	12.3	8.4	

Source: Dataquest (October 1991)

Although 1991 is shaping up as a modest-growth year—worldwide market growth averaged 19.1 percent per annum in the 1985 through 1990 period—it is nonetheless a rebound over last year's 1.8 percent growth.

Growth in 1991 was hampered by the following three factors:

- Deeper- and broader-than-expected U.S.-led economic recession
- The recession's growth-arresting affect on computer spending
- Military spending cuts

Growth is forecast to accelerate through 1993 but will be constrained by the relatively moderate rate of overall economic recovery and the effects of saturation and maturity in the relatively developed markets.

Semiconductor Outlook: Regions

North America

The North America systems and semiconductor markets were hit hard by the economic recession of 1991. Both 1992 and 1993 are expected to be years of accelerating growth as businesses resume computer and related equipment spending in an environment of renewed vigor in fixed investment. The following three factors will tend to restrain semiconductor growth below the peak rates experienced in the last decade:

- Two-thirds of desktops have computers on them—After 30 years of innovation and booming sales, there are inevitably fewer opportunities for investment.
- The computer market's share of U.S. capital investment more than *doubled*, from less than 3 percent in 1977 to about 7 percent in

the mid-1980s, but has remained unchanged since then.

- Previously, new systems—those *without* close substitutes—enabled the computer industry to increase its share of capital spending faster than overall investment fell.

These factors should *not* be construed to mean that opportunities for further semiconductor penetration are absent through the forecast horizon. Indeed, the next round of computer and computer-related equipment spending will involve connectivity/networking and higher-level graphics and image-based processing. Both of these areas represent the new frontier for microcomponents and the associated memory complement and for analog and mixed-signal ASIC.

Japan

Japan's growth was hit hard in the first quarter of 1991 by the combined effect of a recession that was already under way in the United States and complicated by the Gulf war. We expect Japan's market to revive in 1992 in response to the resumption of chip and systems export growth to the United States and Europe. Renewed vigor in the computer arena will help firm MOS memories, while advances in camcorders, large-screen TVs, wireless and car telephones, and robot systems designs will boost microcontroller unit (MCU), MOS logic, and analog device growth.

Japanese manufacturers will use the remainder of 1991 to position themselves to take full advantage of the market's upturn in 1992.

Europe

A recession in the United Kingdom plus the reunification-induced drag on the German economy restrained Europe semiconductor market growth in 1991. However, appreciation of the U.S. dollar against the major European currencies masks the true situation of the market: In dollar terms, the market is expected to decelerate to 1.6 percent growth in 1991 from 9.3 percent growth in 1990. In European currency unit (Ecu) terms—a good proxy for a weighted basket of European currencies—market growth is expected to *resume expansion* at a rate of 6.1 percent in 1991 from a 6.0 percent *shrinkage* in 1990 and to accelerate to 10.2 percent growth in 1992.

Improved overall business conditions will help firm up indigenous PC production and consumption in 1992, which will translate into improved prospects for ASICs, microcomponents, and, in particular, MOS memories. In the long term, however, the ASIC market will be fraught with severe average selling price (ASP) pressure stemming from increasing integration and smaller production volumes per design.

Asia/Pacific-Rest of World

Growth in Asia/Pacific-Rest of World (ROW) is and will continue to be fueled by domestic companies' investment, but more importantly from foreign direct investment. The inflow of foreign capital, combined with the relative immaturity of the industry, shields the semiconductor business from the wide swings in activity that tend to rock the other, more established regions. Even so, memory and microcomponent consumption have been severely hurt by the softness of PC business, while analog consumption has felt the pinch of households' curtailed consumer electronics purchases.

Dataquest expects semiconductor consumption growth to accelerate in 1992 and 1993 as the western export markets stimulate data processing and consumer electronics production.

Semiconductor Outlook: Devices

Table 2 presents worldwide detail of the semiconductor device forecast. Volatile pricing make MOS memories the swing factor accounting for year-to-year changes in overall market growth. Microcomponents provide more stable growth in both the short and long term. Overall, worldwide revenue growth is expected to accelerate in 1992 following recovery of the systems markets and peak in 1993. We expect growth to moderate in 1994 and 1995.

Bipolar Digital

The bipolar logic market was hit hard in 1991 by the recession: Businesses postponed major purchases of mainframe and high-end computer equipment, the largest users of these devices. Standard logic, as a share of total bipolar logic, declined at a faster-than-expected rate, also in response to slower-than-expected market conditions.

Compounding the recession's cyclical effects are important structural and technological dynamics: Through 1995, bipolar logic will continue to be replaced by CMOS, BiCMOS, and GaAs ICs as these devices become more cost competitive. Also, as chip functionality and integration increase, unit volumes of ASIC designs will decrease; that is, ASIC manufacturers face the

Table 2
Worldwide Semiconductor Consumption by Device—1990-1995
(Factory Revenue in Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Total Semiconductor	58,225	63,648	72,211	83,537	93,786	101,661	11.8
Annual Growth (%)	1.8	9.3	13.5	15.7	12.3	8.4	
Total IC	47,303	51,863	59,672	69,840	79,106	86,141	12.7
Annual Growth (%)	0.8	9.6	15.1	17.0	13.3	8.9	
Bipolar Digital	4,440	4,095	3,966	3,843	3,637	3,390	-5.3
Annual Growth (%)	-1.6	-7.8	-3.2	-3.1	-5.4	-6.8	
Bipolar Memory	459	414	407	407	378	352	-5.2
Annual Growth (%)	-15.0	-9.8	-1.7	0.0	-7.1	-6.9	
Bipolar Logic	3,981	3,681	3,559	3,436	3,259	3,038	-5.3
Annual Growth (%)	0.3	-7.5	-3.3	-3.5	-5.2	-6.8	
MOS Digital	32,292	35,926	42,496	50,980	58,661	64,546	14.9
Annual Growth (%)	-2.2	11.3	18.3	20.0	15.1	10.0	
MOS Memory	13,091	13,418	15,958	19,378	22,583	24,447	13.3
Annual Growth (%)	-20.0	2.5	18.9	21.4	16.5	8.3	
MOS Microcomponent	10,068	12,063	14,494	17,465	19,982	22,216	17.2
Annual Growth (%)	22.8	19.8	20.2	20.5	14.4	11.2	
MOS Logic	9,133	10,445	12,044	14,137	16,096	17,883	14.4
Annual Growth (%)	7.9	14.4	15.3	17.4	13.9	11.1	
Analog	10,571	11,842	13,210	15,017	16,808	18,205	11.5
Annual Growth (%)	12.6	12.0	11.6	13.7	11.9	8.3	
Total Discrete	8,235	8,777	9,241	10,040	10,656	11,172	6.3
Annual Growth (%)	7.5	6.6	5.3	8.6	6.1	4.8	
Total Optoelectronic	2,687	3,008	3,298	3,657	4,024	4,348	10.1
Annual Growth (%)	2.3	11.9	9.6	10.9	10.0	8.1	

Source: Dataquest (October 1991)

prospect of increasingly complex chips and smaller volume production runs.

Bipolar logic's remaining life cycle will be driven by the quick-processing and switching requirements of centralized, high-end computer systems.

MOS Memory

Slow DRAM bit growth in 1991, which in turn added to ASP softness, combined to make 1991 revenue only marginally improved over 1990. Weak market conditions have also permitted users to extend the 1Mb life cycle until higher density per-bit prices fall to appropriate levels. The anticipated recovery of computer production in addition to the emergence of memory-intensive PC applications—including more powerful operating systems, user-friendly graphical user interfaces, and digital video—will help drive DRAM bit growth in 1992 and beyond. The emerging generation of laptop, hand-held, and pen-based PCs is also expected to give renewed vigor to the DRAM market.

Softness in the PC market, vendors in oversupply, and customers selling off inventory have combined to make for very slow SRAM bit growth and rapidly falling ASPs. Slowing bit growth and Korean/Taiwanese manufacturers "buying" market share will constrain revenue growth. Actual future revenue growth may be further constrained as manufacturers follow through with plans to switch fab capacity to SRAM devices, exacerbating an existing overcapacity situation. On the positive side, expected growth will be bolstered by further application of caches in PCs, and slow SRAM bit growth will be fueled by new applications in consumer markets.

The nonvolatile memory market will be bolstered by continued penetration of flash memories but at the expense of EEPROM market growth. We expect flash growth to accelerate in the forecast period, fueled by consumer and data processing applications. Acceptance of palm-top and pen-based computers and the substitution of memory cards for disk drives for the task of mass storage will be critical to flash's future growth. In the long term, consumer acceptance of electronic photography will be the wild card that adds a superlative increment to growth.

MOS Microcomponents

Notwithstanding the slowdown in PC shipments, microcomponents is expected to be the fastest-growing device family in 1991, 1992, and, on average, through 1995. Two factors contribute to this situation. Intel's proprietary position in the 80486 MPUs places a floor underneath prices and MCUs are steadily penetrating consumer electronics and telecommunications. Furthermore, Dataquest expects microcomponent growth to be fueled by the trend toward higher-performance PCs that include multimedia and networking functions, which in turn will require a higher level of dedicated processing power for implementation.

Market revenue will be boosted by Intel's proprietary edge in the MPU market with its 80486 chip. Helping to constrain revenue growth, however, will be ASP pressure originating from competitive alternate sources to an Intel-based PC (for example, the AMD-led price pressure in 80386 MPU applications).

MOS Logic

Workstations, laptop PCs, and telecom applications are the driving forces behind today's MOS logic growth, although the lackluster showing in the PC arena at large tends to drag unit and revenue growth below what it would be otherwise. The recession has spelled lower unit volumes per ASIC design, putting a further squeeze on manufacturers' profit margins. We look to field-programmable gate arrays, MOS gate arrays, CBICs, and application-specific standard products to drive future device growth and to MOS full-custom chips to restrain growth.

Analog

Dataquest's analog forecast remains essentially unchanged from the May forecast. As 1991 draws to a close, Dataquest will be looking to consumer confidence to improve, forming a firm foundation for 1992 growth. Beyond peak growth in 1993, analog as a product family faces the prospect of decelerating growth resulting from product maturity in large segments of the market plus decelerating growth in some (mature) end markets. Integration of analog functions to MPU and digital signal processing chips, however, will provide continued vitality to analog technology. We expect telecom-specific applications and computer-related mass-storage and graphics applications to be the areas driving incremental growth.

Dataquest Perspective

Dataquest expects the 1990 through 1995 period to be characterized by relatively moderate market growth: Average growth in the 1990 through 1995 period is forecast to be 11.7 percent per annum versus 19.1 percent per annum in the 1985 through 1990 period. Part of this growth deceleration is a result of the moderation of the major world economies' growth prospects vis-à-vis the decade of the 1980s. More important, however, are the combined effects of the maturing end-use markets on the demand-side and the increasing incremental costs associated with marginal changes in manufacturing technology and system/chip performance.

In the 1980s, the workplace and households in the world's major industrialized economies could be characterized as a vacuum waiting to be (further) filled by the breath of solid-state technology. The void was filled with desktop processing systems and VCRs, systems that were unrivaled by close product substitutes.

The task of the 1990s will be to continue to *add* to the stock of electronic gear but also (and at least as important) to enhance the stock's productivity through, for example, networking and image-based processing. Both these areas are new and fruitful ground for cost-competitive, innovative, and technology-oriented semiconductor companies. But because of the relative complexity of these systems, their investment profiles will likely be more smooth—less "peaked" than, for instance, the booming PC market of the 1980s.

Semiconductor manufacturers are advised not to miss out on the plodding progress the workplace segment is making toward connectivity and image-based processing while waiting for the next PC boom. ■

By Terrance A. Birkholz

The Downside and Upside to Our '92 Forecast

Dataquest's semiconductor forecast for 1992 calls for 13.5 percent growth in worldwide device sales, up from 9.3 percent growth in 1991. A critical assumption of the forecast is an improvement in the semiconductor end-use markets—data processing, consumer, communications, industrial, military/aerospace, and transportation. Our forecast assumes that a moderate recovery in the major end-use markets will be well under way by the first quarter of 1992.

This assumption has a downside. Currently, there are few signs of a recovery in most of the semiconductor end-use segments. If the major end-use markets, i.e., data processing or consumer, fail to turn up soon, as we have assumed in our forecast, then our estimated growth for the worldwide semiconductor industry in 1992 may be too high.

On the other hand, there is also an upside to our forecast. The semiconductor end-use markets have historically seen strong growth as the electronic equipment industry pulled out of a recession. If history repeats itself and there is a strong recovery in end-use markets rather than the moderate growth assumed in our forecast, then our estimated growth for the worldwide semiconductor industry in 1992 may be too low.

Perhaps the best methodology for bracketing the upside and downside of our forecast is to consider different outcomes in terms of probabilities (see Table 1). In order to better understand the qualitative arguments for assigning these probabilities, a more careful review of the factors driving individual end-use markets must be considered.

Table 1
1992 Semiconductor Forecast Probability Distribution

Annual Growth Rate (%)	Probability
<9	0.15
≥9 but <12	0.25
≥12 but ≤15	0.50
>15	0.10
Total	1.00

Source: Dataquest (October 1991)

Applications

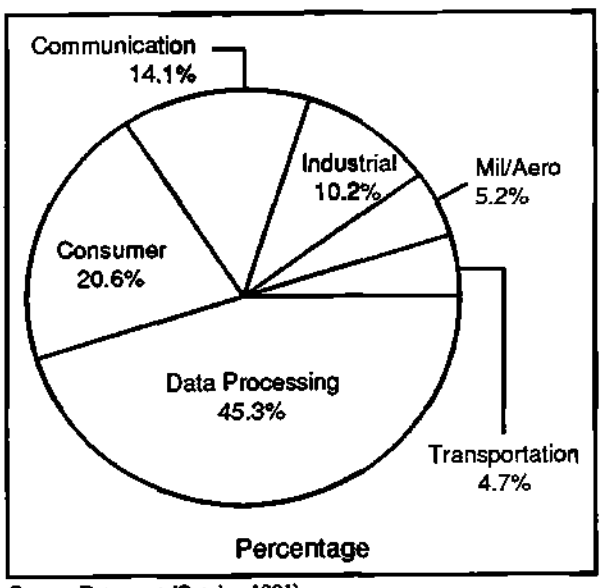
Data Processing

Data processing applications accounted for 45.3 percent of the semiconductors shipped in 1990 (see Figure 1). This segment includes mainframe computers, minicomputers, workstations, personal computers, and peripheral equipment. It is quite obvious from the size of this end-use market that the health of the semiconductor industry is tied very closely to the fortunes of the data processing equipment industry.

Dataquest believes that business conditions in data processing will show improvement in 1992 as businesses begin to relax their budgets. Data processing is forecast to grow 10.3 percent in 1992 versus 5.8 percent in 1991.

To achieve our estimated growth in 1992, the computer equipment cycle must begin to turn up in the fourth quarter of 1991. However, August data from the U.S. Department of Commerce (DOC) on office and computing equipment are still giving mixed signals (see Table 2). Orders were up 9.0 percent in August 1991 versus monthly orders a year ago. Yet, last year's data were very weak because of the Mideast crisis, so 9.0 percent growth over an August 1990 base cannot be viewed as a strong positive signal.

Figure 1
Semiconductor End Use by Application Segment



Source: Dataquest (October 1991)

Table 2
Office and Computing Equipment Data
U.S. Department of Commerce
Monthly 1991 Growth Rate versus Same Month in 1990

	June 1991	July 1991	August 1991
Orders	4	-13	9
Shipments	-3	1	-1
Backlog	1	-4	-1
Inventory	-16	-14	-16
Production	-5	-1	-3

Source: U.S. Department of Commerce

An optimistic note in the DOC data is the inventory cycle. Inventories were depleted at an 11 percent clip, while shipments declined by 1 percent. At some point, we anticipate that computer companies will be forced to begin ramping production in order to replenish their inventories. Assuming that inventory levels are very lean, a strong recovery in data processing will cause semiconductor demand to snap back, and growth could well surpass the 13.5 percent we have forecast.

But the bottom line is that orders for data processing equipment have been weak through the third quarter of 1991. And although it is a little early to be an alarmist, if orders continue to run at current levels through the fourth quarter, we expect our forecast to be optimistic. Needless to say, any delay in an upturn for data processing will only push the semiconductor industry recovery out further.

Consumer

Consumer applications accounted for 20.6 percent of the semiconductors shipped in 1990 (see Figure 1). Consumer electronics is forecast to grow 9.8 percent in 1992 according to Dataquest. To achieve this growth, U.S. consumers will have to increase their spending within the next several quarters.

Yet the Conference Board, a private business research firm, reported that the level of consumer confidence in the United States continued to deteriorate in September (see Figure 2). The survey showed that, compared with a month ago, consumers are a good deal less positive in their assessment of prevailing conditions and also somewhat less optimistic in their expectations for the months ahead. The consumer confidence index is well below its level of just prior to the beginning of the Mideast crisis. Moreover, employment data released on October 3 show little improvement in the U.S. unemployment rate, which is stuck in the 6.7 percent area.

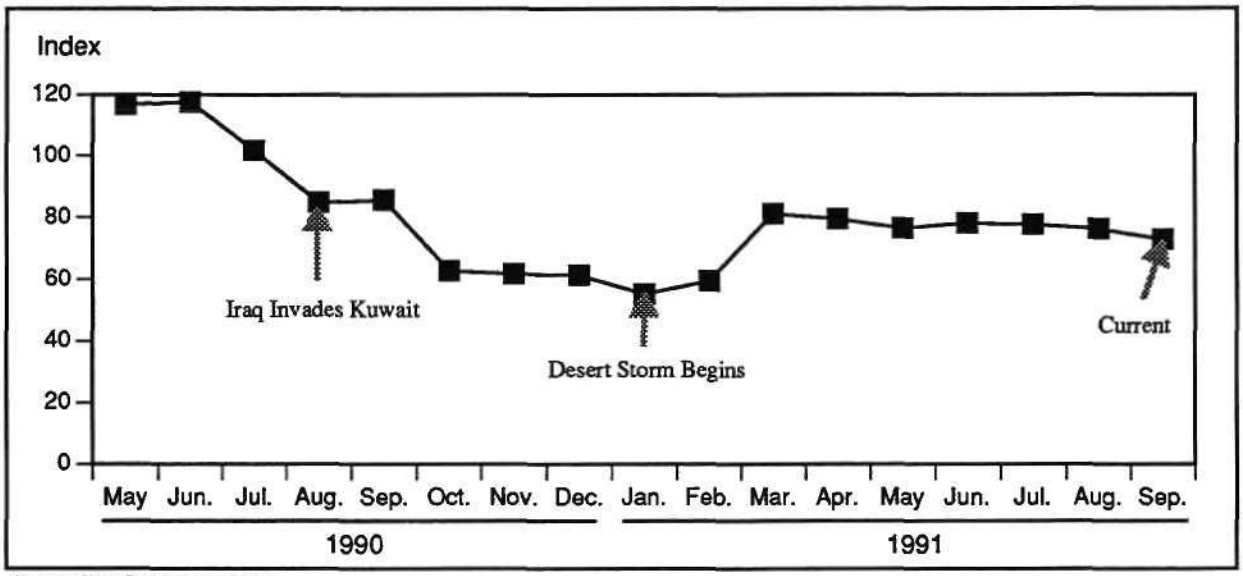
In Japan and Germany, consumers have maintained a strong level of spending through 1991, although their continued spending into 1992 is questionable considering that, according to The Dun & Bradstreet Corporation, both economies are decelerating. In Japan, the growth in gross national product (GNP) is expected to fall from 4.5 percent in 1991 to 3.2 percent in 1992; in Germany, growth in GNP is forecast to fall from 3.0 to 2.0 percent.

It can be argued that an uneven recovery in the United States and the weakening economic climate in Japan and Germany will delay consumer electronic equipment purchases. However, the consumer is getting help. Monetary policymakers in both the United States and Japan are loosening the reins. Interest rates have fallen to a 20-year low in the United States and are creeping lower in Japan. Stock market activity in both countries also seems to be pointing to better times: The U.S. market is reaching an all-time high, and the Japanese market has stabilized and is moving higher. This factor bodes well for consumer confidence; the demand for consumer electronics could well surpass our expectations. If this happened, our 1992 forecast would err on the conservative side.

Communication

Communication applications accounted for 14.1 percent of the semiconductors shipped in 1990 (see Figure 1). This end market, albeit small, remains a bright spot in terms of drivers for the semiconductor industry. The largest segment of communications equipment is telecommunications. Because of the weak global economic climate, there has been a slowdown in the ordering patterns of long distance and

Figure 2
Consumer Confidence Index



Source: The Conference Board

cellular companies in the industrialized countries. It appears that companies are delaying purchases of switching equipment at this time and are settling for stripped-down versions of some switching equipment until volumes pick up.

On a positive note, the fastest-growing regional markets for telecommunications equipment are the less-developed countries, and there has been no slowdown in this segment. Many of developing countries are quickly upgrading their antiquated analog systems with digital lines. Smaller segments of the communications equipment market—i.e., LANs and personal communication—are also experiencing strong growth.

Industrial

Industrial applications accounted for 10.2 percent of the semiconductors shipped in 1990 (see Figure 1). The industrial segment is expected to show marginal growth in 1992. Spending on medical electronics and analytical instruments helped bolster the industrial segment through 1991 and should perform well through 1992. The measure and control electronics segment is in a recession, and Dataquest expects little increased spending in this segment in 1992.

Mil/Aero

Mil/aero applications accounted for 5.2 percent of the semiconductors shipped in 1990 (see Figure 1). The mil/aero segment will provide little growth for semiconductor demand any time soon. U.S. President George Bush's recent announcement concerning changes in the U.S. government's nuclear strategy is expected to put several programs in immediate jeopardy of losing funding. The rail-mobile MX missile program, Boeing's Short Range Attack Missile, the U.S. Navy's nuclear-armed Tomahawk cruise missile, and perhaps the B-2 bomber are all expected to suffer when Congress evaluates the defense budget.

Automotive

Automotive applications accounted for 4.7 percent of the semiconductors shipped in 1990 (see Figure 1). The automotive segment is expected to improve during the next several months. U.S. domestic auto sales are forecast to increase from the depressed level of 6.0 million in August to 6.5 million in October and November according to Morgan Stanley, a New York investment bank. The big problem in the automotive segment is the consumer with his disastrous real disposable income and lack of consumer confidence.

On a more positive note for the semiconductor industry, there was a 20-year low in auto inventories at the end of model year 1991. According to industry estimates, in early September the 1992 models had only a 50-day

supply when 65 days is normal. Therefore, a small increase in demand by the consumer is expected to cause auto manufacturers to ramp their production, increasing the demand for automotive electronics.

Dataquest Perspective

The growth in semiconductor demand is forecast to accelerate in 1992. But, in order to achieve the forecast growth rates, the major semiconductor end-use markets—the data processing and consumer segments—need to begin showing more life soon.

The fourth quarter of 1991 will be pivotal. If the U.S. economy pulls itself out of recession and if Japan and Germany experience only a moderate deceleration of their economies, then our 1992 forecast is very reasonable. In fact, Dataquest's forecast may be conservative if the major end-use markets perform better than our expectations. ■

By Mark FitzGerald

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

Vol. 1, No. 2 **November 18, 1991**

Market Analysis

Market Analysis

Computer Digital Video: A Multimedia Opportunity

Is It Really an Opportunity?

Within the realm of multimedia computing are emerging, real hardware—and therefore IC—opportunities for image and sound processing. For purveyors of hardware, it is a badly needed opportunity to add value in a market driven by commodity economics. The fundamental user benefit is a more natural and effective use of PCs and workstations. Central to market acceptance of computer digital video and its derivative chip demand are the following two assumptions:

- Hardware and software standards will firm, and interoperable and widely available products will emerge.
- Producers and viewers of multimedia source material (e.g., an interactive mulitmedia training manual) will find this technology easy to use and helpful in their jobs.

Software standards are now available for multimedia extensions to Windows (DOS) and OS/2 for IBM-compatible PCs. IBM Corporation and Microsoft Corporation have agreed to what is known as the Media Control Interface (MCI) specification and have set in motion 40-plus independent software vendors (ISVs) producing multimedia tools and applications. This effort complements an already robust effort for Apple Computer Inc. platforms.

Furthermore, at least 30 hardware vendors, including many platform makers, are beginning to build a substantial market for digital video add-in cards and embedded functions. Compression is one of the enablers of digital video because of the overwhelming amount of data involved in storing and transmitting it. The Joint Photographic Experts Group (JPEG) and JPEG-compatible digital video interactive (DVI) is the emerging image data compression standard of choice for most PCs and workstations. The Motion Picture Experts Group (MPEG) compression standard for motion applications is probably only a year away. To further market acceptance of MPEG, consumer multimedia (principally CD-I) players are moving to the MPEG standard as well.

As for the demand side of the equation, such early adopters as companies that produce ad copy with photographs are already users. According to Dataquest surveys, we can expect a substantial percentage of the corporate, educational, and government users to begin following in the coming two to three years as titles and applications appear.

This article assesses the growing hardware and IC market for the capture, processing, and compression of digital video images by PCs and workstations.

What Is It?

There will not be a homogeneous use for multimedia computers. Some will be on the desktops of producers of publications, training and educational programs, and sales presentations. These installations will most likely be a minority of hardware sales but crucial for the market to develop. The bulk of users of multimedia will require only the playback of image-embedded material. A more complete listing of computer digital video uses includes the following:

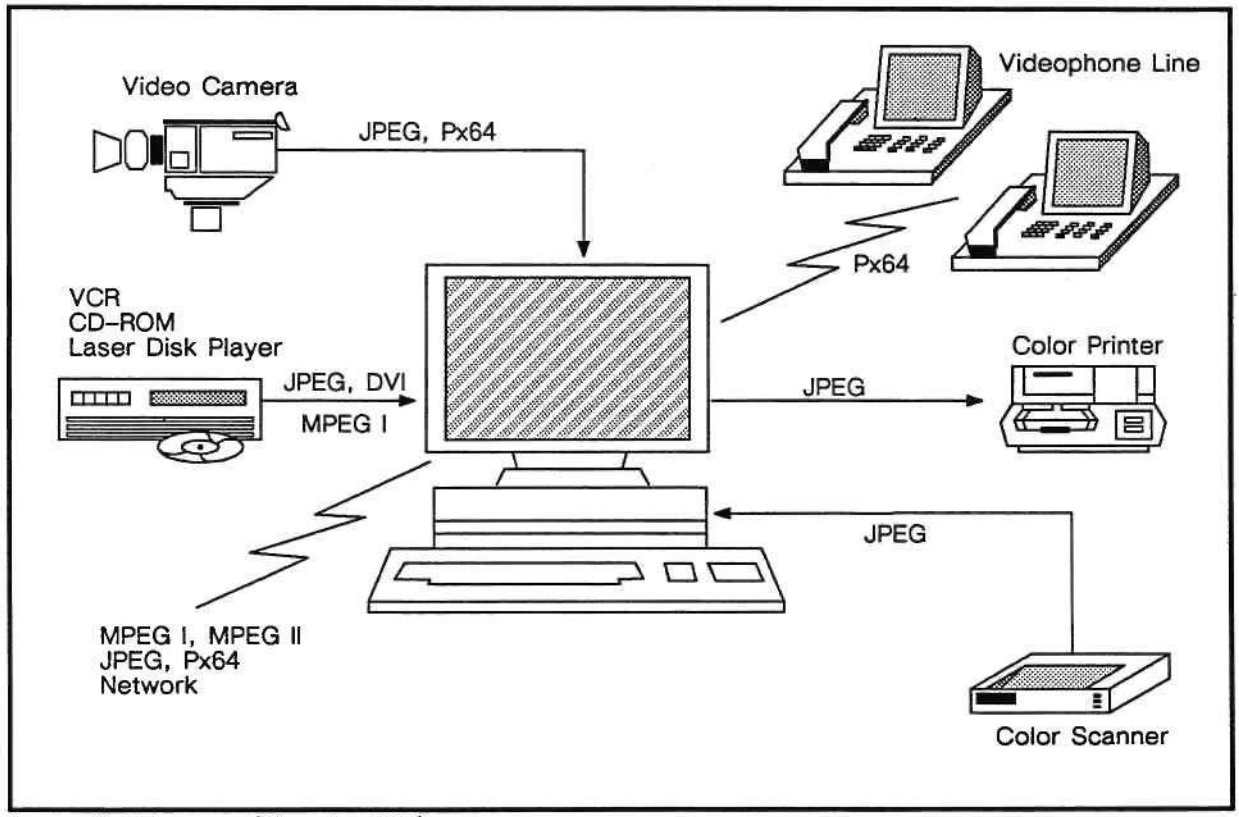
- Photo processing (advertising, publishing)
- Interactive training
- Interactive education (K-12)
- Interactive presentations (personal sales, point-of-sale)
- Interactive information displays (Kiosks)
- Image processing and analysis (medical, military, resource, inspection)
- Video/image library (e.g., multiple listings)
- Desktop publishing
- Video communications (video phone, e-mail)
- Video entertainment/games

Figure 1 illustrates the hardware dimensions of digital video. It spans the range of such gray-scale and color-image capture systems as cameras, video phones, and scanners to output systems such as printers to storage systems and networking. It is important to note that color peripherals require high bandwidths and are candidates for compression ICs as well.

Standards and Alliances

What about market-enabling factors such as operating system support, application program interfaces (APIs), and, ultimately, application

Figure 1
Computer Digital Video System



Source: IIT, Dataquest (November 1991)

software? A tidal wave of support is building with many key players. Three key developments are the introductions of Apple's QuickTime multimedia extension to its System 7.0 operating system, Microsoft's multimedia extension 1.0 for Windows 3.0, and IBM's OS/2 2.0 multimedia extensions. A group led by Microsoft and Tandy has created a baseline specification called Multimedia PC (MPC), which guarantees the user interoperability with other vendors' systems.

The Apple Computer platform sports easily a dozen ISVs producing software editors and presentation creators. IBM and Microsoft have agreed to adopt a multimedia programming interface (MPI) and data specifications that address ISV needs for common APIs and data formats across DOS, OS/2, and Windows. The MPC group claims that at least 60 multimedia applications are available from 40 companies. Likewise, IBM claims that at least seven companies are working on ISV toolkits for its products, with availability starting early next year.

Other activities in multimedia include Kaleida, the new Apple/IBM joint venture that is planning product availability within two to three years. The result of this effort could be embedded multimedia on the motherboard. For the educational market, publishers such as McGraw-Hill are developing interactive subject software. Early results show that images and the interactive nature of this style of learning yield better retention results than regular computer programs.

Video Editing

One of the key enablers of the computer video market will be the availability and ease of use of economical editing hardware and software for the creation of source material. This aspect is probably what will limit the early proliferation of digital video the most. Video editing systems priced from $10,000 to $60,000 are entering the market, the products of such companies as Avid Technology (Burlington, Massachusetts), Digital F/X (Mountain View, California), and Editing Machines (Washington, D.C.).

These systems are PC centered and involve add-in boards, attachable boxes, and program-controlled VCRs. These systems generally have graphical user interface software interfaces with multiple windows for viewing multiple images. One of the key functions of these systems is adding time codes (SMPTE) to each video frame along with sound synchronization. The recent MPC and IBM announcements highlight more focus on "layman" editing; we should expect more economical and easy-to-use editing packages throughout 1992.

Compression Is Expanding

One reason that digital image handling had not been incorporated into mainstream PCs is that the data bandwidth and storage required had made it economically impractical. A good-quality color photograph can require upward of 20 Mbytes to store it uncompressed. Likewise, moving 20 Mbytes to and from a VHS tape or over a LAN, for example, would require an inordinate amount of time. Compound the problem by manipulating 30 frames a second for motion video; then the need for compression becomes a prerequisite.

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. For motion images, 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.

To address the need for compression, several standards have been proposed. Some are open, and some are proprietary. The algorithms employed in image compression are inherently "lossy," meaning that the decompressed image is not exactly the same. However, the losses are generally not noticeable to the human eye. Table 1 presents the various open standards and their features such as maximum compression ratios. The JPEG standard is principally applied to full-color still images while the MPEG standard applies to full-motion color video and sound. Both standards are open and managed by committees of the International Standards Organization (ISO)/IEC. It is important to note that these proposed standards can be implemented in either hardware or software. In fact, both Apple and Microsoft have MPEG algorithms built into their multimedia extensions providing an interim alternative—albeit, slow—for users until the hardware is available.

Another open standard optimized for teleconferencing and video phones is known as H.261 (or Px64) and managed by the International Telegraph and Telephone Consultative Committee (CCITT). The DVI standard from Intel Corporation involves proprietary coding schemes but has been modified to support the open standards as well. Initially, DVI was asymmetrical; however, with the release of its i750B product on its ActionMedia II board (with IBM), Intel can support real-time video capture.

In a recent survey, Dataquest determined that the majority of OEMs designing digital video systems are using JPEG compression because of its virtue as an open, multisourceable standard. The symmetry feature or ability to create source material (real-time and compressed) on the desktop is also an advantage. When finalized next year (planned), the MPEG I will offer users an ability to compress motion images even further (up to 200:1) while keeping the bandwidth at 1.5 Mbps (CD-ROM and T-1

Table 1
Open Compression Standards

Feature	Standard 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 1.5Mbps	to 10Mbps	64Kbps-2Mbps

*Requires higher bandwidth
**Varies with resolution, frame rate, and image complexity
Source: Dataquest (November 1991)

rates). Real-time MPEG encoding currently is difficult to implement economically. A variation known as the JVC extension offers less lossy compression with a 50:1 ratio but trades off by generating a 6-Mbps bit stream. MPEG III is targeted at HDTV resolution (2 million pixels) with 60-Mbps bandwidth.

Compression Players: Getting Compressed

Both large and small players have entered the video compression chip set market. Some offerings are optimized toward one or more of the specs. Some were also the result of projects with particular customers. The leading participants currently include C-Cube Microsystems (JPEG/MPEG), Intel (DVI/JPEG/MPEG), LSI Logic (Px64/JPEG/MPEG), SGS-Thomson (JPEG), and IIT (JPEG/MPEG/Px64). Brooktree Corporation, Cypress Semiconductor Corporation, Motorola Incorporated, and Texas Instruments Inc. are rumored to be working on MPEG chip sets. Intel is reportedly working with PictureTel to create a 30-frame-per-second MPEG encoder capable of 1 billion operations per second.

Computer platforms are only one of many markets for these compression ICs. The advent of color and its need for high communications bandwidth is forcing fax machines, scanners, and printers to consider JPEG. The video conferencing and phone markets are of course the home for Px64 ICs. Another very interesting market for compression is home delivery of more channels and higher resolution TV by broadcast (terrestrial or satellite) or cable companies. In this case, a decoder would be needed for TV sets to receive the improvements. Additionally the regional Bell telephone companies in the United States are moving closer to being allowed to deliver TV and TV-based services over regular phone lines in competition with the cable companies. Image compression will be necessary for this as well as a means to deliver video bandwidth to residential areas, which are mostly not on optical fiber.

The Hardware

Initially, add-in cards for PCs and workstations will be the principal means of adding digital video to those platforms. Currently, different cards perform the functions of image capture and compression. There are also cards for TV tuning, for capturing broadcast or cable signals, and for audio processing. The audio cards can offer CD-quality sound capabilities and can interface to musical instruments through the musical instrument digital interface. Substantial peripheral hardware will be required for most multimedia setups including such storage devices as digitally controlled VCRs, laser disk players, and CD-ROM (including CD-I and CD-ROM/XA). Certainly rewriteable optical disks will become very important to image storage as well. Other equipment such as digital still or motion cameras and color scanners will be required for image capture.

There is a good chance that by 1995 the image capture and compression functions will appear on the motherboard coupled with the other graphics subsystem functions like the graphics controller, buffer memory, and RAMDAC. The motivation for this migration is the continual search for differentiated products by hardware vendors.

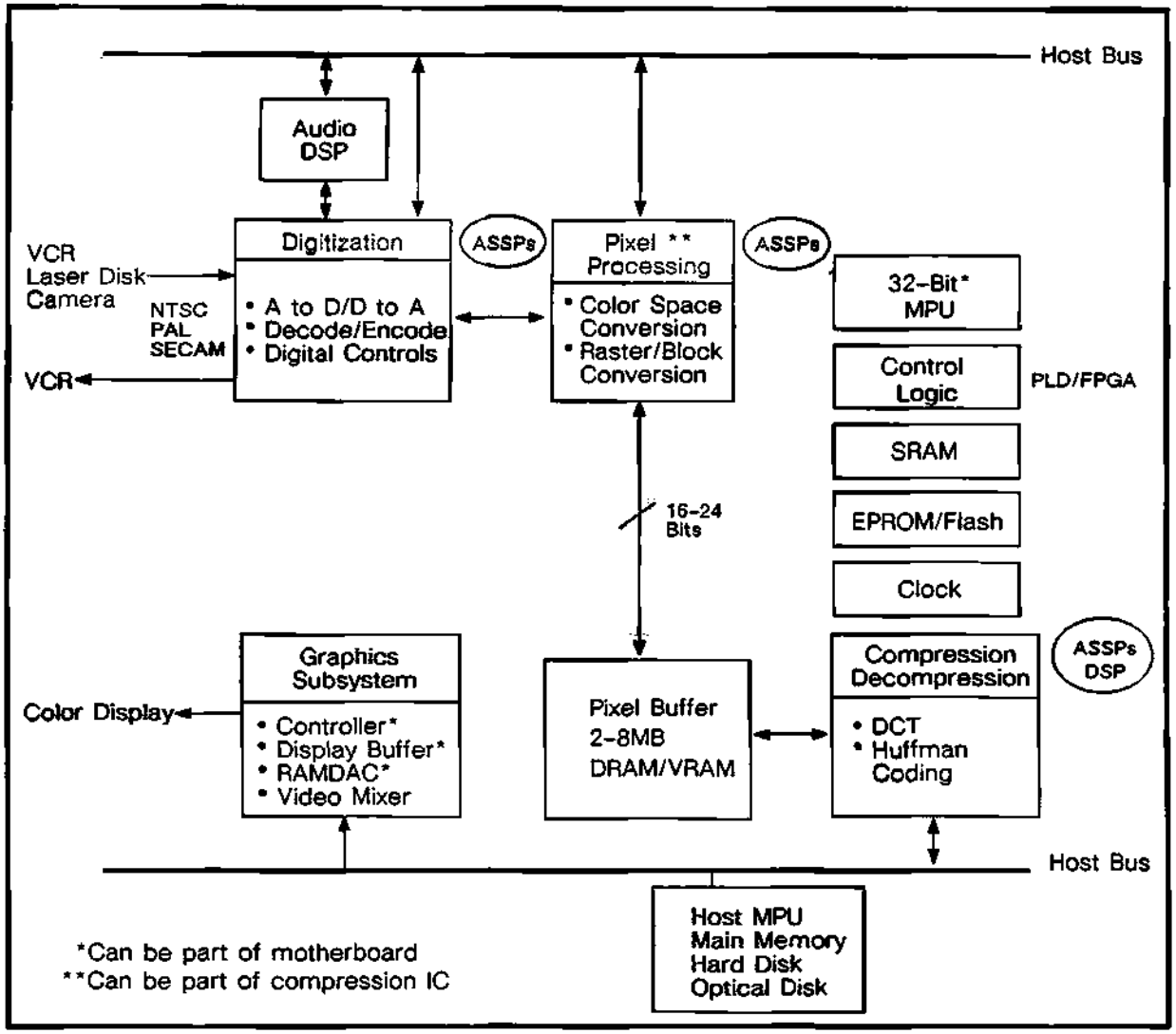
Figure 2 presents a generic, full-featured computer digital video system. Video signal input and output are managed by a set of digitization functions that digitize and restore TV signals like NTSC or PAL. The input signal can either be composite or come with separate luminance and chrominance signals as with S-VHS. Generally, the output is in a digital form of the YUV color space. The pixel stream created by this function is then converted into the RGB color space and corrected (inverse gamma). Then the data can be stored in a pixel frame for the compression function to take over. This series of steps is generally what comprises the capture function so far.

The compression function takes the buffered data and creates pixel blocks out of the rasterized data so that compression functions of discrete cosine transformation (DCT) and Huffman coding (for JPEG/MPEG) can operate. The compressed images can be output in standardized file formats (for example, TIFF and PICT) and then be stored or transmitted. To decompress for display, the above mentioned steps are reversed. The embedded graphics hardware can be shared by employing a video mixer. This arrangement also allows "windowing," which combines resident graphics with video stills or moving images.

Chip Opportunities

As shown in Figure 2, there are several semiconductor opportunities in digital video. Many of them are for application-specific standard products (ASSPs). The data conversion ICs are mixed-signal opportunities while the ASSPs are principally digital CMOS. As market economies develop, certainly many of these functions are subject to integration. Most of the systems

Figure 2
Generic Computer Digital Video



Source: Dataquest (November 1991)

handle <352 × 240 pixel resolution at 30 frames per second. The trend is to push this to 640 × 480 in the coming years. Examples include the following:

- D to A, A to D (video rates, 8-bit)
- NTSC/PAL/SECAM encoder/decoder
- Audio signal processor (16-bit)
- Video mixer
- RAM-palette DAC (video, RGB)
- Color space converter (YUV/RGB) implemented on integrated compression ICs
- Raster/block conversion ICs, implemented on integrated compression ICs
- JPEG/MPEG/Px64 compression ICs
- Pixel buffer (2MB to 8MB of DRAM/VRAM, 80ns, x8)
- SRAM buffer/scratch pad (1/4MB, <45ns, x8)
- EPROM/Flash control code (1/4MB)
- PLD/FPGA (2K to 3K gates)

Hardware Vendors

Table 2 lists some of the announced suppliers of digital video hardware. The majority of the offerings come in the form of add-in cards for popular buses like NuBus, S Bus (Sun), ISA/EISA, and MCA. Functions performed include image capture, compression, display management, and TV tuning. We expect platform makers to join the list over the coming year as they scramble for product differentiation. As can be seen, the list is long and undoubtedly some shakeouts will occur. It is possible that this market will behave as the VGA card market did because the video function could move to the motherboard.

Forecast: A Scenario

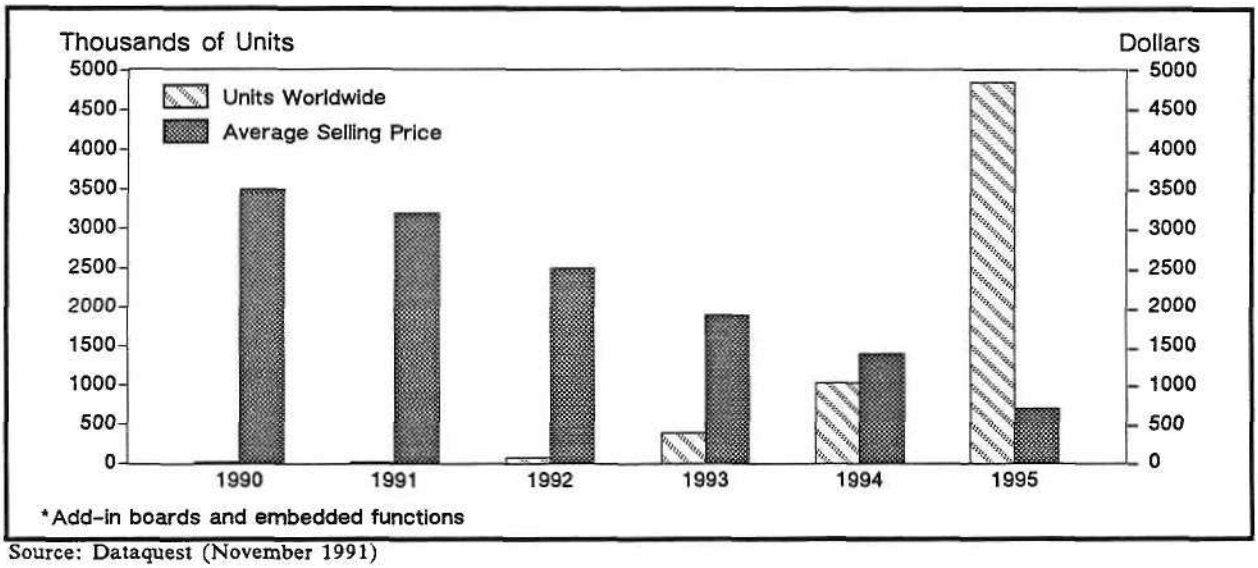
Figure 3 presents a forecast of how digital video functionality could pentrate the worldwide installed base. Penetration should not

Table 2
Digital Video Hardware Vendors

Company	Location	Company	Location
Aitech	Fort Worth, Texas	NEC Technologies	Tokyo, Japan
Apple Computer	Cupertino, California	New Media Graphics	Billerca, Massachusetts
Commodore	West Chester, Pennsylvania	NewTek	Topeka, Kansas
CompuAdd	Austin, Texas	New Video	Venice, California
DesignTech	San Jose, California	Philips Consumer	Eindoven, Netherlands
Digital F/X	Mountain View, California	Radius	San Jose, California
E-Machines	Beaverton, Oregon	RasterOps	Santa Clara, California
IBM	White Plains, New York	Rapid Technology	Amherst, New York
IEV International	Salt Lake City, Utah	Sun Microsystems	Mountain View, California
Intel	Princeton, New Jersey	Tandy	Ft. Worth, Texas
Magni Systems	Beaverton, Oregon	True Vision	Indianapolis, Indiana
Mass Microsystems	Sunnyvale, California	Video Logic	Cambridge, Massachusetts
NCR	Dayton, Ohio	Zenith Data Systems	Glenview, Illinois

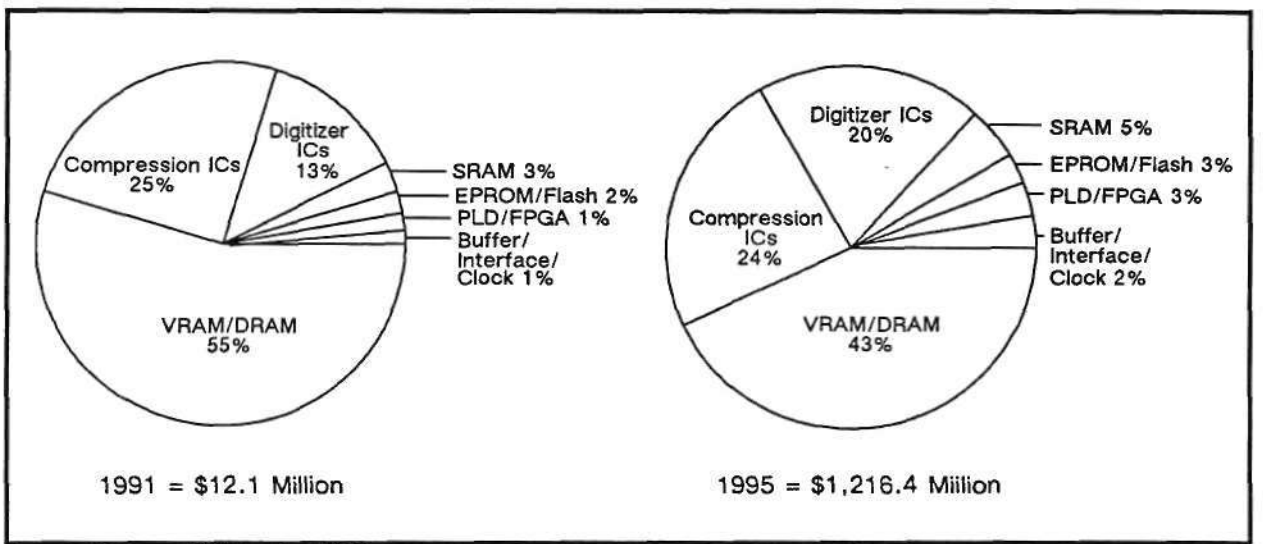
Source: Dataquest (November 1991)

Figure 3
Computer Digital Video Opportunity*



Source: Dataquest (November 1991)

Figure 4
Computer Digital Video Semiconductor Opportunity



Source: Dataquest (November 1991)

exceed 1 percent before 1994. As of today, it should take another year to settle the standards and generate a critical mass of application software and titles. It will then take another one to two years for the early adopters and producers (authors) of source material to move into action. This sets the stage for the market to take off by 1995. The worldwide market for boards (1 set per platform) could reach 4.8 million units by 1995. Most of the production of these boards will initially be in the United States and some in Europe; then production will migrate to Japan, Taiwan, and South Korea as the market matures.

Based on the above scenario, the semiconductor total available market presented by add-in boards and motherboard functions will be a billion dollar world market by 1995. About 55 percent of the opportunity is in VRAMs, DRAMs, and, to a lesser degree, Flash memory and SRAMs (with bit price assumptions) as shown in Figure 4. Another 20 percent of the opportunity is for ASSPs for NTSC/PAL/SECAM digitization and control. Another 20 percent of the opportunity is in the compression chip ICs. The remaining 5 percent is for control logic, clock ICs, and bus transceiver/buffers. The RAMDAC, graphic controller, SCSI ICs, and CD-ROM controller opportunities are not counted in this analysis but will be positively impacted by digital video growth.

Dataquest Perspective

Clearly, any outlook on computer-based multimedia and digital video is governed by the assumptions regarding the development of a critical mass of users wanting this functionality and suppliers agreeing to provide useful, multisourced, and economical systems. It appears that these factors are coming together and that a substantial market is emerging. As we have said, it will take the market a few years to develop, as producers and users of image information go down the learning curve and rediscover the axiom of a picture saying a thousand words.

The opportunity to semiconductor companies as modeled from the above scenario is principally in two areas. One is certainly for commodity products like DRAM, VRAM, SRAM, EPROM/Flash, PLD logic, and interface logic. The other is for complex ASSPs for the digitization of TV signals and compression. This is an opportunity to produce value-added products. It is very likely that digital video applications will become price sensitive quickly in order to develop a mass market. Dataquest believes that the challenge will once again be placed on the semiconductor industry to drive out costs through superior design and manufacturing. ■

By Gregory Sheppard

Rigid Disk Drives: A Case for Integration

The State of the Rigid Disk Drive Industry

This has not been a good year for personal computers. While PC sales were flat, the rigid disk drive (RDD) industry was gearing up in anticipation of a rapidly growing portable PC market only to find itself with an oversupply of rigid disk drives, vendor consolidation, and depressed drive average selling prices (ASPs). However, as tradition has it, down markets allow equipment manufacturers to focus heavily on new product development. So in the past year we have seen a myriad of new product announcements that include gigabyte-class 3.5-inch RDDs, 2.5-inch drives that offer 130MB, and the newest 1.8-inch RDDs at 42MB. There is no sign of slowing down the pace of innovation, and the race to produce faster, smaller, and less expensive drives at ever-increasing capacities is picking up.

According to Dataquest's Computer Storage group, the 1991 overall RDD increase in unit shipments over 1990 was a modest 13.4 percent (see Table 1). Dataquest expects a total unit volume increase of 19.6 percent in 1992. In particular, the 2.5-inch rigid disk drives should outpace the pack with a 115 percent increase in 1992, followed by a 23 percent increase for the 3.5-inch form factor. The 3.5-inch RDDs will be the preferred drive for desktop PCs, for workstations, and generally for systems that need higher capacities and data throughput. The 2.5-inch drives are the form factor of choice for notebook and a portion of the pen-based PCs. The 1.8-inch, a newcomer, should reach a volume perhaps as high as 1 million units in 1992. As expected the more mature form factors of 5.25, 8, and 14 inches will be in decline. The rigid disk drive ASPs should remain relatively stable (see Table 2).

The worldwide RDD market will grow at a modest 5 percent (revenue) rate in 1992, reflecting heavy pricing pressures (see Table 3).

Dataquest's worldwide factory revenue for rigid disk drives shows the 3.5-inch drive revenue growing at a compound annual growth rate (CAGR) of 17.8 percent, from about $6.2 billion in 1991 to about $11.9 billion in 1995. The 2.5-inch form factor revenue will grow at a CAGR of almost 43 percent over the same period to approximately $3 billion by 1995.

Table 1
Worldwide Rigid Disk Drive Unit Projections (in Thousands)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
2.5-Inch	714	2,888	6,192	9,960	12,968	12,836	45.2
3.5-Inch	21,742	23,727	29,262	31,516	35,304	34,955	10.2
5.25-Inch	6,877	6,750	4,684	3,734	4,384	6,396	-1.3
8-10-Inch	377	417	318	282	127	85	-32.8
14-Inch	237	167	134	95	44	33	-33.3
Total	29,947	33,948	40,591	45,587	52,828	54,305	12.5

Source: Dataquest (November 1991)

Table 2
Rigid Disk Drive Factory ASPs (in Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
2.5-Inch	263	247	244	280	284	231	-1.6
3.5-Inch	258	260	275	297	338	339	6.9
5.25-Inch	474	535	777	926	866	915	14.3
8-10-Inch	7,580	9,485	9,705	9,455	8,230	6,794	-8.0
14-Inch	21,934	24,523	23,643	23,184	20,892	19,697	-5.3

Source: Dataquest (November 1991)

Table 3
Worldwide Rigid Disk Drives Factory Revenue (Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
2.5-Inch	187	714	1,513	2,786	3,678	2,970	42.8
3.5-Inch	5,612	6,162	8,047	9,373	11,915	11,864	17.8
5.25-Inch	3,262	3,613	3,641	3,457	3,798	5,851	12.8
8-10-Inch	2,855	3,951	3,085	2,664	1,045	577	-38.2
14-Inch	5,207	4,098	3,178	2,198	928	650	-36.9
Total	17,123	18,537	19,464	20,478	21,363	21,913	4.3

Source: Dataquest (November 1991)

Table 4
Worldwide Rigid Disk Drive Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1995	CAGR (%) 1991-1995
2.5-Inch	34	124	248	369	493	512	42.5
3.5-Inch	990	994	1,165	1,204	1,362	1,403	9.0
5.25-Inch	323	301	217	190	257	431	9.4
8-10-Inch	113	131	105	98	46	33	-29.4
14-Inch	83	61	52	38	19	15	-30.0
Total	1,543	1,612	1,787	1,899	2,178	2,394	10.4

Source: Dataquest (November 1991)

Table 4 represents the worldwide semiconductor market for RDDs. The 2.5-inch drives will enjoy the highest growth as far as semiconductor content is concerned. This is primarily due to the need for substantial integration, dictated by limited space, and power availability.

RDD Controllers—How Many ICs Are Needed?

The movement toward an ever-shrinking form factor has created a need for higher levels of integration. Today's 3.5-inch RDD controller electronics is designed around one or two dozen ICs. The trend is for 2.5-inch drives to use just 10 to 12 ICs, with 1.8-inch drives now using six very large scale integration devices.

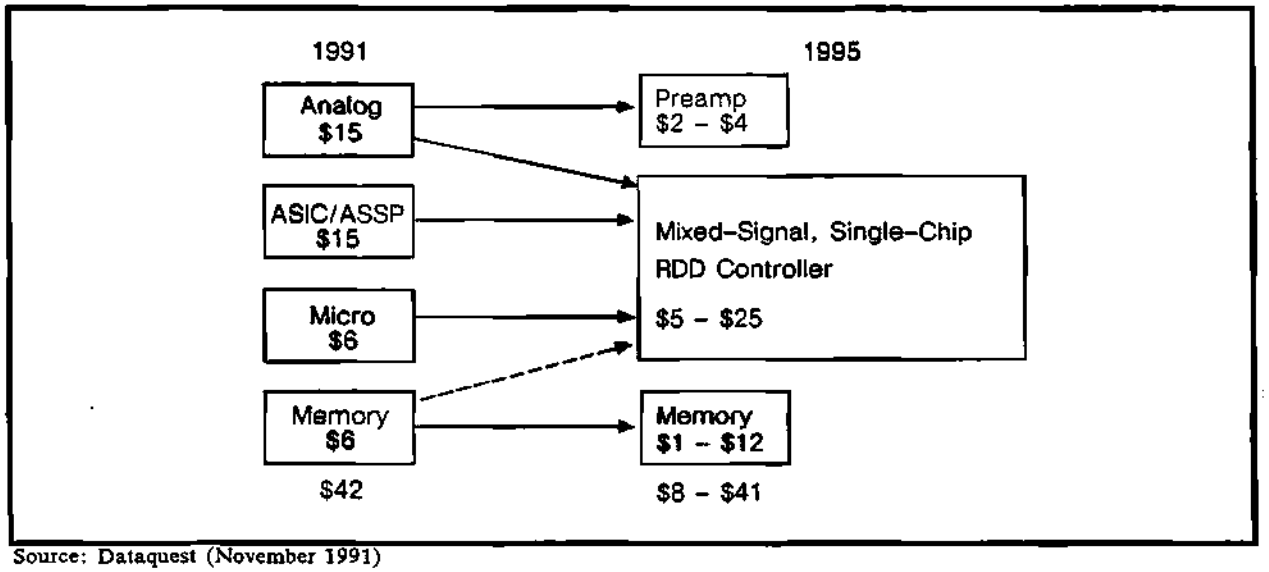
Most likely, the market for RDDs will expand as both ASPs and form factors shrink. New opportunities ought to provide for RDD market growth.

The day of the single RDD controller IC is approaching, along with its significant implications for semiconductor vendors. When the chip count drops from a dozen ICs to two or three, it is natural to assume that revenue loss for semiconductor vendors will follow. This assumption is partially true; the vendor base serving the RDD market will shrink. To be a player in the future, a semiconductor company will need to understand all aspects of the RDD design, including mechanical. The only other option would be to form a very close relationship with the drive manufacturer acting perhaps as a foundry. The price of single chip drive controller will not be $42 (the cost of the current average semiconductor content of a small drive). Most likely it will be somewhere between $8 and $25, allowing for different controller versions. That should give birth to the $100 drive with a low capacity of about 40MB to 100MB. The market is elastic and thus may provide for unprecedented growth into areas that never used RDDs. Thus the $5 to $25 single controller IC may become the "enabler" for new market growth.

The Semiconductor Makeup of an RDD

The semiconductor content of a small rigid disk drive (5.25 inches or less) costs approximately $42 in 1991 (see Figure 1). The cost breakdown

Figure 1
Estimated Rigid Disk Drive Semiconductor Content (Cost per Drive)



Source: Dataquest (November 1991)

is as follows: analog ($14.91), micro ($5.99); memory ($6.33), ASIC/ASSP ($15.17), and standard logic ($0.34). By 1995 almost all the functions may be integrated in a mixed-signal, single-chip controller. Then the drive electronics will most likely be reduced to three ICs: the controller, the buffer memory, and the head preamp. Under some conditions a small amount of buffer memory may be integrated into a low-end controller, resulting in a two-chip solution. The head preamp IC is and most likely will remain separate, a condition dictated by the necessary proximity to the disk drive's head(s) and needed noise isolation from the controller section of the system.

Process Technology

Mixed-signal is a key technology. Semiconductor vendors with such capability and experience will do very well supplying components to the RDD market.

Improving RDD Performance

Disk Arrays

Current-generation PCs are about 40 times faster than the original XT. By comparison, current-generation RDDs are only 10 times faster than the equivalent original XT drives. AS CPU performance increases, so does the percentage of time that programs wait for disk I/O. Disk drive makers are trying to address this problem by offering both logical and innovative solutions.

Disk arrays fall in the logical category. For example, four drives equipped with a SCSI interface can be connected together in parallel and serve a single-host computer. Data then can be striped across the four drives and provide for a substantial performance increase over single-drive systems.

As vendors attempt to remain competitive and offer ever-increasing capacities in ever-shrinking form factors, RDDs may for the first time be displacing semiconductor memories in some applications....

Another scheme called "mirroring" uses two drives per system to provide for redundancy. The same data are written to both drives; if one drive fails, the data are still available on the other. Beyond that, the two disks can be used to improve the overall system performance by sharing the data storage and retrieval task.

In the innovative category, RDD companies are experimenting with the use of parallel data

channel usage on 3.5-inch drives. Here 9 disk drive heads are synchronized to offer a "parallel" read/write configuration. Spindle drive synchronization of up to 10 drives is also believed possible.

The Quest for Higher Densities

Attempts to increase disk drive capacity include a move to offer Constant Density Recording (CDR) or a subset of CDR, Zoned Density Recording (ZDR). CDR/ZDR increases the amount of data stored on each track by keeping a constant bit density on every track through an increased data rate for tracks of increasing radius. CDR can increase a drive's density by nearly 50 percent. ZDR is simpler to implement and offers density increases near those of CDR. However, implementing CDR or ZDR complicates the servo system and the read/write channel electronics.

Buffer/Cache Sizes

The preferred size of the buffer/cache memory in the small form factor RDDs is 32KB (a single 256Kb SRAM). Buffer sizes should increase to between 128KB and 512KB by 1995 (a single 1MB/4MB device that may be either SRAM or DRAM). Only the higher-performance drives seem to implement data caching schemes. A small amount of memory, perhaps 8KB, may be integrated with low-end disk drive controllers. High-end systems may keep the memory separate to provide flexibility in system design.

The Drive to Dominate: Microcontroller versus DSP

The Motorola 68HC11 and Intel 8051 are beginning to be replaced by 16-bit microcontrollers in RDD control functions. Digital signal processors (DSPs) such as the Texas Instruments Inc. TMS320 or high-end 16-bit microcontrollers that incorporate DSP functions (multiplier-accumulator) such as the National Semiconductor Corporation HPC-Plus are increasingly being used. This trend is seen as necessary to achieve higher capacities in ever-shrinking drives.

Interface Preferences

So far the RDD interface has remained a mixture of IDE and SCSI or SCSI-2. The RDD vendors appear to be flexible and most are offering both interfaces as they wait for the marketplace to point the direction. In the long run it appears that SCSI may dominate as the interface of choice, because it offers the most flexibility and highest data throughput rates.

Forces Driving RDD Development

Downsizing

Smaller form factor rigid disk drives fit into notebook and pen-based PCs as well as other equipment where space is at a premium and where semiconductor memories are typically found. Oddly enough, this is perhaps the most significant technological development for RDDs. A 1.25-inch drive creates immense opportunities for market growth.

Lower Power Consumption

Lower power consumption is necessary if RDDs are to be used in future (ever-shrinking) and power-stingy portable PCs. The 2.5-inch and 1.8-inch RDDs consume approximately 2W in the active mode and about 0.4W in standby; 1.8-inch drives offer a 0.015W sleep mode. Both 2.5-inch and 1.8-inch drives operate from a single 5V supply; 3V versions should be introduced shortly. Some 3.5-inch drives still require a 12V supply in addition to the 5V.

Cost Reduction

Beyond the obvious (widespread usage of RDDs in portable PCs), lower costs are a necessary condition if new markets are to be created. Along with size and power consumption reductions, lower ASPs will enable penetration into new applications where mass storage was not used at all, such as television sets, VCRs, and automobiles.

Dataquest Perspective

Although it is masked by the current turmoil in the PC market (inevitable consolidation of RDD manufacturers and the myriad of new product announcements), something interesting is taking place within the rigid disk drive market. As vendors attempt to remain competitive and offer ever-increasing capacities in ever-shrinking form factors, RDDs may for the first time be displacing semiconductor memories in some applications—an interesting turn of events.

RDD vendors would differentiate their products based on performance or cost.

At a future 1.25-inch or 1-inch form factor, RDDs will occupy the same board space as a couple of IC packages while offering megabytes

of nonvolatile storage. It is true that the information stored cannot be accessed as easily as with semiconductor memories, but this is acceptable for many applications. Laser printer fonts are an example. There are other applications where serial data storage is a natural fit: TV and VCR video buffers, for example.

Does this mean that RDDs will steal significant market share from semiconductor memories? We do not believe that this will happen. Most likely, the market for RDDs will expand as both ASPs and form factors shrink. New opportunities ought to provide for RDD market growth.

Will the semiconductor market for RDDs essentially dwindle to nothing? Not likely. As we move toward the single-IC RDD controller the number of suppliers may drop to less than a dozen. In a future scenario similar to today's DRAM market, the "drive controller" may become a high-volume commodity item. For the suppliers (semiconductor companies) that remain, the game may prove very profitable.

The future rigid disk drive market may be 2 to 10 times its current size and far less dependent on the personal computer market.

Alternately a variety of single-chip drive controllers offering a spectrum of capabilities may become the norm. RDD vendors would differentiate their products based on performance or cost. In either case the single-chip controller will enable the RDD market to expand and penetrate new applications, something not achievable before because of space or cost constraints.

The future rigid disk drive market may be 2 to 10 times its current size and far less dependent on the personal computer market. ■

By Nicolas Samaras

T-Carrier Equipment Market Offers Mixed-Signal Semiconductor Opportunities

T-Carrier Overview

T-1 protocol is a point-to-point digital communications facility that can carry 24 voice-frequency (VF) channels over a single line. Typical T-1 equipment users include Fortune 2500 companies, universities, medical facilities, financial institutions, local telephone companies, interexchange carriers, and government agencies.

The North American T-1 standard allows the multiplexing of 24 VF channels (64 Kbps) over a single line at a combined rate of 1.544 Mbps. T-1 service can be provided by span lines, satellite, digital microwave, coaxial cable, and fiber optics. The major trends in the North American T-1 market include the following:

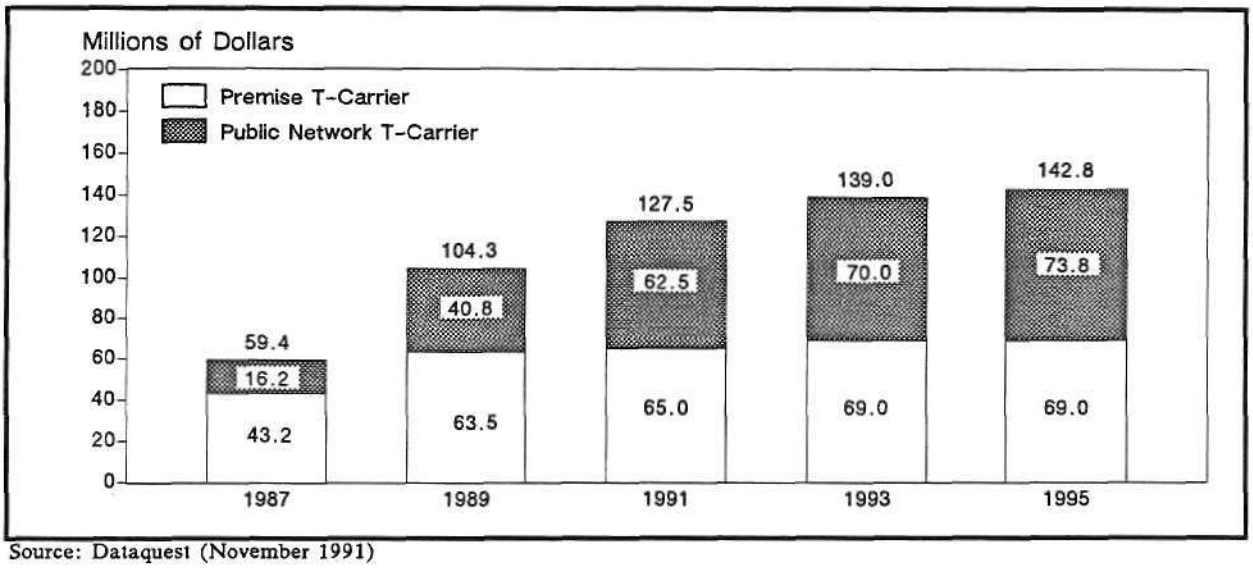
- Significant T-1 equipment price erosion due to functional very large scale integration (VLSI) and vigorous competition
- Incorporation of encryption and packet switching features
- Enhanced network management and control features

It should be noted that an increasing amount of carrier voice transmission is now based on higher-capacity T-2 multiplexers (96 VF channels per line) as well as fiber-based T-3 multiplexers (672 VF channels per fiber) and broadband fiber-based SONET multiplexers. The emergence of extensive fiber-optic communication networks, together with the evolution of Integrated Services Digital Network (ISDN) standards over the next decade, will accelerate the trend toward SONET-based fiber-optic multiplexers.

T-Carrier Semiconductor Content

Dataquest observes the emergence of highly integrated, mixed-signal T-1/T-3 application-specific standard product (ASSP) chip sets that address the digital and analog functions

Figure 1
Estimated North American T-Carrier Semiconductor Market (Millions of Dollars)



Source: Dataquest (November 1991)

required to implement the transmission portion of asynchronous 1.544 Mbps T-carrier line card. Earlier-generation T-carrier cards used separate bipolar analog line interface chips and digital pulse-code modulation multiplexing chips in order to interface to the T-carrier pipeline emerging from the premise. Such discrete early implementations of T-1 using bipolar analog interface chips, phase-lock loops, and digital MOS multiplex logic suffered from voltage drift and temperature drift problems that affected the performance of the T-1 line. The emergence of mixed-signal design techniques based on CMOS and BiCMOS process technologies has given impetus to the single-chip integration efforts for T-carrier line card applications.

Many telecom semiconductor companies offer T-carrier ASIC cores in addition to ASSP products.

T-carrier transceiver ASSPs support various framing standards such as super frame, extended super frame, SLC-96 (AT&T digital loop carrier standard), T-1 data multiplexer (T1DM), and ISDN primary rate applications. Performance monitoring is supported through features such as on-chip error detection and correction algorithms and data-link controllers.

In addition to the T-carrier ASSP transceiver chip set, typical T-carrier line-cards will contain an 8- or 16-bit CMOS microcontroller with a parallel bus interface to the transceiver. The microcontroller allows distributed control and programming of the T-carrier operation. Lower-cost T-carrier line-cards, alternatively, have limited hard-wired program instruction sets directly embedded on the ASSP. In such cases, the ASSP transceiver bus can be directly accessed to relay execute instructions. In addition to the transceiver ASSP and the microcontroller, the T-carrier line-card may have some buffer memory (16 to 64K SRAM), EPROMS (256K) for program storage, and some programmable logic devices such as programmable logic arrays or field-programmable gate arrays.

Many telecom semiconductor companies offer T-carrier ASIC cores in addition to ASSP products. Such core ASIC libraries include T-carrier line performance monitors, transceiver cores, and line-interface circuits. T-carrier equipment companies use these ASIC cores to customize their system with regard to features such as backplane interface, network monitoring and testing, and digital cross-connect features.

T-Carrier Semiconductor Market and Applications

Figure 1 shows Dataquest's market estimates for the history and future growth of the T-carrier-related semiconductor device market. The total

T-carrier semiconductor market is expected to grow at a sedate compound annual growth rate (CAGR) of 3.8 percent from $118 million in 1990 to $142 million by 1995. The market is essentially composed of mixed-signal ASIC and ASSP devices. The merchant-supplied portion of this market should grow substantially faster than the captive portion. T-carrier semiconductors are used in both premise and public (central office and network) applications.

Semiconductor Forecast Assumptions

Dataquest assumed a tenfold multiplication factor to arrive at the combined T-1/T-3 node units based on the annual end-to-end T-1/T-3 installed lines. Such a multiplication factor accounts for the multiple number of T-carrier line-cards in a typical end-to-end public network trunk line with multiple repeater and digital cross-connect stations. Based on such an approach, Dataquest estimates that the number of public network T-carrier nodes will increase at a CAGR of 16.1 percent from 0.777 million nodes in 1990 to 1.64 million nodes by 1995. The semiconductor content per public T-carrier node is assumed to change from $70 per node in 1990 to $45 per node in 1990 by 1995.

For the premise portion of the T-carrier market, Dataquest assumed an I/O ratio of 12 percent for the semiconductor content of premise T-carrier systems. Dataquest believes that the premise T-carrier equipment market, which includes channel service units (CSUs), data service units (DSUs), and embedded T-1 line cards in PBX systems, will grow at a CAGR of 1.5 percent from $530 million in 1990 to $571 million by 1995. We have applied a 12 percent semiconductor I/O ratio to the premise T-carrier equipment forecast to arrive at the premise T-carrier semiconductor market.

In 1991, the total T-carrier semiconductor market was almost equally divided between public and premise telecom applications. Dataquest expects the public telecom portion of T-carrier semiconductor applications to grow at a CAGR of 6.3 percent from $63 million in 1991 to $74 million by 1995. In contrast, the premise portion of the T-carrier semiconductor market is expected to be relatively flat, it will only grow at a CAGR of 1.5 percent from $65 million in 1991 to $69 million in 1995.

Digital cross-connect systems that are used in public networks to flexibly configure, multiplex, and monitor fiber-optic SONET data streams, together with lower bandwidth T-1 and T-3 trunk lines, are a high-growth factor in the public telecom T-carrier market.

In the future, even the smallest business office locations should be able to afford a T-1 pipe that can carry voice, data, image, video, and graphics directly to the interexchange carrier.

The premise T-carrier market has become relatively mature because of the high penetration of T-1 lines into the premise telecom market. Point-to-point trunk T-1 trunk lines and private network T-1 lines are facing increasing competition from broadband fiber-based SONET private network data service providers. Only the network access segment of the premise T-carrier market will exhibit growth between 1991 and 1995 because of the increasing affordability of T-1 line-cards and their incorporation in low-end PBX systems. The new market of fractional T-1, which allows for subrate usage and sharing of a trunk T-1 line, is expected to proliferate the applications of T-1 network access line-cards in small office premises. In the future, even the smallest business office locations should be able to afford a T-1 pipe that can carry voice, data, image, video, and graphics directly to the interexchange carrier.

Dataquest Perspective

The past few years have seen a proliferation of focused semiconductor companies that address the telecom ASSP and ASIC market. Some of the key T-carrier semiconductor vendors include AT&T, Base2, Crystal Semiconductor, Dallas Semiconductor, Level One, Mitel, and VLSI Technology. The deregulation of the long-distance network business, the emergence of broadband network standards, coupled with the availability of mixed-signal IC design tools and VLSI process technology, has spurred the emergence of a merchant T-carrier semiconductor market that challenges the proprietary in-house expertize of vertically integrated telecom companies such as Alcatel, AT&T, Fujitsu, Northern Telecom, NTT, and Siemens. Dataquest believes that broad-range telecom ASSP suppliers that cater to the emerging fiber-optic SONET networking market as well as the more mature T-carrier market will be well positioned to exploit the hybrid nature of future long-distance networking solutions. ■

By Krtshna Shankar

In Future Issues

The following topics will be featured in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in pen-based computers
- Opportunities in personal communications networks (PCNs)

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Dataquest Perspective

Semiconductor Application Markets *Worldwide*

Vol. 1, No. 3 **December 16, 1991**

Market Analysis

Inquiry Summary

Market Analysis

LAN/FDDI Applications: Excellent Chip Set Opportunity

Desktop connectivity continues to be the driving force behind the need to provide shared access to data and devices independently of geographic and time boundaries. Applications to date that have impacted desktop connectivity include electronic mail, word processing, spreadsheets, desktop publishing, databases, and voice.

Dataquest expects networking applications for the 1990s to be multimedia in nature, including voice, data, graphics, still image, and full-motion video connectivity. High-speed (bandwidth), fault-tolerant, distributed-intelligence, seamless networks will be needed to cope with the increasingly demanding requirements of graphics and video communication. This article examines the LAN and fiber-distributed data interface (FDDI) application chip set market trends.

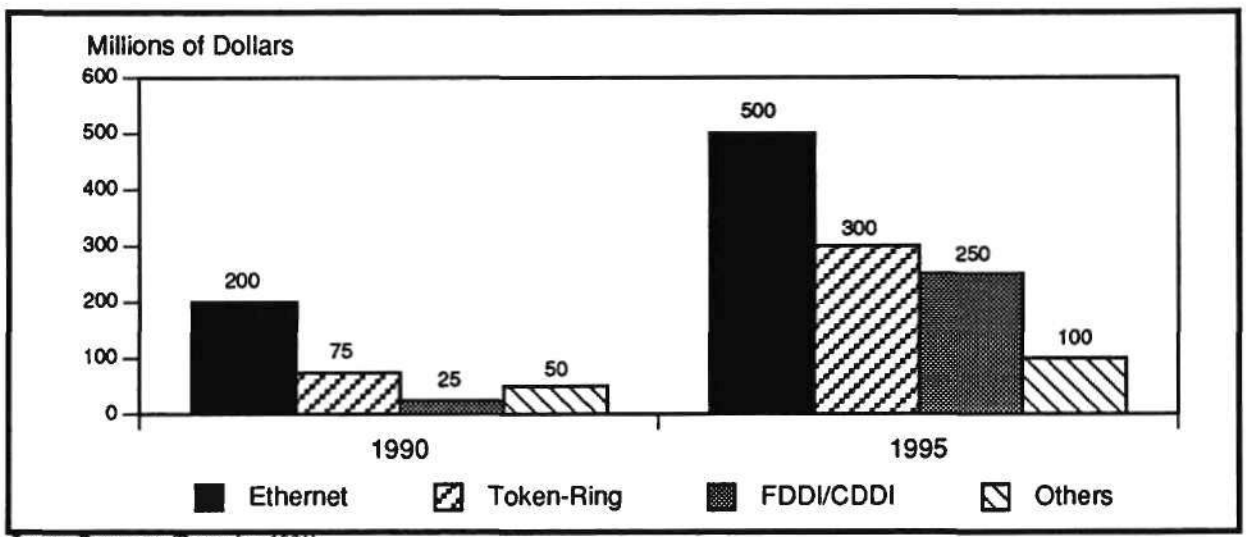
Worldwide LAN/FDDI Chip Set Consumption Market Forecast

We estimate that the worldwide LAN/FDDI chip set market will grow at a meteoric compound annual growth rate (CAGR) of 27 percent from $350 million in 1990 to $1.15 billion by 1995.

The North American consumption market accounts for almost 70 percent of the current worldwide LAN/FDDI chip set market because of the region's leading position in networking equipment production. However, the North American LAN/FDDI chip set consumption market is expected to decline to 50 percent of the $1.15 billion market by 1995 as Asia/Pacific-Rest of World (ROW), European, and Japanese LAN equipment companies emerge to exploit the high-growth global networking market. Many North American semiconductor companies will increase their shipments of low-end LAN chip sets to the Asia/Pacific region for incorporation in low-price, high-volume NIC add-in card applications.

Figure 1 shows the growth of different segments of the LAN/FDDI chip set market between 1990 and 1995. Ethernet chip sets accounted for the dominant portion (57 percent)

Figure 1
Estimated Worldwide LAN/FDDI Chip Set Market, by Segment (Millions of Dollars)



Source: Dataquest (December 1991)

of the $350 million 1990 market. The affordability and increasing momentum of unshielded twisted-pair (UTP) media, together with the early adoption of ethernet by network leaders such as Digital Equipment Corporation, has led to ethernet's position as the largest LAN chip set market. Token-ring chip set consumption accounted for 21 percent of the 1990 market.

The LAN chip set market is segmenting into low-end, midrange, and high-end segments that address different price/performance points within end-user markets.

The token-ring LAN market has traditionally been driven by IBM Corporation. The token-ring LAN market recently acquired significant momentum because of the joint announcement of 16-Mbps Token-Ring products for UTP media by IBM and SynOptics Communications Inc. These products apparently successfully address traditional customer concerns about network signal distortion (jitter) and crosstalk problems that can occur with UTP-implemented Token-Ring solutions.

Dataquest believes that the worldwide ethernet LAN chip set market will grow at a CAGR of 20 percent to $500 million by 1995. The emergence of UTP Token-Ring protocol is expected to spur growth of the token-ring chip set market at a higher CAGR of 32 percent to $300 million by 1995. Higher average selling prices for token-ring chip sets are also partially responsible for the higher token-ring chip set market CAGR, compared with the ethernet chip set market CAGR.

Dataquest believes that the FDDI/CDDI chip set market will grow rapidly at a CAGR of 59 percent from only $25 million in 1990 to $250 million by 1995. The emergence of global, well-defined FDDI standards, together with a low-cost copper-wire media implementation scheme, is expected to spur the adoption of high-bandwidth-oriented (100 Mbps and above) desktop connectivity schemes for graphics and desktop video communications applications. Table 1 compares ethernet and FDDI LAN features. The tenfold increase in bandwidth from 10 Mbps to 100 Mbps, together with vastly increased network size, is expected to favor the ultimate extension of FDDI internetworking backbones to the desktop.

LAN Chip Set Market Trends

The LAN chip set market is segmenting into several distinct market segments, based on applications and desired features.

Low-End Segment

The low-end segment includes the low-price, high-volume 10BASE-T LAN market that is increasingly being used as the mainstream office work-group networking solution. The traditional network interface card is being shrunk to two- or even single-chip solutions that are migrating to the motherboard. Such core LAN chip sets are used in high-end desktop PCs, portable PCs, and entry-level workstations. Dataquest believes that high-end PC manufacturers will increasingly adopt built-in networking capability on the motherboard in an attempt to differentiate themselves in a commodity market.

Such high-volume, low-end LAN chip sets incorporate the Ethernet CSMA/CD protocol core hooked to an 8-bit or 16-bit host data bus. A limited amount of on-board cache buffer memory supports serial communications rates of 16 Mbps to 20 Mbps, together with capabilities for automatic retransmission without host processor intervention. Some LAN chip set vendors have successfully integrated the LAN

Table 1
FDDI versus Ethernet

Feature	FDDI	Ethernet
Maximum Physical Bandwidth	100 Mbps	10 Mbps
Maximum Packet Size	4,500 bytes	1,500 bytes
Access Method	Token-passing	CSMA/CD
Topology	Dual ring/star/tree	Bus/star
Maximum Length of Network	100km	2.5km
Maximum Length between Nodes	2km	500m

Source: Dataquest (December 1991)

controller function and the serial transceiver functions on a single chip.

Midrange Segment

Applications for the midrange LAN chip sets include midrange workstations, diskless workstations, and local intelligent hubs that provide limited support for mixed protocol environments. Chip sets in this segment offer users some programmability and customization options for product differentiation. Recently, mixed-protocol chip sets that claim to offer token-ring and ethernet support have emerged to address this market.

High-End Segment

Applications for high-end LAN chip sets include distributed enterprisewide intelligent hubs, bridges, intelligent routers, high-performance servers, and high-performance workstations in distributed computing applications. Such high-performance LAN/FDDI backbone environments always tend to support several LAN protocols. High-end LAN chip set vendors are beginning to offer shrink-wrapped silicon and software solutions that are optimized to operate in a mixed-protocol environment.

Figure 2 shows a functional schematic block diagram of general partitioning trends for a high-end LAN chip set. In addition to the LAN controller and serial interface blocks, such chip sets are bundled together with RISC coprocessors and generous amounts of buffer SRAM or DRAM memory in order to allow LAN equipment vendors to offer feature-rich, high-performance, customized solutions. These chip sets support multiple industry-standard network operating systems.

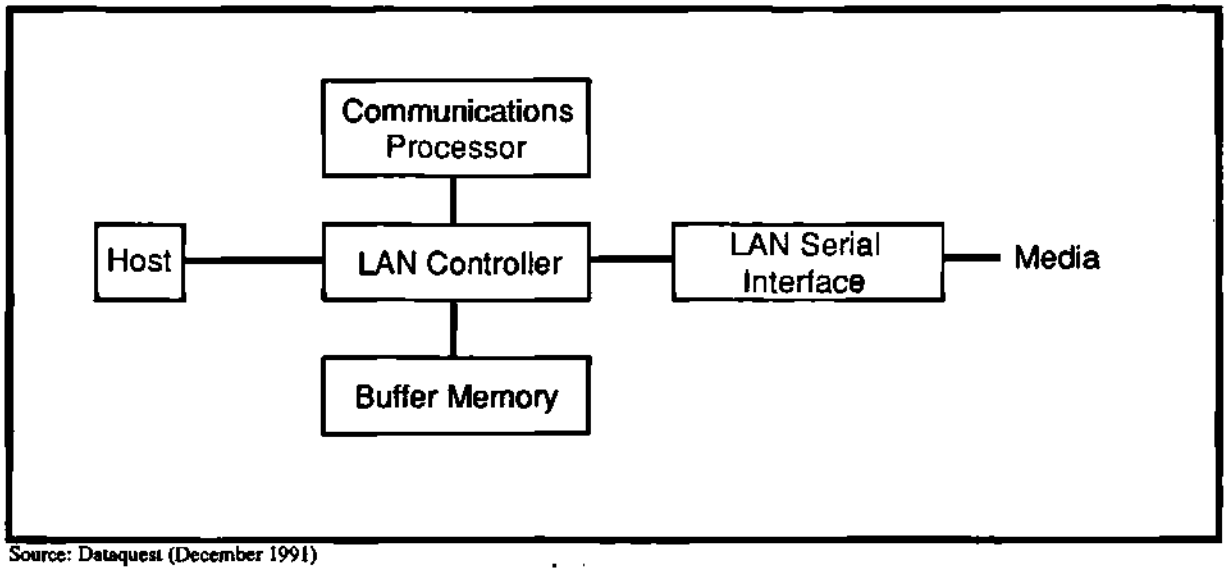
High-end LAN controllers will offer features such as buffer memory management, mixed protocol network performance monitoring and control, remote boot-up, 32-bit direct host bus interface and memory access, and external address filter capability. The LAN serial interface block will offer features such as programmable protocol selection, on-chip data/clock recovery, loopback self-diagnostics capability, and built-in 10BASE-T transceiver.

FDDI/CDDI Chip Set Market Trends

The deterministic, dual counterrotating nature of FDDI LANs, together with their high-bandwidth and enterprisewide inter-LAN capabilities, is considered to be very desirable in fault-tolerant, real-time, large-file transfer applications. The three key applications for FDDI/CDDI chip sets are as follows:

- Backbone LAN supporting LAN interconnections of departmental and work group LANs.
- Back-end networking supporting host-to-host and host-to-I/O connections.

Figure 2
LAN Chip Set Implementation



Source: Dataquest (December 1991)

- Front-end LANs supporting technical and graphics server-workstation graphics-intensive distributed computing applications.

FDDI equipment vendors are exploring several lower-cost copper-media alternatives to the traditional fiber-media solution. These vendors include Cabletron Systems, Chipcom Corporation, Digital, and SynOptics. Lower-cost FDDI NIC products will allow for rapid penetration of FDDI from inter-LAN backbones to the high-volume, desktop LAN market. Dataquest believes that FDDI-II chip sets aimed at multimedia LAN applications will begin to arrive in the market during the 1992 to 1993 time frame. FDDI-II will support multimedia applications by providing 6-Mbps increments of bandwidths (carved out of the 100-Mbps ring) dynamically allocated to isochronous T-1 channels for voice and video. Dataquest believes that high-end graphics workstations and high-performance file servers will incorporate ULSI-level single-chip FDDI-II on the motherboard in the 1994 to 1995 time frame.

Dataquest Perspective

Dataquest sees emergence of a global, high-value-added, merchant LAN/FDDI chip set market that will grow phenomenally at a CAGR of 27 percent from $350 million in 1990 to $1.15 billion by 1995. Ethernet and token-ring chip sets make up the bulk of the market today. However, because of the emerging need for high-bandwidth, fault-tolerant, enterprisewide networking for graphics and multimedia applications, Dataquest forecasts the high-speed FDDI/CDDI chip set market to grow dramatically from $25 million in 1990 to $250 million by 1995.

Dataquest believes that semiconductor companies should forge timely, strategic OEM partnerships with LAN/FDDI networking equipment companies in order to take advantage of end-user experience and potentially big design wins.

The LAN chip set market is segmenting into low-end, midrange, and high-end segments that address different price/performance points within end-user markets. PC, workstation, and high-performance file server products will incorporate customized, feature-rich, high-end LAN chip sets on the motherboard in their quest for product differentiation in an increasingly commodity hardware market. Dataquest believes that semiconductor companies should forge timely, strategic OEM partnerships with LAN/FDDI networking equipment companies in order to take advantage of end-user experience and potentially big design wins.

By Krishna Shankar

Automotive Applications: More Controls Offset Vicious Economics

Clearly 1991 was a year to forget if one depends on the global automotive and truck electronics market. The dominant markets for electronics-rich vehicles are the G7 economies, all seven of which were either in recession or slowing during the year. The outlook for 1992 is for a moderate recovery in consumer durables, which includes vehicles.

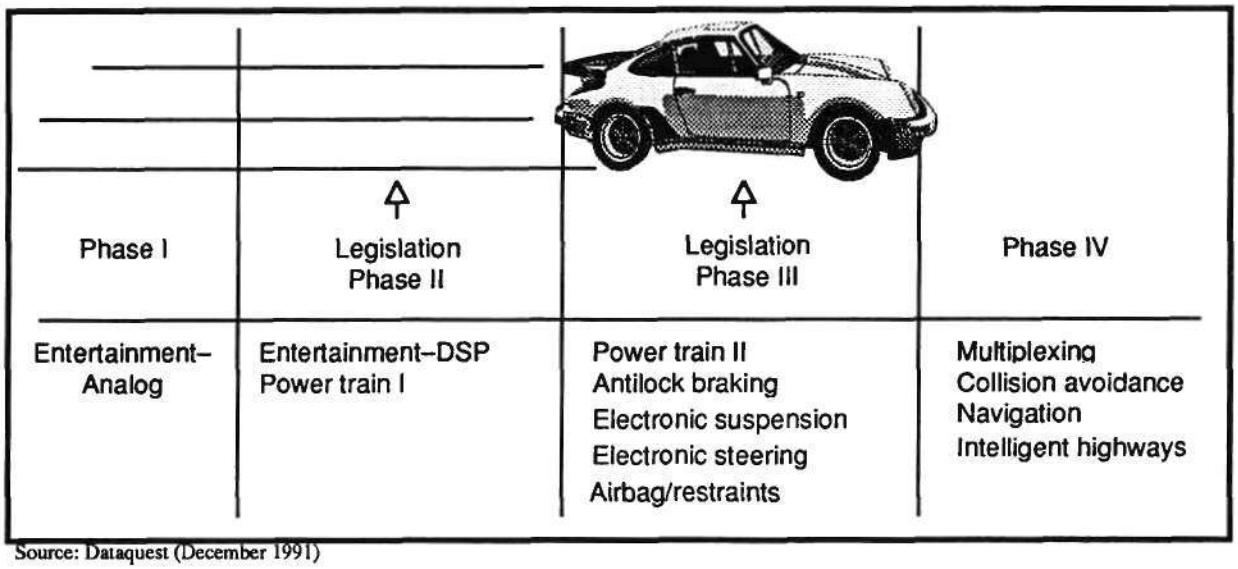
The continued penetration of new and more sophisticated controls and features into vehicles continues to buffer the market variability and to offer new opportunities. Figure 1 illustrates the various phases of the automotive electronics market. Cars and trucks for the North American market have entered phase III, while vehicles in Japan are in the later stages of phase II and European vehicles are midway through phase II.

New Opportunities

There are dozens of emerging uses for electronics in vehicles. Three forces generally push the increased use of electronics, as follows:

- Regulations for reduced air emissions, improved fuel economy, and safety
- Product differentiation
- Economics—cases where chips and printed circuit board (PCBs) are cheaper than electromechanical parts

Figure 1
Road Map for Vehicle Electronics Penetration



Source: Dataquest (December 1991)

Emission Controls Shift to Next Gear

Designing an engine that is both efficient at using hydrocarbon energy and able to simultaneously minimize air emissions is a techno-economic challenge. The California Air Resources Board (CARB) continues to be the global pacesetting regulatory body for establishing emission requirements. CARB regulations are being adopted across the United States in the form of the Clean Air Act of 1990. Many European and Asian countries are also following CARB guidelines. The principal impact on the semiconductor industry will be a new evolution of power train electronic controls.

In the United States and Japan, these controls are becoming 32-bit microcontroller unit (MCU)-based, with multipoint electronic fuel injection (EFI), integrated cruise control, and distributorless ignitions. This 32-bit real-time processing also allows integration of transmission control for optimal shifting.

Electric Vehicles

Another innovation from CARB is a requirement that 10 percent of the new cars sold in California by 2003 (2 percent by 1998) have zero air emissions (that is, be electric). These vehicles would be battery operated using electric motors rather than engines. The concept is to target commuting vehicles and let the local power plants (with strict emission controls) with coal-derived electric energy power the commuters.

To support development of an electric car battery, an industry group known as the U.S. Advanced Battery Consortium has been formed. Its charter is to develop a quick-charge, high-power-density battery that can run a vehicle more than 100 miles at freeway speeds before recharging. The group comprises Chrysler Corporation, Ford Motor Company, and General Motors Corporation (GM); EPRI (an electric utility research group); and the U.S. national laboratories. The consortium plans to spend $260 million over the next four years, with half of the funding coming from the U.S. government.

The principal impediments to the electric vehicle market are costs and standards.

Green movement pressure in Europe is expected to stimulate efforts for that market as well. The Japanese effort seems to be a wait-and-see approach, although Nissan's FEV technology based on nickel-cadmium batteries is capable of a range of 156 miles at a maximum speed of 81 mph. In the United States, GM is

the apparent leader in electric vehicle technology; a production variant of its Impact test vehicle is rumored to be ready by 1993.

The electronic content of an electric vehicle should be similar in dollar value to the combustion engine version, but different power train technology will be needed. The traditional power train electronic elements would be replaced by battery and electric motor controls. A transmission might not be needed because direct-drive DC motors accommodate torque demands. Semiconductor applications for electric vehicles include the following:

- Battery charging (4 to 6 hours), management (loading and distribution), and monitoring (status and safety)
- DC propulsion motors and management
  - Greater than 300V smart power ICs and transistors, switches, DC/DC conversion, voltage regulators, and protection circuits
  - 16- to 32-bit MCUs for motor control
  - Multiplexing and diagnostic interface ICs

The principal impediments to the electric vehicle market are costs and standards. Key costs include those of the vehicle and inclusive battery technology, maintenance (such as replacement batteries), and infrastructure changes (for example, 220/440V battery recharging units for the home). On the standards front, the U.S. National Highway Traffic Safety Administration estimates that it will take 18 months to establish safety standards (that is, 300V handling), service tools, and service training. Assuming that other U.S. states and countries follow California's lead, the electric vehicle market could reach 1 million units a year by 2003.

32-Bit Controls Stimulated by Smart Transmissions

Many vehicle manufacturers, including Ford, GM, and Toyota, have announced their intention to use 32-bit MCUs in the power train. Motorola Incorporated is the prime beneficiary of design-wins to date. The design goal is to integrate traditional engine control functions with those of transmission and cruise control management. The driving force behind this integration is the processing power the CARB regulations will require, along with a separate request for improved fuel economy. The U.S. Congress is expected to soon approve some form of increase in the corporate average fuel economy (CAFE) requirement from 27.5 mpg today to 34 mpg or higher by 2001.

Car and truck semiconductor applications will continue to present an attractive opportunity through the forecast period.

It is interesting to note that Ford chose a variant of Motorola's 88K RISC technology as its controller. Ford cited small die size and the availability of high-level language programmability as some of the decision criteria. Other semiconductor opportunities for electronic transmission control include fuzzy logic (to augment the MCU) for shifting decisions, power transistors (either MOSFET or bipolar) to drive solenoids, and various sensors (accelerator pedal, fluid pressures, and torque).

Air Bags

Air bags continue to penetrate the available market as regulatory deadlines near. Dataquest estimates that more than 25 million units (including passenger-side air bags) will be shipped worldwide annually by 1995. Nissan, Siemens, Toyota, and TRW Incorporated are some key air bag controller OEMs. These shipments translate into a $350 million annual semiconductor market for air bag control units (assuming a $14 content). Next-generation bill-of-material requirements include the following:

- Voltage regulator, zener diode, DC-DC converter
- 8-bit MCU with 2-Kbit serial EEPROM, 10-bit A/D at 18us
- Driver circuits (3-5)
- Signal conditioning circuits (from sensors)
- Acceleration sensors (2 solid-state)

Antilock Braking System (ABS)

Like air bags, antilock braking systems are being driven by the consumer desire for safety. Dataquest projects that the world market for these systems could exceed 30 million units annually by 1995. The semiconductor content for a typical four-wheel ABS (courtesy of

Dataquest's ESAM service) runs at $24 including two MCUs (8- or 16-bit), voltage regulators, drivers, signal conditioners, a diagnostic IC, and an EEPROM. This translates into a $450 million semiconductor market annually by 1995. Key OEMs include Bosch, Delco, ITT-Teves, Kelsey-Hayes, Nippon ABS, and Nippondenso.

Multiplexing

Efforts at creating standardized data communication inside and outside of the car continue. The key issue inside the vehicle involves settling on and implementing a protocol. The leading candidates are the SAE J1850 and the Bosch/Intel CAN. J1850 appears to be the leader for diagnostic or class B applications as it has the broadest base of support. It operates between 10 and 100 Kbps over a single wire or a differential pair.

Remaining issues are related to implementation and will most likely take another year or two to settle. The total available worldwide market for standalone J1850 or CAN communications ICs, assuming that the price is right ($2 to $4 per node), could reach 120 million units annually by 2000 (assuming 10 nodes per vehicle penetrating 25 percent of all vehicles). A substantial fraction of this function could move to the MCU communications block, however.

Navigation and Intelligent Highways

The need to navigate optimally through heavy urban traffic or over seldom-traveled country roads continues to be a draw for vehicle navigation systems, especially for mobile jobs such as trucking, repair services, and emergency crews. Initial versions used dead-reckoning technology with CD-ROM-based maps. The latest versions are using the U.S. Air Force's Global Positioning System (GPS) to add satellite-derived location data to improve the location calculation. The driver interface is a CRT display that can show a map, a suggested route, current location, and estimated time of arrival. The rest of the system comprises motion sensors, odometer input, receivers (GPS or other RF directional sources), a navigation computer, and a CD-ROM. (For more information, see SAM newsletter 1991-11, "OEM Monthly: Personal Communications Stimulates RF Market," for GPS receiver semiconductor content.) Suppliers of these systems include Blaupunkt, Pioneer Electronics, Teletrac (for locating stolen vehicles), Toyota (with Nippondenso), Nissan, and Mazda.

Communications technology between the car and road system also continues to be developed. Use of such systems includes traffic congestion avoidance and automatic vehicle identification (for tolling, among others). Many international efforts are under way in this area, including a pan-European effort known as Prometheus, a U.S. effort known as Intelligent Vehicle Highway Systems (IVHS), and in Japan the Advanced Mobile Traffic Information and Communication System (AMTICS). Each system is a testbed examining feasibility and proving concepts.

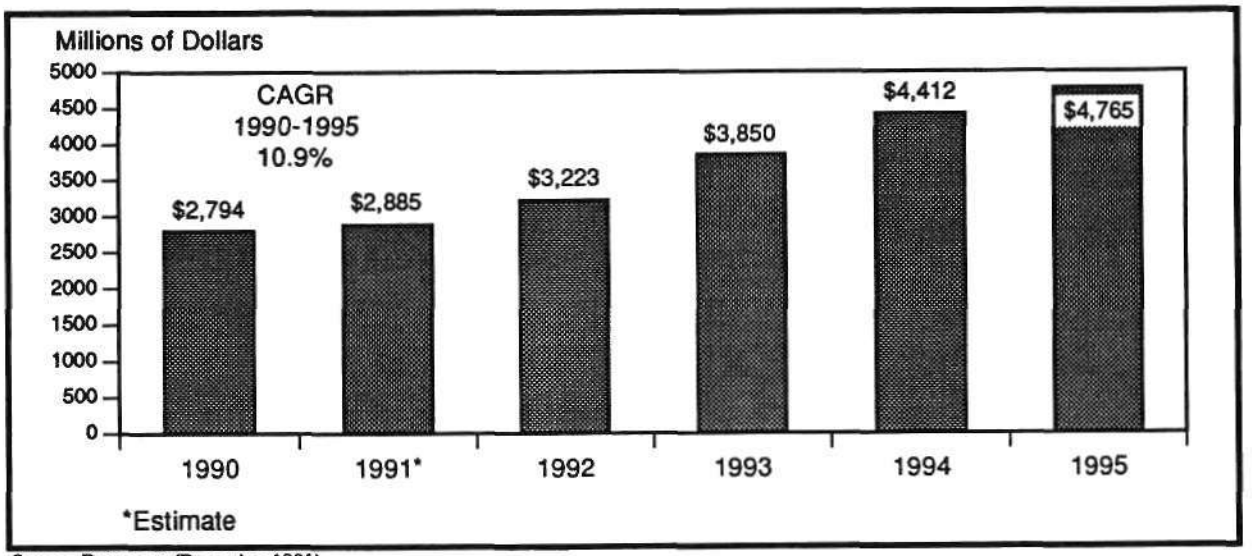
Semiconductor Consumption Forecast

Figure 2 presents Dataquest's forecast of worldwide automotive and truck semiconductor consumption. Overall consumption is expected to grow at a 10.9 percent CAGR until 1995, when it reaches $4.8 billion. The key growth markets will be in Europe and Asia/Pacific. Growth in Europe is driven by tougher emission laws and air bag and ABS penetration. Asia/Pacific countries such as Taiwan are imposing pollution laws as they mature and can now afford to concentrate on such issues. Because of the relative maturity of their markets, North America and Japan will grow more slowly; but applications such as advanced power train control, advanced entertainment (such as CD/DAT), ABS, and air bag controls will be the main drivers of those markets.

The challenge is investing in effective customer relations, the best-quality programs, and the right technology and products.

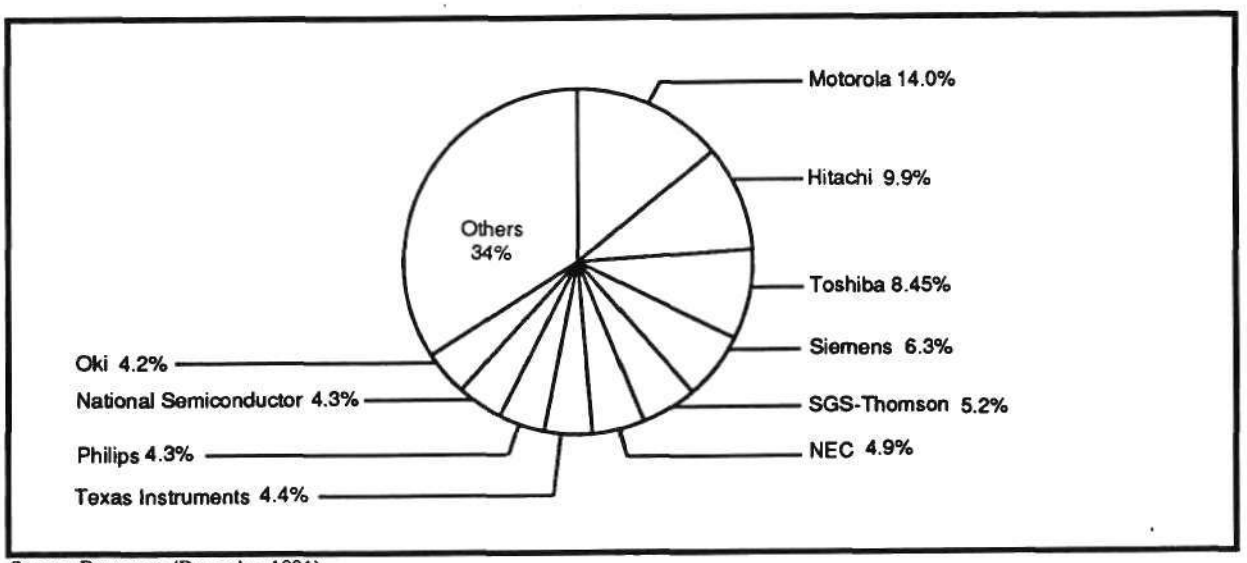
Key semiconductor technologies for automotive use will be analog and mixed-signal application-specific ICs (ASICs) and functions (bipolar and BiCMOS particularly), power ICs and transistors (bipolar and DMOS-MOSFET), MCUs (8-, 16-, and 32-bit with configurable memory blocks), and to a lesser degree standalone MOS nonvolatile memories.

Figure 2
Worldwide Automotive Semiconductor Forecast (Millions of Dollars)



Source: Dataquest (December 1991)

Figure 3
Worldwide Automotive Semiconductor Market Shares—1990



Source: Dataquest (December 1991)

Industry Players

Motorola is the world's largest merchant supplier of automotive and truck semiconductors (see Figure 3). An estimated 40 percent of its revenue is from versions of its popular 6805 and 68HC11 families. The company recently announced engine controller design wins with its 32-bit 683XX and 88K families for Ford, GM, and Toyota. Motorola also sells most of its broad product line of analog ICs and discretes into this marketplace. A substantial percentage of Motorola's automotive revenue is for custom or semicustom versions of its standard products. Its success in vehicle applications is clearly attributable to focused customer relations and Baldrige-award-winning quality. An in-house customer such as the Motorola Automotive and Industrial Electronics Group is also an advantage.

Japanese suppliers such as Hitachi Ltd., NEC Corporation, and Toshiba Corporation have benefited from global market share increases by Japanese automakers. All three companies offer automotive product portfolios ranging from LEDs to microcontrollers. Especially interesting to note are gains made by European suppliers Philips, SGS-Thomson Microelectronics, and Siemens—primary beneficiaries of high growth of the European market, largest vehicle market in the world. These three grew an average 23 percent last year.

Dataquest Perspective

Car and truck semiconductor applications will continue to present an attractive opportunity through the forecast period. The reward for diligent suppliers is million-unit orders, the likes of which are seen only in the consumer and PC/peripheral markets. The challenge is investing in effective customer relations, the best-quality programs, and the right technology and products. All three are needed; if any one is missing, the business would be unattainable and unprofitable. Moreover, as in those other high-volume markets, economics is paramount. A 5 percent anomaly in a supplier's cost structure could be fatal in a market where design-ins can produce for five or more years.

By Gregory Sheppard

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: *Which are the leading semiconductor suppliers to the global communications equipment market?*

A: The following table lists the 1990 leaders, in terms of millions of dollars in revenue.

Company	Revenue ($M)
Motorola	927
NEC	887
Toshiba	719
Fujitsu	691
AT&T	630
Hitachi	506
Texas Instruments	397
SGS-Tomson	357
Philips	305
National Semiconductor	251
Others	2,178

Source: Dataquest (December 1991)

Q: *What is the size of the North American point-of-sale system market?*

A: The following table provides size data, in terms of millions of dollars in revenue.

	1990	1995	CAGR (%) 1990-1995
PC-Based Terminals	610	665	1.7
Electronic Cash Registers	220	165	-5.6
POS Terminals	175	175	0
Scanners	60	180	24.6
Credit Authorization Terminals	125	135	1.6
Total	1,190	1,320	2.1
North American Production (%)	65	50	
Semiconductor Content (%)	12	13	

Source: EIA, Department of Commerce, Dataquest (December 1991)

Q: *What are the leading application candidates for 32-bit control?*

A: The following table summarizes in units some leading opportunities.

	1990	1995
Automotive Engine Management	0	800[1]
Graphics Boards—High End	450	6,100
Imaging (Medical/Industrial)	48	105
Disk Drive—High End/Arrays	400	900
X Window Terminal	70	860
Laser Printer	3,965	9,580
Audio/Voice PC Processing	800	18,000[2]
Digital Video Boards (PC/ Workstation)	40	4,500[3]
FDDI NICs/Bridges/Concentrators	4	1,900[4]
Ethernet or Token-Ring Network Hubs/Bridges	70	200[4]
PBX Control	68	105[4]
High-Speed Modem (≥9.6K)	590	3,000[4]
Digital Cellular	0	4,500[5]

[1]Includes integrated transmission control; future applications: active suspension and collision avoidance
[2]Assumes 40 percent of PC platforms have some sort of communication processor including fax and modem functions
[3]Worldwide preliminary estimate; assumes penetration of 10 percent of PCs
[4]Worldwide preliminary estimates
[5]Assumes migration to 32-bit DSP solution for high-end and hybrid (AMPS/TDMA or CDMA) versions
Source: Dataquest (December 1991)

In Future Issues

The following topics will be featured in future issues of Semiconductor Application Markets Worldwide *Dataquest Perspective:*

- Opportunities in pen-based computers
- Opportunities in workstations

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- *Product Analysis*--Presents the impact of new products on the industry
- *Company Analysis*--Highlights new activities or organizational changes and provides analysis of strategies, finances, and major product segments
- *Technology Analysis*--Zeroes in on key or changing technology and its impact on the markets and companies in the industry
- *Conferences and Exhibitions*--Identifies trends and analyzes key events at recent conferences and trade shows attended by Dataquest analysts
- *News and Views*--Provides Dataquest's perspective on recent major industry events

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	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
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