Industry Trends
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Introduction to the Service

The following is a list of material in this section:

Introduction To The Service--April 1988

Introduction to the Service

INTRODUCTION

As a client of Dataquest's Semiconductor User Information Service (SUIS), you have the largest semiconductor business information resource in the world at your disposal. More than 55 research and support people monitor worldwide semiconductor industry developments from offices in San Jose, California; London, England; Tokyo, Japan; Taipei, Taiwan; and Seoul, South Korea. Research specialists in the areas of semiconductor users, application markets, and semiconductor equipment and materials supplement our regional industry research worldwide to provide the most comprehensive data base available in the industry. Our staff of senior analysts, who, combined, have more than 150 years of industry experience, analyze data and maintain close contact with executives in all segments of the industry. Through this process of data gathering, monitoring, speaking with high-level industry contacts, and providing in-depth analysis, we determine critical industry trends and their impact on semiconductor users and their suppliers.

SUIS provides data and analysis in a form that helps semiconductor procurement managers analyze their semiconductor bill of materials and make the most effective procurement decisions possible. Information is offered in a variety of formats to serve different client needs. The service has the following five basic elements:

- **Notebooks.** Two loose-leaf reference notebooks serve as a resource for information needed to prepare reports and presentations to management regarding business conditions and their effect on semiconductor procurement. These notebooks contain a wealth of information for managing your product portfolio and vendor base. They act as the cornerstone of the service by providing the information that appeals to the broadest client base of SUIS. At the same time, they contain the essential data that are at the core of the service's methodology.
- **Newsletters.** Two to four research newsletters each month keep you apprised of current industry developments and their expected effects on your business. Newsletter topics include price and cost trends, industry trends, product and technology developments, semiconductor company news, and semiconductor application trends.
- **Annual Conference.** An annual two-day industry conference brings together semiconductor manufacturers, major semiconductor users, the financial community, and the Dataquest staff to discuss key issues affecting users and suppliers. Many of our clients have developed important business relationships at this conference.
- **Corporate Library.** Clients may also access and use Dataquest's Corporate Library. The extensive material in the library includes information by both subject and company, the semiconductor portion of which is electronically indexed. The library regularly receives numerous periodicals, including government data, annual reports, and foreign publications.
- **The Inquiry Privilege.** You have direct access to the SUIS research staff for clarification of information in the notebooks and access to unpublished data on SUIS topics that may be available in our library. To place an inquiry, you may call or fax any of the SUIS staff. You may also use our Inquiry Center, which provides on-the-spot support and access to available data.

If your inquiries extend beyond the need for additional data, and you need detailed analyses or opinions on topics that are relevant to the service, we suggest that you contact the SUIS staff directly, as mentioned above.

Clients are often unaware of what they can seek via the inquiry privilege. The inquiry privilege allows the notebook holder access to information within Dataquest that is unpublished, or of analyst expertise and opinion. It allows clients to "personalize" the information that they require in order to make decisions that are particular to their (or their company's) needs. We invite clients to make use of the inquiry privilege in order to seek this additional and available information. The inquiry is typically not a means for additional primary research.

The following are typical inquiries that have been made of the SUIS service:

- What is the background for the latest DRAM price forecast?
- What are semiconductor memory trends for DRAMs, SRAMs, EPROMs, EEPROMs, and ROMs?
- What are the 8051 price and market trends?
- What are the latest FMV ranges for DRAMs?
- What are the long-range fast DRAM price trends?
- What are the surface-mount price premiums for standard TTL logic?
- What are the price differentials for logic, PLDs, and gate arrays through 1991?
- What are the long-term price trends for gate arrays?
- What were the Japanese and U.S. 128K EPROM prices on 11/86 and 6/87?
- What are the quarterly slow SRAM price trends?
- What is the current status of the U.S./Japan trade agreement?
- What are Intel's MPU product and price trends?
- What are 8-, 16-, and 32-bit MPU price trends?
- What semiconductor manufacturers supply 1Mb SRAMs?
- Why are my MPU prices higher than those forecast by Dataquest?
- What impact has the stock market crash had on semiconductor pricing?
- What are the current and historical book-to-bill ratios in the United States?
- What were the 1983-1984 semiconductor market forecast analysis utilization percentages for the United States and Japan?
- How is MITI production control affecting future DRAM price trends?
- What are the earnings and revenue for Intel, AMD, National, Motorola, and Texas Instruments?
- What are the pre-1983 semiconductor consumption data?
- What are surface-mount versus through-hole package trends for standard logic and ASICs?

NOTEBOOK FORMAT

The SUIS notebooks are organized to make it easy for you to find specific types of information. Tabs identify each information category. An easy-to-read menu tells you what reports are located behind each tab. This flexible system enables us to focus our research on the most important semiconductor issues affecting you and your suppliers.

Status and Outlook

This section of the notebook contains a series of reports that track current industry trends and forecasts industry conditions for both the short term and the long term. An economic outlook report provides our opinion of the world economies for the next two years. This report is updated twice yearly. Our quarterly industry forecasts predict quarterly semiconductor consumption growth rates, which help you to decide when you should change your buying strategies. We publish a five-year forecast of worldwide semiconductor consumption. This information is useful to companies that do annual long-range strategic procurement planning. The forecast is made by major product and technology. Users can examine long-range technology and average selling price trends and set their own objectives relative to these industry trends. A market share estimates report contains our estimates of more than 100 semiconductor companies' market shares for 17 integrated circuit, discrete, and optoelectronic product categories. An annual report on capital spending provides essential information for determining the industry's future capacity for performing supply/demand analysis. Procurement planners use these data for preparing annual analyses of the semiconductor industry and the industry trends that can affect purchasing decisions.

Prices

Dataquest tracks prices of more than 200 types of integrated circuits. Prices are updated quarterly and forecast for the current year and the year following. Between published updates, any new information is offered through our on-line service. A brief summary of the effects of industry trends on pricing is written for each product area covered.

Costs

Understanding material costs is an important part of achieving target system costs. Dataquest has developed models for determining the cost of semiconductor devices. This section describes our models and includes tables of cost information from which specific product models can be developed. Reports on specific product areas assist purchasing and project managers to estimate material costs for short- and long-term project needs. These models have also been used as benchmarks to compare costs of captive facilities against merchant suppliers.

Products

An overview positions products in their life cycles and summarizes the positions that most integrated circuit families occupy in their family groups. This is a very useful tool for doing a quick product portfolio analysis. These reports keep you apprised of the status of leading-edge products by providing you with important business and technical information for comparing the various companies' product offerings. These reports are designed to help purchasing and engineering teams to make the most informed product selection decisions.

Company Profiles

Dataquest maintains files on more than 165 semiconductor manufacturers worldwide. We also follow start-up companies. Our files contain financial, product, technology, and market information from published sources as well as personal interviews. This is an excellent source of information for vendor selection and business analysis. Most of this information is accessible through your inquiry privilege.

User Guide to the Service

Table 1 summarizes the service benefits for each of the four major users of the service. To use the table, find your function along the left column; next, find the note where the service can help you via the service deliverables listed along the top matrix.

Table 1

Information Guide
Semiconductor User Information Service

Client Activity	Binder Service Section							Company Profiles	Keyword Search	On-Line Information			Newsletters			Inquiry	Conference
	Industry Introduction	Industry Outlook	Prices	Costs	Products	Quality	Glossary			Table Data	DQ Monday	Newsletters	Procurement Pulse	N. American IC Watch	Special Topics		
Buyers	O						O		O								
Price Negotiation Review			O							O	O	O	O	O	O	O	
Quality Review						O			O			O			O	O	
Inventory Assessment													O	O		O	
Lead Time Review			O							O	O	O	O			O	
Supplier Update								O	O			O			O	O	
Industy Assessment		O										O	O		O	O	O
Packaging Trends									O			O			O	O	
Competitive Review																O	O
Procurement Planning	O						O		O								
Supplier Analysis									O			O			O	O	
Technology Analysis					O			O				O	O		O	O	O
Regional Price Analysis			O							O	O	O		O	O	O	
Quality Analysis						O						O	O		O	O	
Cost Analysis				O						O						O	
Macro Capacity Analysis		O		O								O			O	O	
Industry Assessment		O										O	O	O	O	O	O
Packaging Analysis												O	O		O	O	
Competitive Review																O	O
Component Engineering	O						O		O								
Component Analysis					O	O						O			O	O	
Supplier Qualification								O				O			O	O	
Technology Analysis					O							O			O	O	O
Data Sheet Correlation																O	
Packaging Analysis															O		
Design Engineering	O						O		O								
Component Analysis			O		O	O						O			O	O	
Supplier Qualification								O				O			O	O	
Technology Analysis					O											O	O
Packaging Analysis												O			O	O	
System Breakdown												O			O	O	
Competitive Cost Analysis				O								O			O	O	

Introduction to the Industry

The following is a list of material in this section:

- Industry and Technology Overview

Industry and Technology Overview

HISTORY

The semiconductor industry is less than 30 years old. Although some simple diodes were manufactured earlier, the first transistor was produced by Bell Laboratories on December 23, 1947. Technical breakthroughs in the manufacturing of transistors followed rapidly, and by 1952 a number of companies were producing devices commercially. These devices, however, used germanium as the semiconductor material.

In 1954, Texas Instruments (TI) began to manufacture silicon transistors on a commercial scale. (Prior to that time, TI was not a factor in the semiconductor industry.) In the late 1950s, the industry was still in its infancy with sales just beginning to pass the $100 million mark. The major market for semiconductor devices was provided by the military, which recognized the potential of semiconductors and actively supported the industry's development. Another large semiconductor market, of course, was for transistor radios.

In 1959, Fairchild Camera and Instrument developed the planar technology for making transistors, which later became the basic technology for the manufacture of integrated circuits (ICs). Integrated circuits, however, were not commercially produced until 1961, when they were first marketed by Texas Instruments. About the same time, semiconductor devices began to proliferate, including metal-oxide semiconductor (MOS) devices, junction field effect transistors, and Schottky diodes. At this time, several improvements in manufacturing technology also occurred, providing rapid increases in productivity and device reliability.

In the late 1960s, the use of integrated circuits grew rapidly; by 1965 worldwide industry sales had passed the $1 billion mark. Uses for semiconductor devices escalated in this period, including many markets for industrial products, data processing devices, and communications equipment. During this time, MOS devices also began to be sold on a commercial scale. U.S. companies began to assemble their products overseas and both the European and Japanese markets became important. In 1968, the first light-emitting diodes (LEDs) were sold commercially by Hewlett-Packard. Bell Labs developed the LEDs in 1964.

The late 1960s and early 1970s brought some major changes to the semiconductor industry. During that time, more than 36 new merchant companies entered the market. At the same time, many captive semiconductor facilities emerged. These new participants added technical and competitive impetus to an already fast-moving industry. This period also saw the rapid rise of the MOS integrated circuit as a major product area in the semiconductor industry. Major emerging products in this area included semiconductor memory, custom devices, complex linear circuits including operational amplifiers, voltage regulators, and A to D and D to A convertors. The early 1970s marked the advent of large-scale integration (LSI) devices, and uses for consumer devices such as calculators and watches. An era of low-cost electronics was emerging.

Industry and Technology Overview

The late 1970s saw the emergence of a large worldwide semiconductor industry, with competition on an international scale. The emergence of very large scale integration (VLSI) devices brought important new products, including microprocessors. Other major new devices included various types of customizable semiconductors such as ROMs and EPROMs.

The 1980s have seen continuing growth in VLSI circuit complexity leading to 64K, 256K, 1 megabit, and 4 megabit (Mb) RAMs, and the 32-bit microprocessor. Chip complexities have increased to the point that standard products cannot fill all market needs, which has led to the rapid growth of application-specific integrated circuits (ASICs). Major innovations in wafer fabrication equipment that allow for the shrinking of device geometries, and in powerful computer-aided design (CAD) tools that automate the chip design process, have combined to make possible today's advances in component density and customization.

Technological milestones that have occurred in the past are summarized in Table 1, which shows the year a technology was developed and the pioneering company, and gives pertinent comments on current status. This table shows the constant evolution of semiconductor technology.

Table 1

Semiconductor Industry Milestones

Year	Technological Advance	Pioneering Company	Comments
1947	Point contact transistor invented	Bell Laboratories	By Shockley, Bardeen, and Brattain
1948	Junction transistor proposed	Bell Laboratories	By Shockley
1950	High-purity germanium developed	Bell Laboratories	Early transistors were germanium
1950	Junction transistor	Bell Laboratories	
1951	Zone refining of semiconductors developed	Bell Laboratories	By William Pfann
1951	Junction device sold commercially	General Electric and others	
1951	Gallium arsenide material	Siemens	
1952	Alloy transistor	Bell Laboratories	
1953	Surface barrier transistor	Philco	No longer in competitive market
1953	Unijunction transistor	General Electric	Not commercially successful.
1953	Silicon solar cell	Bell Laboratories	

Continued

Table 1 (Continued)

Semiconductor Industry Milestones

Year	Technological Advance	Pioneering Company	Comments
1954	Junction field-effect transistor proposed	Bell Laboratories	by Shockley
1954	Diffusion process developed	Bell Laboratories	
1954	Oxide masking	Bell Laboratories	
1954	Photolithographic techniques	Bell Laboratories	
1954	Zener diode	National Semiconductor and others	
1954	Transistor radio	Texas Instruments, Regency	
1954	Silicon transistor	Texas Instruments	Development started TI as a major manufacturer
1954	Interdigitated transistor	Transistor Products	Idea survived, company did not
1955	Diffused base transistor	Bell Laboratories	
1956	Silicon controlled rectifier	General Electric	Commercially successful
1956	Commercial unijunction transistor	General Electric	Not commercially successful
1957	Mesa transistor	Motorola	
1958	First integrated circuit	Texas Instruments	
1958	Tunnel diode	Sony	Not commercially successful
1958	Step recovery diode	Hewlett-Packard	
1959	Planar process, planar transistor	Fairchild	Invention boosted FCI as a major manufacturer and led to modern commercial ICs
1960	Epitaxial transistor	Bell Laboratories	
1960	MOS FET	Bell Laboratories	
1960	Schottky barrier diode	Bell Laboratories	
1961	First commercial IC	Fairchild, Texas Instruments	
1961	First planar field effect transistor	Amelco	
1961	RTL logic IC	Fairchild, Texas Instruments	Obsoleted by DTL
1962	Solid state (GaAs) laser	General Electric, IBM	Parallel inventions, 10 days apart
1962	DCTL logic IC	Fairchild	Never became popular
1963	Gunn diode	IBM	
1963	TTL logic IC	Sylvania	Sylvania left semiconductors in 1970
1963	ECL logic IC	Motorola	Still leads market
1963	Commercial MOS discrete	Fairchild	
1963	Linear IC	Fairchild, TI, Westinghouse	
1964	Light emitting diode	Bell Laboratories	
1964	GaAsP LED	Bell Laboratories	
1964	MOS IC	General Microelectronics	GMe was purchased by Ford and later dissolved
1964	First static flip-flop IC	Fairchild	
1965	IMPATT diode	Bell Laboratories	
1965	LSA diode	Bell Laboratories	
1965	High speed TTL	Texas Instruments	

Continued

Table 1 (Continued)

Semiconductor Industry Milestones

Year	Technological Advance	Pioneering Company	Comments
1966	NMOS	Fairchild	
1968	Ion implantation	Accelerators, Inc.	Acquired by Veeco
1968	Commercial light emitting diode	Hewlett-Packard, Monsanto	
1968	Low-power TTL IC	Texas Instruments	Obsoleted by Schottky TTL
1968	CMOS IC	RCA	Still leader
1969	GaAs junction FET	IBM	
1969	ROM	Electronic Arrays	Purchased by NEC
1969	Silicon gate MOS	Intel	
1970	Charged coupled device	Philips	Developed commercially by Intel and Fairchild
1970	Schottky TTL	Intel, Texas Instruments	
1970	Single chip for calculator	Texas Instruments	
1971	Isoplanar process	Fairchild	
1971	Barrit diode	Bell Laboratories	
1971	Commercial silicon on sapphire	Inselek	Went bankrupt
1971	Ion implantation	-	
1971	Bipolar PROM	Monolithic Memories	
1971	EPROM	Intel	
1972	Low-power Schottky TTL	Texas Instruments	
1972	Microprocessor	Intel	
1973	Electrically erasable nonvolatile memory	Hitachi, NCR	
1973	Emergence of optical projection aligners	Perkin-Elmer	
1974	I^2L logic circuits	Philips, IBM Texas Instruments	TI did not invent, but made first commercial devices
1975	Japan launches VLSI project	MITI/NTT	Key to establishing expertise in high density devices
1975	Bit-slice bipolar microprocessor	Bipolar	MMI, AMD
1976	Power MOS FET	Siliconix	
1977	E-beam mask making	Bell Labs	Bell Labs licensed the technology to a number of companies
1977	Memory with on-chip-redundancy	IBM	
1977	Microprocessor controlled automobile engine	GM	
1978	Japanese firms enter MOS memory and micro-processor market in U.S.		
1978	Wafer stepper technology	GCA	
1978	Emergence of programmable logic device (PLDs)	Signetics	Major PLD supplier
1978	Speech synthesis chip	Texas Instruments	
1979	Programmable array logic (PAL) product introduced	MMI	Major PLD supplier

Continued

Table 1 (Continued)

Semiconductor Industry Milestones

Year	Technological Advance	Pioneering Company	Comments
1980	Single-chip color TV sensor	Sony	
1981	32-bit microprocessor	AT&T	WE3200 used in AT&T computer systems--was not shipped commercially
1981	Speech-recognition chip	Weitek	
1982	Emergence of standalone IC CAD workstations	Daisy, Mentor, Valid	
1982	Introduction of IBM Personal Computer		Major end market for ICs
1983	Use of 6-inch wafer		
1984	First automated fabs		
1984	President Reagan signs semiconductor chip protection act		Key intellectual property law
1985	1Mb DRAM developed	IBM/AT&T	Both companies had working die at this time
1985	Gate array achieve more than $1 billion worldwide sales		
1985	Tokyo University launches TRON project 32-bit microprocessors		
1985	Commercial trial of "smart card" devices	Mastercard	Potential major IC end market
1986	BiCMOS SRAM	Hitachi	
1986	First "Fabless" semiconductor company speaks at Dataquest conference	Lattice	Marks industry trend toward adding value through design expertise
1986	Signing of U.S.-Japan semiconductor trade agreement		

Source: Dataquest
February 1990

The pioneering company is not necessarily the company that was successful with the technology despite introducing the first commercial devices. Four pioneering companies (Westinghouse, Sylvania, General Microelectronics, and Cogar) are no longer in the IC business. Texas Instruments has been the most successful company in retaining a position of leadership in the technology it pioneered, with much of its success derived from its development of silicon transistors and iterations of the TTL technology.

SEMICONDUCTOR INDUSTRY STRUCTURE

Products

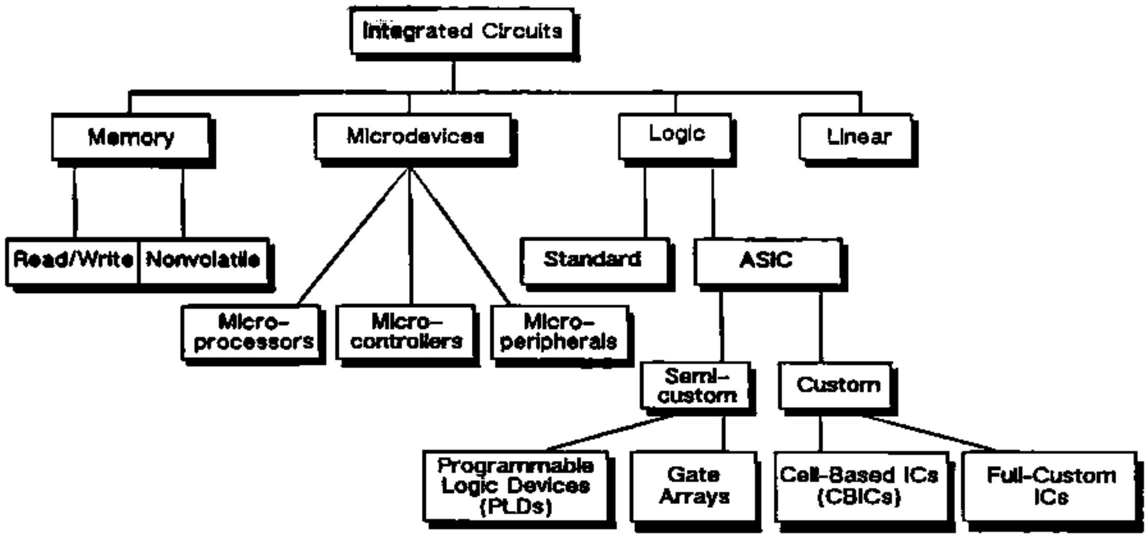
The semiconductor industry has a wide diversity of products. The most basic breakdown consists of ICs, discrete devices, and optoelectronics. An integrated circuit is a single chip that has more than one active device on it. For example, it may have a number of transistors, diodes, resistors, or capacitors as part of the electronic circuit. Integrated circuits vary widely according to the functions that they perform and the technologies used in their manufacture. Circuits can perform digital or linear electronic functions and may be based on a number of basic technologies, such as bipolar or MOS. ICs can be configured to an almost limitless number of different types of circuits.

Discrete devices have an even wider diversity. They consist of many types of transistors, diodes, and switching devices such as SCRs and triacs. Again, the wide diversity of product applications requires tens of thousands of types of discrete devices. This product diversity requires many variations in manufacturing.

As semiconductor products proliferate and change in terms of technology, function, and application, it will be necessary to reevaluate current schemes of IC classification. For now, Dataquest uses the classification chart shown in Figure 1 to distinguish further between IC products.

Figure 1

IC Classification



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Source: Dataquest February 1990

The above product categories are described as follows, with some examples of commercially available device types:

- Memory ICs are designed for the storage and retrieval of information in binary form.

- Read/write memory, generally referred to as random-access memory (RAM), allows storage and retrieval of information created by the user. Such information remains in memory only as long as power is supplied (volatile).

  - Dynamic RAMs (DRAMs)
  - Static RAMs (SRAMs)
  - Hierarchical RAMs (HRAMs)

- Nonvolatile memory devices do not lose information when power is turned off.

  - Read-only memory (ROM)
  - Programmable read-only memory (PROM)
  - Erasable programmable read-only memory (EPROM)
  - Electrically erasable programmable read-only memory (EEPROM/E^2 PROM)

Industry and Technology Overview

- A microprocessor can be a single chip component or a collection of architecturally independent components that function as the central processing unit (CPU) in a system. Microprocessors may contain some input/output (I/O) circuits but they do not usually operate in a standalone fashion.

- A microcontroller is an IC containing a CPU, memory, and I/O capability, that can perform the basic functions of a computer.

- Microperipherals are support devices for microprocessors or microcontrollers that either interface external equipment or provide system support.

  - Disk drive controllers
  - CRT controllers
  - Graphics chips
  - Bus controllers
  - Serial and parallel I/O chips

- Logic, in the semiconductor sense of the word, may be thought of as the "glue" that surrounds the IC devices listed above. Logic devices handle digital signals in a variety of ways: routing, multiplexing/demultiplexing, encoding/decoding, counting, comparing, and also serve as I/O interfaces.

- Standard logic ICs are readily available "off-the-shelf" from a number of suppliers.

  - Transistor-transistor logic (TTL)
  - Emitter-coupled logic (ECL)
  - MOS logic

- ASICs are integrated circuits designed or adapted for a specific application.

  - Programmable logic device (PLD)
  - Gate arrays
  - Cell-based design
  - Full custom design

Industry and Technology Overview

In more recent years, the demand for customized IC applications has stimulated promising growth in ASIC devices, while equipment and design tool advances have made it profitable for semiconductor manufacturers to offer ASIC products to lower volume niche markets. For ASIC suppliers, the emphasis no longer resides most heavily in manufacturing, but in close customer support, service and the lowest possible turnaround time from customer order to first silicon.

Markets

Dataquest has standardized semiconductor end users into the following six major application market segments:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Data processing comprises all equipment whose main function is flexible information processing, including all personal computers, regardless of price or environment in which they are used.

The communications segment is made up of telecommunications, which Dataquest classifies as customer-premises and public-telecommunications equipment, and all other communications equipment such as radio, studio, and broadcast equipment.

Industrial consists of all manufacturing-related equipment, including scientific, medical, and dedicated systems.

The consumer segment comprises equipment that is designed primarily for home or personal use, such as audio and video equipment, and household appliances.

Military equipment is primarily defense-oriented electronic equipment as classified by major budget area. This does not include all electronic equipment procured by the government, in order to avoid double-counting equipment that belongs in an already included applications market segment.

Transportation consists mainly of automotive and light truck electronics.

Industry and Technology Overview

The major markets supplied by the semiconductor manufacturers have a large number of different applications that result in an extremely large number of smaller market segments. The smaller markets often require special types of devices with unique technologies or specialized applications. This situation creates opportunities for small companies to be both competitive and profitable.

Manufacturing

The central manufacturing focus in the semiconductor industry is the fabrication of semiconductor devices from extremely thin, raw silicon wafers, typically 3 to 6 inches in diameter. This process entails hundreds of individual manufacturing steps, each requiring complex technology and high precision. The manufacture of the semiconductor device can be divided into three major operations: wafer fabrication, testing, and assembly.

The manufacturing structure of the semiconductor industry is experiencing change. In the past, semiconductor companies typically performed all or most of the steps required to produce the devices they supplied. A number of newer semiconductor companies are now disassociating design and manufacturing, choosing a strategy based on adding value through design innovation and service, rather than solely through improved manufacturing. While changes in technology that effect the design process and chip densities have contributed greatly to this emerging strategy, another key element is the sheer cost of building a wafer fabrication facility. Dataquest estimates that a company wishing to build a state-of-the-art CMOS wafer fab will need to invest more than $100 million for the facility alone. Given today's venture capital climate, the price of admission to the exclusive domain of IC manufacturers will be beyond the means of most future start-ups.

Among companies that possess a manufacturing capability, marked differences exist in the number of support functions that they integrate. These support functions include fabrication of the package in which the devices are assembled, manufacture of the semiconductor wafers on which the devices are made, manufacture of the masks involved in the photolithographic process, and other related functions. Larger (or older) companies, such as IBM and Texas Instruments, operate on a greater level of backward integration. Smaller (or newer) companies, in general, do not perform these manufacturing functions. Intel, for example, purchases masks, wafers, and packages.

In recent years, there has been a proliferation of companies offering various semiconductor manufacturing services. These services include semiconductor device design, mask making, semiconductor wafer fabrication (wafer foundries), assembly and packaging services, and testing services. This vertical segregation has made it possible to design, manufacture, and market semiconductors without a significant investment in manufacturing or engineering manpower. These companies design and make various custom devices that serve the needs of manufacturers and users alike.

Industry and Technology Overview

Dataquest has observed an increasing number of alliances between companies involving the exchange of technology for manufacturing capacity. This trend is becoming more pronounced between U.S. and Asian firms.

Distribution and Marketing

Semiconductor devices are sold and distributed in the following three basic ways:

- Through a direct sales force with shipment from the manufacturing company
- Through a sales representative organization with shipment from the manufacturing company
- Through a distributor typically with shipment from its own stocks

Historically, semiconductor companies have preferred to market directly whenever possible, especially to larger users. However, a direct sales force cannot market economically to smaller users or in areas where sales volumes are low, such that direct selling represents a proportionately larger fixed cost. As a result, many companies have turned increasingly to manufacturers' representatives (reps). These organizations may handle several companies with nonconflicting product lines. Generally, a representative organization receives a higher commission than does the direct sales force. However, for small companies that cannot economically maintain a direct sales force, this approach is a viable alternative.

Distributors generally buy semiconductor devices from the manufacturers in large quantities and resell them in smaller quantities and at higher prices. Distributors also often market actively to many companies. They relieve the semiconductor companies of the problems associated with handling many small orders and perform a valuable inventory function for the industry, as well as some marketing functions.

Forward Integration

In the past, forward integration has rarely played a role in the structure of the U.S. semiconductor industry. Well-known domestic manufacturers that entered the consumer products business include Fairchild (video games), Intel (watches), National (calculators and watches), and Texas Instruments (calculators, educational toys, and home computers). Although TI continues to produce educational toys and calculators, it assembles these products offshore. Most U.S. chip makers that attempted to crack the consumer market abandoned it in the wake of Asian competition.

Notable exceptions to this rule have been AT&T, Delco (a General Motors supplier), and IBM. Although some U.S. semiconductor manufacturers have increased their forward integration with ventures into higher-level products (particularly board-level products), the separation of semiconductor manufacturing and end-product manufacturing still prevails in the majority of cases.

One major problem that U.S. firms have experienced in simultaneously addressing the semiconductor components business and the consumer products business stems from the marked differences in operational structure that these markets necessitate. The separation of semiconductor component and end-product manufacturing certainly does not apply to Japanese electronics firms. The vertical structure of Japanese electronics companies has proved effective in linking the design, manufacture, and end-product application of semiconductors in a highly synergistic way. Japan's success in doing so has given captive Japanese semiconductor companies significant advantages over their U.S. rivals in manufacturing economies of scale and capital resources.

Ownership

The ownership of semiconductor manufacturing can be divided into three broad categories: independent manufacturers, divisions of major corporations, and captive manufacturers. These distinctions are not always entirely clear, but they serve generally to identify the various types of companies. The first two groups actively compete in the merchant market, but the latter does not.

Independent Manufacturers

Most semiconductor manufacturing (about 70 percent in the United States) is performed by independent manufacturers. By definition, the semiconductor operations of these manufacturers constitute a major portion of their businesses. Companies in this category include Advanced Micro Devices (AMD), Intel, Motorola, National Semiconductor, and Texas Instruments. A very large number of smaller companies, both publicly and privately owned, are in this category.

A basic characteristic of these companies is that their survival depends on their performance in the semiconductor industry. As independent companies, they have neither guaranteed markets or financing. In general, they are competitive, aggressive, and leaders in bringing new technologies to the marketplace. Moreover, they have been leaders in expanding the international scope of the industry, both in manufacturing and marketing.

Divisions of Major Corporations

Many major corporations in the United States, Japan, and Europe have divisions that manufacture semiconductor devices. These divisions are distinct from totally captive manufacturing in that they actively market their semiconductor products. In some cases, the divisions do not supply products directly to their parent corporations, although many of them do. Most such organizations, however, derive only a minority of their sales from captive markets. Companies with large semiconductor divisions include Fujitsu, Harris, Hitachi, Hughes, ITT, Matsishuta, Mitsibishi, NCR, NEC, Philips, Raytheon, Rockwell, Siemens, Toshiba, and many others.

Structurally, these organizations may be treated as divisions of the parent corporation or they may be organized as semiautonomous companies.

These companies vary greatly in (1) their outlook toward the semiconductor industry, (2) their treatment by the parent company, and (3) their competitiveness in the industry. They may be slightly less competitive and aggressive than the independent companies, but it is difficult to generalize. All of these companies, however, can benefit from the financial resources of the parent. Considering the increasingly high capitalization requirements in the industry, having parental resources available is a distinct advantage. Furthermore, large parent corporations often have a sheltered market that the semiconductor division can supply. On the other hand, such companies can have problems attracting talented individuals from the industry because the fast pace of the semiconductor industry frequently is at odds with the slower decision-making processes of a large corporation. Moreover, the senior officers of the parent corporations often have little or no experience with the semiconductor industry.

Captive Manufacturers

Several companies have totally captive semiconductor facilities and make semiconductor devices for their own use, but do not market devices to industry. Major manufacturers with captive lines include General Motors, Hewlett-Packard, Honeywell, IBM, and Unisys. It is interesting to note that HP and Honeywell market certain products to the merchant market and reserve others for proprietary use. The existence of such captive facilities tends to decrease the market available to the companies competing in the semiconductor industry. Many captive facilities provide services and special devices not available in the marketplace, i.e., these companies make what they cannot buy.

As semiconductors have become more important to major manufacturing companies, captive facilities allow semiconductor design to be integrated with final product design. Moreover, there are often planning and control advantages. The ability of a captive facility to know the future quantity while controlling its output, and the lack of marketing costs are strong advantages.

Captive facilities have many of the same problems facing divisions of major corporations: difficulty in attracting top-grade technical personnel, slow decision-making processes, and changes in the technology that may outmode facilities. In the past, only a few manufacturers (e.g., AT&T and IBM) have had sufficient in-house requirements for semiconductors to support the necessary efficiencies of scale for cost-effective semiconductor manufacturing. However, this situation is rapidly changing with both the increasing scale of equipment manufacturers and the increasing solid-state content of their products. Companies with semiconductor purchases in excess of $100 million numbered only 2 in 1975, increased to 7 in 1979, and exceeded 50 in 1987.

SPECIAL INDUSTRY CHARACTERISTICS

The semiconductor industry has many characteristics that set it apart from other industries. For the most part, these characteristics arise from the industry's high technological dependence, intense competitiveness, and broad variety of products. These special characteristics include the following:

- Intense competition
- Product diversity
- High technology
- Rapid rate of change
- Cost and price reductions
- Short product life cycles
- Maturity with change

Competition

The semiconductor industry has always been intensely competitive and should remain so in the foreseeable future. The effects of this competition are to make the industry aggressive, to make it readily adaptive to any change or competitive advantage, and to limit profit margins.

The reasons for this intense competitive situation are as follows:

- A lack of any major barriers to competition
- Market share advantages
- A wide range of products
- A very large number of companies
- A continual influx of new products and new markets

Industry and Technology Overview

In any given semiconductor market segment, there are usually many competitors from which a buyer may choose. The large number of semiconductor companies may be reduced in the future, but they can exist at present because of the wide range of products in the industry. A company can specialize in a given area and have a particular advantage in manufacturing a few products. Although any competitive advantage in a product line is temporary, the diversity of products allows all the companies in the industry to be competitive in at least some areas.

New products are continually being developed by the industry. Since a new product, by definition, does not have established suppliers, the company producing it can gain a short-term advantage. Thus, many small companies compete effectively in the semiconductor industry by continually advancing the state-of-the-art technology. The same advantage inherent in new products also applies to new markets created by these products. Nevertheless, since market share and the resulting volume production is important in the industry, particularly as markets become mature, competition is intense. This situation leads to recurrent price competition, which can be extremely severe.

Product Diversity

The semiconductor industry is characterized by an extremely wide range of products. Several different types of transistors or other semiconductor devices are based on different physical laws. Each type of product has a large number of operating characteristics, including power-handling capability, speed, amplification level, and rated voltage. The possible design value chosen for each of these characteristics for a given product can vary over an extremely wide range, and the possible combination of product characteristics is nearly infinite. Integrated circuits have even wider diversity than discrete devices because of variations in circuit designs.

Product diversity occurs because semiconductor products have been specialized to perform distinct functions, and their design and manufacture have been optimized for those functions. Thus, there are literally tens of thousands of different products in the industry.

The extremely wide diversity of semiconductor products has many important consequences for the industry. Because diversity allows a large number of competitors to exist by forming a large number of specialized markets, it paradoxically increases the competition in the industry. Product diversity also decreases volume manufacture of any single product, thus inhibiting increased industry automation.

Technology

It is important to emphasize the role that technology plays in the industry. The primary products—discrete devices and integrated circuits—are, of course, technological in nature. Their concept, design, and function are the very basis of sophisticated electronics. It is also important, however, to note that the manufacture of the devices is also highly technical in all its aspects—the processes employed, the sophisticated equipment used to manufacture and test the devices, and the skill levels of all personnel concerned with the operation. Furthermore, the products in which most semiconductors are used are also highly technological.

An LSI semiconductor memory exemplifies this technological complexity. To be competitive in this field, a company must have a thorough understanding of the device's complex end use. Moreover, the manufacturer must have the design capability and the processing technology to make the device. The company must also be able to choose successfully among the trade-offs available in the various technologies to produce a successful cost-competitive product. This understanding is fundamental to being a competitive supplier with state-of-the-art design, state-of-the-art manufacturing, and products that are useful and cost effective for the user.

Furthermore, the technological nature of the business makes timing critical. Every facet of a product—its design, its process, and its market—is viable and competitive for only a short period of time. Before that time, manufacture is too difficult, too costly, or simply not viable; after that time, the product may be obsolete.

Because of the technological intensity of the industry, research and development expenses are unusually high compared with those in many other industries and constitute from 10 to 20 percent of revenue. Extensive research and development is a necessary investment for any company that wishes to remain competitive.

A recurring problem for all companies is the threat of technological obsolescence of their products. This threat occurs not only over time, as new and improved products displace old ones, but also because at any time a completely different semiconductor technology could obsolete the products they manufacture. For example, silicon transistors replaced germanium transistors, TTL logic replaced DTL logic for integrated circuits, NMOS replaced PMOS for low-cost memory, and CMOS is now replacing NMOS in devices requiring low power and high density.

Rate of Change

The semiconductor industry is very dynamic; it truly suffers from "future shock." It has very rapidly changing technology, processes, products, manufacturing methods, and markets. This characteristic of rapid change is perhaps the least understood and the most underrated by observers of the industry.

Industry and Technology Overview

Improvements in the capability of semiconductors come at breathtaking speed. For example, in the 14 years between 1962 and 1976, the products of the industry progressed from a simple transistor, to an IC performing a simple logic function (such as a gate), to an IC performing an entire functional block of a system (such as an adder), to a one-chip calculator circuit, to a one-chip computer processor. Similarly, RAM densities have increased from 1,000 bits in the early 1970s to more than 4,000,000 (4Mb) in today's DRAMs—with devices of more than 16 million bits (sampling now). Processing technology has changed from alloy junctions to bipolar planar technology to MOS technology—all with many alternative variations. Markets have changed from primarily military applications to a wide range of industrial equipment, Electronic Data Processing (EDP) applications, and consumer products.

The dynamic nature of the semiconductor industry is both exciting and profoundly unsettling. Products, technologies, and even companies are based on the shifting sands of technological progress. Past benchmarks are not applicable to the future. It is important to understand that this rapid rate of change is not a transitory phenomenon. Rather, it is a built-in characteristic of the industry. That is, the industry is geared to change. Indeed, its dynamic nature is a more fundamental element of the industry than are the semiconductors that the industry manufactures.

The following three main factors account for the dynamic nature of the industry:

- Technological progress
- A large number of talented people
- Heavy competitive pressure

None of these factors is independent, but they work together in constant reinforcement. Because the industry is highly competitive, companies strive for improvements in technology to gain a competitive advantage, even if it is only temporary. The industry seeks large numbers of individuals with technological expertise, creative ability, and drive. These people must have the special ability to manage under the constant change that is occurring in the industry—circumstances that bewilder competent managers in other industries. However, it is the excitement and change that attract these people to the industry. In turn, their abilities add to the competitive crush and the high rate of technological progress.

Not all of the effects of this environment are positive. The change takes its toll both in people and companies through technological obsolescence. Although the industry has made laudable progress, adaptation to the rapid change keeps industry profits low and tends to undermine any basic strength that a single company may have, so that any competitive advantage may be short-lived. Moreover, both the change and the growth in the industry create a continual financial strain for most companies.

Cost and Price Deflation

One of the most remarkable characteristics of the semiconductor industry is the rapid and continual price decreases that occur. The price of an average function in an integrated circuit has declined an average of more than 40 percent per year since 1962. If these price changes over the past 20 years had been matched by the automobile industry, one could buy a car today for $1.00. In 1960 the average price of one transistor was more than $5.00. In 1985, one could purchase an integrated circuit with 500,000 transistors for $5.00 or less. The price of a semiconductor is effectively decreased in the following four ways:

- Decreased unit price
- Increased functions per device
- Improved device parameters
- Greater sophistication or complexity per device

The greatest change in semiconductor prices comes from the increasing number of functions performed by a single device. In 1962, each unit sold performed essentially a single function because nearly all devices were discrete units such as transistors or diodes. With the advent of integrated circuits, the average number of functions of a single unit began to increase. In 1969, the estimated average was 3 functions per unit; by 1972, the average was about 16 functions per unit. The increasing market penetration of VLSI ensures that the average number of functions per unit will continue to increase. Because a 1Mb DRAM contains up to 1.2 million transistors, relatively small unit sales of these devices can have a dramatic effect on the average number of functions per unit for the overall industry.

Unit pricing has also been affected by the vast improvement that has occurred in device performance, such as greater power-handling capability, increased speed, greater reliability, lower power consumption, and longer life. For example, one of the greatest factors in the growth of the power semiconductor transistor market in the last few years was not lower prices per se, but the ability of these devices to handle either higher power or higher voltages and to do so with greater reliability. Integrated circuits capable of higher speeds have allowed computers to have much greater computational power using the same amount of electronics.

Besides being larger (more functions) and better (improved parameters), ICs can also be more complex, i.e., more sophisticated. For instance, a microcontroller is no larger nor more difficult to manufacture than many memory devices that were introduced earlier by semiconductor manufacturers. However, a microcontroller employs sophisticated systems design concepts. It comprises a complicated interplay between logic design, random access memories, read-only memories, and input-output circuits. Many different logic and memory designs are on the same chip and complicated computer organization concepts are used. In other words, it is more sophisticated. This type of improvement takes time to evolve; it is important as a means of greater performance at a given price. Even if semiconductor process technology remained at its current limits, this type of design innovation and optimization would continue for many years. In the semiconductor industry, technological advances always remain ahead of the diverse commercial implementations that they drive.

There are several underlying reasons for the four types of price reduction discussed above. The highly competitive nature of the industry has spurred technological improvement as a means of gaining competitive advantages or opening new markets. Price decreases have come from the continuing improvement of old technologies and the development of new technologies, manufacturing improvements, the use of new materials (especially in packaging), the move to overseas assembly to take advantage of lower labor costs, and a large increase in unit volume.

For new products, improvements in device yields per wafer, combined with larger batch fabrication, have significantly reduced the costs of semiconductor chips and, therefore, prices. As the technology becomes more refined, the yields should improve for more complex or more sophisticated devices.

While the effects of improved manufacturing techniques and market forces may decrease unit prices for specific IC products, such as 1Mb DRAMs, the learning curve theory does not hold true for ICs as a whole. Between 1976 and 1987, the number of ICs shipped on a worldwide basis increased by a CAGR of 21 percent. Rather than decreasing, however, the ASP for IC devices in total rose by 9 percent.

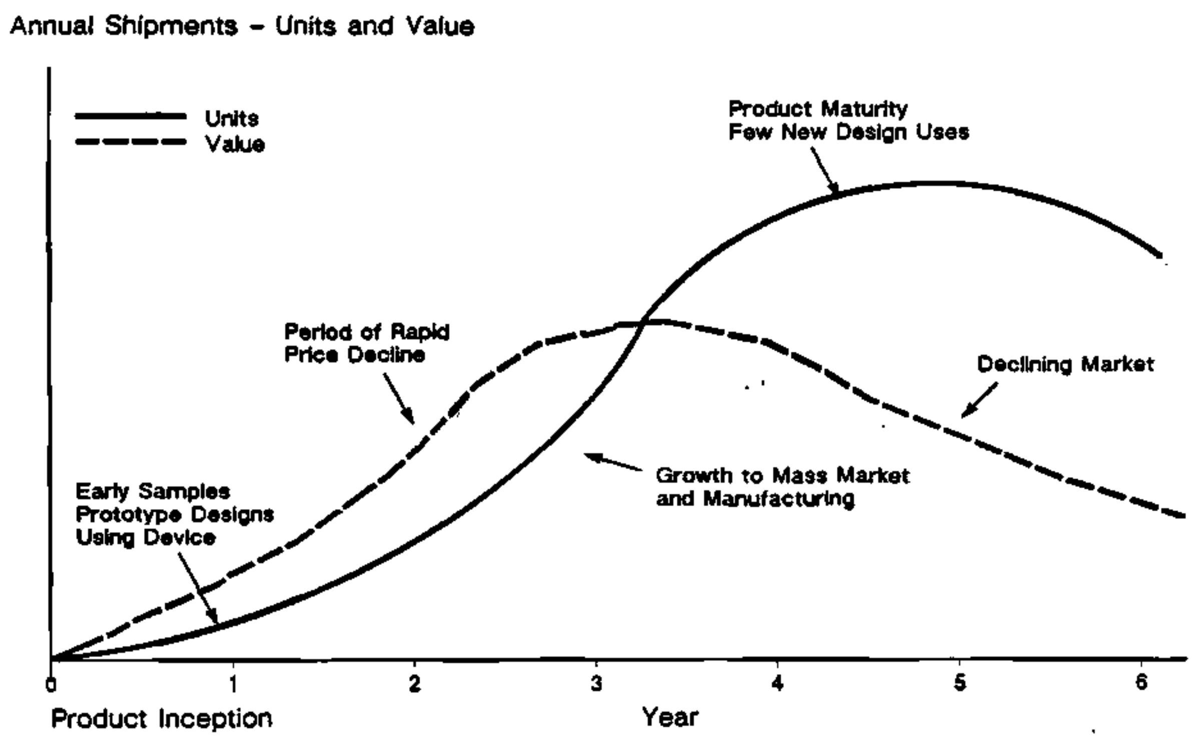
As the cost per bit or per transistor in an IC diminishes, manufacturers must increase the functional density of their devices in order to keep their profits per unit from seriously eroding. This trend has been highly evident in memory ICs. Companies employing the latest technological advances to produce higher capacity DRAMs may initially enjoy a higher margin of profit as a reward for early market entry. As economics of scale and increased competition take their toll on the price per function, however, technology becomes a relentless taskmaster. To remain a force in the memory IC market, a company must continue to push chip densities higher in an effort to shore up unit profit.

Product Life Cycles

Figure 2 shows a typical semiconductor product life cycle. Short product life cycles are a basic consequence of the rapid change in the semiconductor industry. Any product is useful in the marketplace for only a certain period of time after its inception, but in the semiconductor industry that time can be extremely short. It is important to differentiate between the single product and the product family (in which the actual products themselves change). A product family has a somewhat longer life time, usually three to five years. A technology's life cycle may be even longer since it may be used for a number of successive product families. For more information on particular product life cycles, please refer to the product section in this notebook. It is imperative that semiconductor users manage system life cycles with those of the components they are designing in.

Figure 2

Typical Semiconductor Product Life Cycle



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Industry and Technology Overview

INDUSTRY TRENDS

The semiconductor industry has always been characterized by change. The most basic industry trends may be described as follows:

- Low-cost electronics
- Market pervasiveness and new markets
- Device complexity
- Market crowding
  - Fewer suppliers
  - Increase in very large users
- Merger, acquisitions, and alliances
- Internationality
- Vertical integration
- Continuing rapid technical change
- Captive semiconductor manufacturing
- Increasing automation
- A move toward application-specific products
- A service, customer-oriented focus

Low-Cost Electronics

A principal feature of the semiconductor industry is the continual reduction in costs and prices, resulting in the emergence of even lower-cost electronics. Previous concepts of electronics as being expensive must be discarded. Cost, of course, must refer to the function that a semiconductor performs and not simply unit price. Costs can be expected to decrease in the future for the following reasons:

- An increasing number of functions on integrated circuit chips
- Improvements in yields through larger wafers, better equipment, and improved processing
- Greater unit volume and, therefore, greater efficiencies of scale

The results of lower-cost electronics are expected to become even more visible in the future. Some of these capabilities—such as in low-cost, hand-held, personal calculators and inexpensive home computers—are already visible. In discrete devices, much of the effect is yet to be seen, but capability has increased and cost has decreased to the point where discrete devices such as triacs and SCRs are cost competitive with a wide range of electromechanical and electromagnetic components. Because these components have a definite requirement for raw materials, their costs have set lower limits. Moreover, many of them cannot be batch fabricated, allowing semiconductor devices to be more cost competitive. In the future, semiconductors are expected to be substantially less expensive than electromechanical and electromagnetic devices.

Market Elasticity

In general, decreasing semiconductor prices have opened up enough new areas of market growth to allow increases in the dollar value of the total market. In other words, the semiconductor market has a basic elasticity greater than one. Precise determination of this elasticity, however, is extremely difficult because the effective change in semiconductor prices is difficult to measure. Furthermore, there is a question of timing. It is apparent that changes in semiconductor prices or capability—essentially the same thing—lead to new markets. However, it may take several years for these markets to develop because many electronic systems are so complex that they require a long learning curve in employing new devices, designing them into systems, and developing the market for those systems. Thus, even if semiconductor prices do not change in the future, the market can be expected to expand at current prices for several years. Items such as telecommunication applications, large computers, and military systems have life cycles lasting many years. With the very high rate of price decline for electronic functions, ignoring timing differences might indicate that the average 15 percent rate of growth in the semiconductor industry indicates elasticity a little greater than one. But in many cases, current markets reflect the devices developed several years ago. Today's products ensure market growth for several more years at current long-term growth rates.

Market Pervasiveness and New Markets

Market growth, particularly from the penetration of new markets, should be a continuing characteristic of the industry. Growth in the semiconductor market comes from either expansion of established markets or creation of new markets. Even in an established market, the redesign of a product resulting in the use of more semiconductors occasionally makes the difference between "new" and "established" markets less defined.

Established markets, such as those for radios or minicomputers, grow in the following two different ways:

- The end market grows: For example, the basic market for minicomputers has grown rapidly, spurring a demand for the semiconductor devices used in them. However, because of the declining prices of semiconductors, market growth must be rapid enough to overcome the effect of declining prices if the dollar market is to grow.

- New or changed products that employ more semiconductor devices are introduced: For example, a new computer may use more electronics to make it faster or more powerful. In some semiconductor markets, it is common for product designers to take advantage of falling semiconductor prices to increase instrument or product capability. As a result, these markets grow through higher semiconductor content.

The largest market growth in semiconductors still comes from the creation of new markets. These markets develop because of the increasing capabilities of semiconductor devices and their decreasing costs. The following describes the three basic types of new markets:

- Component replacement
- Creation of completely new products
- Replacement of labor with capital

Component replacement has recently opened up vast new markets for semiconductor devices. This market is of two basic types—individual component replacement and replacement of small systems. Individual components are replaced by semiconductors in the following three areas:

- Electronic components
- Electromechanical devices
- Electromagnetic devices

Basic electronic component replacement includes such items as the replacement of lights with LEDs, or the substitution of semiconductors for tubes in products such as television or high-fidelity equipment. In the past, the switch from electronic tubes to solid state in color television created a strong area of growth for the semiconductor industry.

Large areas of growth have come from the replacement of electromechanical and electromagnetic devices, including: solid-state engine controls; solid-state relays and SCRs replacing electromagnetic relays; disk memories; and semiconductor timing circuits replacing electromechanical devices in appliances. These new markets open up vast areas of growth for semiconductors.

At the systems level, semiconductors are replacing basic electromechanical or mechanical systems. For example, semiconductor controllers are replacing electromechanical devices in industrial control applications. Occasionally, as in watches, semiconductors have replaced a fully mechanical system.

In some instances, the greater capability of integrated circuits and their rapidly falling prices have created totally new markets. The best known of these is the personal computer market. In this case, semiconductors have resulted in the creation of a market that never existed before. The future proliferation of "smart cards" will open a major end market for ICs in the near future. Numerous small markets of this type are also being created in industrial applications.

A basic factor in the growth of the semiconductor market has been the use of semiconductors in equipment that replaces labor with capital. In some instances, this approach also encompasses mature markets. Integrated circuits have opened up many new market possibilities in such areas as computers, industrial automation, office equipment, and industrial control. These new products are primarily aimed at replacing labor, increasing productivity, or both.

Device Complexity

The complexity and performance of integrated circuit devices are increasing rapidly. Device complexity, already great, is expected to increase a hundredfold over the next 10 years. A current LSI device has interconnections that approach the complexity of a road map of the entire North American continent. Devices in the late 1980s will have an interconnection complexity equivalent to a road map of the entire world. In 1983, a MOS memory bit cost approximately 8 millicents. That cost is expected to decline by a factor of 50 during the next 10 years. Memory costs will be paralleled by similar changes in the thrust of logic and other semiconductor functions. At the same time, the performance of semiconductor devices as measured by their speed, power, or other parameters will increase steadily and significantly. These estimates are based on current semiconductor research.

The Effect of Dimension

One of the overriding engineering concerns of semiconductor manufacturers is to reduce the minimum dimensions of the devices they make. Minimum linewidths for semiconductor devices decreased from about 10 microns to about 5 microns between 1965 and 1978. Most of the increase in complexity of LSI devices (and the reduction in cost per function) came from other factors. These factors are best described by Dr. Gordon Moore of Intel as "cleverness," such as the ability to reduce memory cells from six devices to one device. Once a cell reaches one transistor, further improvements become difficult. As a result, reduced dimension tolerance is now the critical factor in increasing component count.

The yield of semiconductor devices is directly related to the size of the semiconductor chip. If component dimensions are reduced, chip size declines and yield increases significantly. A decrease from 2 microns to 1 micron (HMOS dimensions) can result in a yield increase of a factor of 5 for a device of equivalent complexity. This decrease in size can result in a decrease in die cost and ultimately price, by the same amount. Conversely, if die size remains constant, the complexity can increase by a factor of 2 1/2. It is easy to see why the semiconductor industry is striving to reduce dimension. Those manufacturers who first achieve this reduction will have a significant competitive advantage. This direction ensures that device complexity will increase and device cost per function will decline significantly in the future. Essentially, electronics are inexpensive and will continue to get less expensive.

System Considerations

The increasing complexity and lower cost of semiconductor devices have resulted, and will continue to result, in semiconductors performing more and more systems tasks. Semiconductor design is now concerned not only with circuit design and logic blocks, but very often with system architecture. New devices, such as some microprocessor peripherals, need to take system application and system software into account during the design of the device. For the electronic system manufacturer, some important consequences are as follows:

- In the future, system design and semiconductor design can no longer be organizationally separated.
- System design and semiconductor design must be performed concurrently.
- If the semiconductor manufacturer does the semiconductor design, the manufacturer will gain de facto system knowledge and expertise.
- System manufacturers that effectively use semiconductors to speed system design will gain an advantage.
- System manufacturers that effectively use semiconductors to enhance performance or reduce system costs will gain an advantage.

The latter point is not entirely obvious, but there are many functions that now can be less expensively performed by employing silicon "real estate," i.e., the trade-off between software costs and memory costs will continue to favor memory more and more. It may save costs to reduce wire harnesses by employing more sophisticated digital electronic methods. Only those companies with semiconductor design knowledge can effectively choose the most appropriate trade-offs for any given point in time.

Design Considerations

In the future, a major emphasis will likely be on system design and system integration. The reason for the emphasis is that the complexity of semiconductor devices is increasing so rapidly that the ability to put logic on silicon will outpace the conceptualization of what that logic should be. In the past, the transition from device-to-logic gates to logic blocks to small processors has been fairly steady and reasonably obvious.

Cost of Design. The rapidly increasing complexity of VLSI devices shows up most dramatically in the cost and time it takes to do the device engineering and design. Prior to 1970, the cost to design a state-of-the-art semiconductor device was in the tens of thousands of dollars. Currently, the cost for a state-of-the-art device can be in the millions of dollars. For example, memory devices such as 1Mb dynamic RAMs cost semiconductor manufacturers an estimated $4 million to $6 million to design, including special processing work. The recent cost of design and development for 32-bit microprocessors is estimated to be a minimum of approximately $100 million. Those costs include the design of peripheral chips, software aids, and other considerations associated with chips of this complexity.

It is important to note that these costs are a function of <u>system</u> complexity, whether one or more chips is involved. It is estimated that within five years the entire circuitry of today's 16-bit (or 32-bit) microprocessor chips, peripheral chips, and some memory will be included on a single device. While these costs are not growing quite as fast as complexity, they are escalating rapidly. Design aids, including CAD, redundancy on the chip, modularization of functions, and some other methods of cutting and pasting, help to reduce costs.

Time of Design. Today, the capability of putting a million transistors on a chip is a reality. The time required to design will be an extremely critical factor in the near future. Those companies that learn to reduce those times will have a definite advantage.

IC Complexity—The Consequences

The implications of the preceding discussion are important to captive manufacturers and systems houses. The complexity potential of integrated circuits has increased from single-chip, four-function calculators to 32-bit microprocessors in slightly less than eight years. The following lists some important consequences:

- Potential chip performance will outpace system design capability.

- The major constraints on implementing or designing VLSI devices will not come from wafer fabrication or yield considerations.

- Chip capability will be increasingly important in defining the system and, conversely, the system will be important in defining the semiconductor device.

Thus, the sensitive technical areas that define state-of-the-art limitations will shift. Dataquest believes that the following factors will be future constraints on either advancing the state-of-the-art or implementing a new (VLSI) semiconductor device:

- Semiconductor design, including conceptualization, cost, and time
- Cost, time, and engineering of testing procedures
- Software costs
- System definition, design, and architecture
- Capital equipment costs

Chip yield will be a major constraint only for a limited number of high-volume products. The problems mentioned above apply particularly to custom devices. They indicate the areas where a systems company should be concerned about future allocation of resources—dollars, equipment, and labor. Dataquest believes that these factors are especially important because the future supply will be limited. Systems houses must effectively shift their software and design capability to the semiconductor level.

Rise in Major Users

The number of major users of semiconductors has increased rapidly since 1977. This increase is spurred by the growing pervasiveness of semiconductors and their importance in end-user electronics markets. The larger users, each individually representing hundreds of millions of dollars of purchases, will be powerful market forces and the extent of their needs is likely to alter the structure of semiconductor purchasing. However, the large number of major users probably indicates that any single company will not command undue attention from the suppliers.

Captive Semiconductor Manufacturing

Systems companies that integrate backward with the purpose of producing their own semiconductor components, and that produce solely for their own needs, are considered captive manufacturers. Our research into silicon wafer usage and semiconductor manufacturing equipment indicates that captive manufacturers constitute an estimated 24 percent of the markets for these products.

Successful captive suppliers tend to be those that supply to their parent organizations the services that the merchant semiconductor industry is unwilling, or unable, to cost-effectively supply. These services include the following:

- Special processes—Some captive semiconductor suppliers have developed special processes that are not available elsewhere. These processes make possible products that could not be made in any other way.

- Special designs--This service includes custom VLSI designs that are made in such small volume that they are not of interest to semiconductor firms. Usually, these designs are justified through cost savings and by the fact that they tend to protect proprietary systems concepts.

- Education—It is desirable to educate design engineers in VLSI technology to allow them to develop more competitive systems concepts--concepts that optimize the application of semiconductor technology.

- Second source--A captive facility may be justified as a second or backup source, e.g., as an insurance premium.

- Purchasing support—The captive manufacturing facility can aid in vendor evaluation, cost analysis, and may even help vendors with problems.

- Public relations—Customers of major equipment companies may feel that the supplier is more capable if it has its own semiconductor facility.

- Design integration—A captive facility allows integration of semiconductor and systems design. Among the benefits that may emerge from such integration are faster design turnaround, more efficient handling of engineering change orders, and the optimization of cost/performance through design control of this entire vertical chain.

- Reliability

- Production control and assured delivery

Automation

The need to automate manufacturing is being recognized more than ever by the semiconductor industry. As the device geometries demanded by state-of-the-art semiconductor products become more rigorous, maintaining wafer yield becomes increasingly difficult. A decline in yield translates into lower productivity, and lower return on each dollar invested in capital equipment. For the semiconductor industry as a whole, both these trend lines have been moving downward. Pressure on the U.S. industry to automate is also felt through competition with Japan, where the automation of wafer fabrication plants has been much more successful.

In spite of the large amounts of sophisticated capital equipment required to manufacture semiconductors, the industry is still highly labor intensive. The semiconductor industry as a whole has one of the lowest ratios of revenue per employee, or assets per employee, of any U.S. industry in a comparison on revenue per employee for the semiconductor industry with that of the automotive industry (passenger vehicles only), the oil industry (certainly a "commodity" supplier), and another high-technology business, the computer industry. The disparities in revenue per employee are striking, with the semiconductor industry ranking lowest.

Some areas of semiconductor manufacturing, especially assembly, are performed overseas where low labor costs can substitute for the capital costs that would be incurred using more automated assembly operations in the U.S. However, this area is becoming more expensive because of rapid wage inflation in many parts of Asia. For example, in 1980 wages increased by as much as four times in only 18 months. Today, wage increases continue. There has also been increasing concern over tariffs and duties, particularly Sections 806/807 of the Customs Code, which deal with the rates applied to foreign assembly as interpreted by the U.S. Commerce Department. Regulated freight rates are also an important cost factor for Asian assembly. In 1980 an FCC decision allowed a 60 percent increase in freight rates charged to some semiconductor companies. These high rates may be circumvented in the future by companies that purchase and operate their own airplanes.

Between 1967 and 1983, the unit volume of integrated circuits increased more than 100 times and should increase further in the future. In addition to this volume increase, more devices are becoming industry standards and are manufactured in extremely high quantities. Greater volume makes automation more economically feasible. These factors argue for increased automation. On the other hand, some factors slow automation, including the following:

- Lack of capital in the industry
- Continuing technical changes
- Implementation of communication protocol standards that will link manufacturing equipment in a wafer fab facility

Because the industry generally is underfinanced, it cannot afford a great deal of capital equipment without a large infusion of equity. The continuing evolution of the technology and the consequent rapid obsolescence of products and equipment tend to lower the expected return on investment for equipment. In the past, many companies have been severely affected by the rapid obsolescence of capital equipment.

While semiconductor equipment manufacturers have been able to keep pace with ever tightening design rules and increased device density, the U.S. industry has been slow in integrating equipment for computer controlled wafer processing. Equipment manufacturers are now adding microprocessors to their products in order to facilitate integration through communications software based on semiconductor equipment communications standard (SECs), but implementation of a protocol standard has been slow.

Two areas that have been highly labor intensive are becoming more automated: mask alignment and lead bonding. Operation repeatability and improved process tolerances are the principal motivators to automate these areas. Mask alignment is done primarily in the United States because it is an integral part of wafer fabrication. Automatic aligners are beginning to appear and should see greater acceptance in the future. Lead bonding is performed mainly in the Asian assembly facilities.

In general, newer, more automated equipment will have the following four major features:

- Contamination-free environments
- Repeatable process capability
- Faster throughput or higher productivity
- Integration through a standard communications protocol

There are important consequences of the shift toward increased automation. First, more production will be performed in the consuming nation—that is, manufacturing will be performed where the market exists. Increased automation should make the higher labor costs of these market areas less important. Second, the industry will become less labor intensive, but with higher fixed costs. Third, underfinanced companies that cannot afford automated equipment will be at a competitive disadvantage.

Status and Outlook

The following is list of material in this section:

- Electronic Equipment Forecast
- Overview Electronic Equipment Forecast
- Semiconductor Capital Spending
- Final Worldwide Market Share Estimates
- Semiconductor Shipments

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Overview—Electronic Equipment Forecast

This section presents the methodology used in structuring the forecast data on North American electronic equipment production, describes the organization of the tables, and provides the complete equipment database.

METHODOLOGY

The Electronic Equipment Forecast provides detailed information on the estimated production of electronic equipment in North America for the years 1983 through 1994. This set of tables is the second of two major databases upon which the forecast of semiconductor consumption by application market is based.

The equipment shipment data presented here are used in conjunction with input/output ratios to generate semiconductor consumption estimates by application market. (For a more in-depth discussion on this subject, see the Input/Output Ratios section behind the tab entitled "Introduction.")

The first database, located behind the tab entitled "Company Electronic Equipment Revenue," presents the electronic equipment revenue of various electronic equipment manufacturers. These data provide historical trend information on North American equipment manufacturers and serve as an important input for developing the I/O ratios that we use in our analysis.

Within SAM, Dataquest uses the term "North American shipments" to refer to the value of equipment *produced* in North America. In this context, "shipments" does not refer to the value of products consumed or purchased within the US market.

Data reflecting production in North America are used in this database on the assumption that North American regional semiconductor consumption is more accurately forecast based on the current production of North American electronic equipment and the forecast growth rates of individual equipment types. Much of the currently available data on semiconductor consumption by application market were obtained through surveys of semiconductor manufacturers, and this tends to give a view one step removed from the geographic markets. These latter data indicate the percentage of a semiconductor manufacturer's sales by application area, such as data processing or industrial, but do not indicate in what geographical areas the sales were made, or if they were to North American, Far Eastern, or Western European equipment manufacturers.

For example, typical breakouts of semiconductor consumption obtained from US semiconductor manufacturers often indicate as much as 20 percent of the semiconductors going to consumer applications. When one looks at the percentage of North American-manufactured electronic equipment that is of a consumer type, one sees a very different picture. Dataquest estimates that, although there is a large and volatile consumer electronic equipment market in the United States, consumer electronics account for less than 10 percent of the total electronic equipment produced by North American manufacturers.

North American production statistics are gathered from a variety of sources. The major components of the database are Dataquest's Industry Services and the US Department of Commerce Current Industrial Reports. Other sources include industry contacts, trade association data, and foreign government data.

Dataquest's Industry Services report equipment revenue in terms of factory revenue. Because many of the I/O ratios are developed from information on North American manufacturers' equipment revenue and semiconductor consumption, they may not reflect actual end-user cost due to the variety of potential distribution channels and distributor discounts. For example, revenue reported by a small computer manufacturer that sells to a retailer such as Computerworld may not reflect the actual end-user cost of the equipment, and the I/O ratios derived for that company would be overstated. At present, an informal look into this area indicates that the actual differences in I/Os developed when taking into account the range of companies that have lengthy distribution channels balanced compared with those that sell direct did not significantly impact the long-term forecast of semiconductors consumed.

ORGANIZATION OF THE ELECTRONIC EQUIPMENT FORECAST TABLES

The equipment forecast section contains a series of tables presenting the current and forecast shipments of electronic equipment produced in North America, by application market segment and by individual type of equipment. The first table in the series is an application market segment overview. The overview table presents a condensed version of each of the six segments: data processing, communications, industrial, consumer, military, and transportation. For each segment, the major equipment subcategories are shown. For example, communications has five subsegments: customer premises, public telecommunication, radio, broadcast and studio, and other.

The segment overview is followed by detailed tables—one for each of the six segments. For example, the communications segment has its own table, with the subsegments broken down into detailed equipment types and accompanied by their respective forecasts. To provide flexibility, all equipment types are presented as line items. Where possible, as in the case of medical electronic equipment in the industrial segment, we have supplied subtotals that make it easy to extract and relocate particular equipment types. Line-item values and subtotals are provided for the convenience of notebook users who may require more than six segments, or who need to reconfigure any of the segments to meet individual market segmentation requirements.

The percent growth in equipment in 1990 as well as the CAGR from 1989 through 1994 are calculated in the detail tables. A discussion of the overall assumptions made in developing Dataquest's entire analysis of semiconductor consumption by application market, including segmentation and definitions of specific equipment types, is located behind the Introduction tab of this binder.

Table 1a

North American Electronic Equipment Production Segment Overview History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
Data Storage/ Subsystems (Total)	5,711	7,388	9,598	11,792	11,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Mobile Communications Equip.	3,118	4,073	4,399	4,712	5,392	5,985	6,418
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899
Audio	270	246	252	269	269	279	285
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Personal Electronics	1,048	473	331	235	249	241	239
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457
Military	0	0	47,300	49,370	50,932	51,063	51,727
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292
Total	123,596	153,077	217,419	222,687	237,449	253,879	269,231

Source: Dataquest (August 1990)

Table 1b

North American Electronic Equipment Production Segment Overview Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Mobile Communications Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Idustrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%
Audio	285	292	299	306	311	318	2.5%	2.2%
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%
Total	269,231	284,957	303,057	322,968	344,161	367,463	5.8%	6.4%

Source: Dataquest (August 1990)

Table 2a

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Corporate Resource	11,664	12,956	12,968	13,530	15,168	15,718	16,540
Business Unit	5,184	5,682	6,155	7,121	7,369	7,811	8,372
Large Department	6,287	7,030	7,475	7,139	6,970	8,033	8,456
Work Group & Small Dept.	7,019	10,061	11,708	12,303	13,391	14,346	15,216
Workstation	193	558	1,116	1,835	2,850	3,900	5,398
Personal Computer	7,018	13,162	16,141	14,551	17,040	18,961	20,775
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
14 Inch	2,248	3,139	3,223	3,891	4,239	4,680	4,593
8-10 Inch	943	1,188	1,630	1,927	2,220	2,623	3,060
5.25 Inch	681	1,299	1,760	2,611	2,783	3,185	3,192
3-4 Inch	7	48	96	322	969	1,805	2,990
Fixed Disk (Total)	3,879	5,674	6,709	8,751	10,211	12,293	13,835
Fixed Disk (Sold to OEMs)	0	0	0	0	(2,800)	(2,920)	(3,058)
Fixed Disk (Net)	3,879	5,674	6,709	8,751	7,411	9,373	10,777
WORM Optical Disk Drive	0	0	21	56	88	96	101
Erasable Optical Disk Drive	0	0	0	0	0	5	19
Optical Disk	0	0	21	56	88	101	120
Tape Drive	1,832	1,664	2,868	2,985	3,583	3,726	4,043
Data Storage/Subsystems (Total)	5,711	7,338	9,598	11,792	13,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940

Source: Dataquest (August 1990)

Table 2b

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Corporate Resource	16,540	17,335	18,420	19,617	21,030	22,481	4.8%	6.3%
Business Unit	8,372	8,966	9,712	10,528	11,454	12,428	7.1%	8.2%
Large Department	8,456	8,972	9,501	10,052	10,575	11,135	6.1%	5.7%
Work Group & Small Dept.	15,216	15,946	16,696	17,464	18,232	18,943	4.8%	4.5%
Workstation	5,398	7,160	9,030	11,155	13,322	16,653	32.6%	25.3%
Personal Computer	20,775	22,513	24,714	28,164	31,385	34,270	8.4%	10.5%
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
14 Inch	4,593	4,427	4,106	3,861	3,920	3,854	(3.6%)	(3.4%)
8-10 Inch	3,060	3,325	3,305	3,031	2,702	2,390	8.7%	(4.8%)
5.25 Inch	3,192	3,146	2,788	2,662	2,608	2,486	(1.4%)	(4.9%)
3-4 Inch	2,990	4,209	5,156	6,033	7,195	7,696	40.8%	20.8%
Fixed Disk (Total)	13,835	15,107	15,355	15,587	16,425	16,426	9.2%	3.5%
Fixed Disk (Sold to OEMs)	(3,058)	(3,326)	(3,709)	(4,349)	(5,098)	(5,871)	8.8%	13.9%
Fixed Disk (Net)	10,777	11,781	11,646	11,238	11,327	10,555	9.3%	(0.4%)
WORM Optical Disk Drive	101	141	198	363	552	707	39.6%	47.6%
Erasable Optical Disk Drive	19	81	194	407	808	1,349	326.3%	134.6%
Optical Disk	120	222	392	770	1,360	2,056	85.0%	76.5%
Tape Drive	4,043	4,407	4,507	4,905	5,292	5,662	9.0%	7.0%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%

Source: Dataquest (August 1990)

Table 2c

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Minicomputer-Based	1,357	1,490	1,237	928	954	1,098	835
Non-IBM, Protocol Specific	172	202	171	95	85	99	73
IBM 3270	810	909	1,042	873	802	414	358
Host/Vendor-Independent	421	437	431	447	480	474	402
Alphanumeric	2,760	3,038	2,881	2,343	2,321	2,085	1,668
Graphics Terminals	487	624	3,900	1,264	1,127	1,025	916
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Remote Batch, Job Entry and Output	60	122	275	276	270	290	301
Key Entry Equipment	102	80	70	57	43	30	15
Media-to-Media Data Conversion	102	135	143	140	147	165	180
Magnetic Ink Regcognition	91	79	60	33	28	18	12
Optical Scanning Equipment	195	253	253	274	320	368	412
Computer Plotters	232	241	466	477	525	588	592
Impact, Dot Matrix	2,790	2,299	2,171	2,262	3,016	3,090	3,127
Impact, Fully Formed	1,044	1,033	381	46	162	124	100
Nonimpact, Direct Thermal	120	175	70	46	32	24	17
Nonimpact, Thermal Transfer	0	33	214	116	120	53	52
Nonimpact, Ink-Jet	32	109	97	71	115	281	354
Serial Printers	3,986	3,649	2,933	2,541	3,445	3,572	3,650
Impact, Dot Matrix	332	420	521	611	599	632	660
Impact, Fully Formed	1,423	1,471	1,439	1,370	1,024	976	899
Nonimpact, Direct Thermal	13	5	2	1	0	0	0
Nonimpact, Thermal Transfer	3	7	12	18	29	44	55
Line Printers	1,771	1,903	1,974	2,000	1,652	1,652	1,614
Nonimpact, Plain Paper	573	1,187	1,174	1,745	2,786	3,858	4,560
Page Printers	573	1,187	1,174	1,745	2,786	3,858	4,560
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336

Source: Dataquest (August 1990)

Table 2d

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Minicomputer-Based	835	602	431	291	176	162	(27.9%)	(28.0%)
Non-IBM, Protocol Specific	73	46	29	18	8	6	(37.0%)	(39.3%)
IBM 3270	358	318	212	170	136	116	(11.2%)	(20.2%)
Host/Vendor-Independent	402	254	203	163	122	107	(36.8%)	(23.3%)
Alphanumeric	1,668	1,220	875	642	442	391	(26.9%)	(25.2%)
Graphics Terminals	916	861	837	804	796	782	(6.0%)	(3.1%)
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Remote Batch, Job Entry and Output	301	312	335	350	366	370	3.7%	4.2%
Key Entry Equipment	15	10	8	5	3	2	(33.3%)	(33.2%)
Media-to-Media Data Conversion	180	175	169	162	155	152	(2.8%)	(3.3%)
Magnetic Ink Regcognition	12	10	8	6	4	3	(16.7%)	(24.2%)
Optical Scanning Equipment	412	466	531	616	708	794	13.1%	14.0%
Computer Plotters	592	603	614	622	628	631	1.9%	1.3%
Impact, Dot Matrix	3,127	3,063	2,910	2,650	2,355	2,070	(2.0%)	(7.9%)
Impact, Fully Formed	100	80	54	51	43	36	(20.0%)	(18.5%)
Nonimpact, Direct Thermal	17	11	10	9	7	4	(35.3%)	(25.1%)
Nonimpact, Thermal Transfer	52	51	50	49	48	46	(1.9%)	(2.4%)
Nonimpact, Ink-Jet	354	489	695	986	1,344	1,765	38.1%	37.9%
Serial Printers	3,650	3,694	3,719	3,745	3,797	3,921	1.2%	1.4%
Impact, Dot Matrix	660	669	669	654	621	595	1.4%	(2.1%)
Impact, Fully Formed	899	833	781	716	665	630	(7.3%)	(6.9%)
Nonimpact, Direct Thermal	0	0	0	0	0	0	NM	NM
Nonimpact, Thermal Transfer	55	59	58	63	68	71	7.3%	5.2%
Line Printers	1,614	1,561	1,508	1,433	1,354	1,296	(3.3%)	(4.3%)
Nonimpact, Plain Paper	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Page Printers	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 2e

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
PC	0	0	0	0	0	0	19
Segment 1	150	141	90	137	153	142	129
Segment 2	20	49	120	86	83	102	113
Segment 3	90	173	155	187	191	177	163
Segment 4	48	52	22	229	259	280	302
Segment 5	836	951	957	498	677	681	697
Segment 6	199	208	313	546	586	618	643
Copiers and Duplicators	1,343	1,574	1,657	1,683	1,949	2,000	2,066
Electronic Calculators	188	174	151	149	152	158	155
Dictating, Transcribing	33	19	15	12	9	8	6
Portable and Compact	0	86	162	398	440	462	501
Low-End, Full-Size	40	85	189	162	155	126	100
Midrange, Full-Size	36	40	45	44	4	4	0
High-End, Full-Size	141	252	292	355	320	265	253
Display & Monitor Display	0	39	64	70	83	88	81
Electronic Typewriters	217	502	752	1,029	1,002	945	935
Standalone	515	551	400	137	17	6	2
Shared Systems	888	963	754	232	42	18	3
WP File Servers	0	0	384	108	22	8	1
Word Processors	1,403	1,514	1,538	477	81	32	6
Office Automation	3,184	3,783	4,113	3,350	3,193	3,143	3,168
Check-Handling Systems	58	68	111	137	152	170	180
Funds Transfer Terminals	307	373	307	288	321	343	338
Banking Systems	365	441	418	425	473	513	518
Point-of-Sale Terminals	454	491	414	510	515	530	478
Cash Registers	77	27	45	16	13	11	9
Mailing, Letter Handling, Addressing	508	562	596	793	809	858	818
Other Specialized Terminals	248	242	243	310	312	320	333
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941

Source: Dataquest (August 1990)

Table 2f

North American Electronic Equipment Production Data Processing Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
PC	19	22	26	29	36	39	15.8%	15.5%
Segment 1	129	117	113	108	110	113	(9.3%)	(2.6%)
Segment 2	113	128	153	149	147	146	13.3%	5.3%
Segment 3	163	149	139	131	125	118	(8.6%)	(6.3%)
Segment 4	302	324	338	370	405	436	7.3%	7.6%
Segment 5	697	642	600	525	450	411	(7.9%)	(10.0%)
Segment 6	643	687	700	525	480	455	6.8%	(6.7%)
Copiers and Duplicators	2,066	2,069	2,069	1,837	1,753	1,718	0.1%	(3.6%)
Electronic Calculators	155	152	149	146	144	143	(1.9%)	(1.6%)
Dictating, Transcribing	6	5	4	4	3	3	(16.7%)	(12.9%)
Portable and Compact	501	487	458	441	427	414	(2.8%)	(3.7%)
Low-End, Full-Size	100	77	51	44	38	34	(23.0%)	(19.4%)
Midrange, Full-Size	0	0	0	0	0	0	NM	NM
High-End, Full-Size	253	216	180	112	70	53	(14.6%)	(26.8%)
Display & Monitor Display	81	69	66	50	40	32	(14.8%)	(17.0%)
Electronic Typewriters	935	849	755	647	575	533	(9.2%)	(10.6%)
Standalone	2	0	0	0	0	0	(100.0%)	(100.0%)
Shared Systems	3	0	0	0	0	0	(100.0%)	(100.0%)
WP File Servers	1	0	0	0	0	0	(100.0%)	(100.0%)
Word Processors	6	0	0	0	0	0	(100.0%)	(100.0%)
Office Automation	3,168	3,075	2,977	2,634	2,475	2,397	(2.9%)	(5.4%)
Check-Handling Systems	180	198	209	215	219	228	10.0%	4.8%
Funds Transfer Terminals	338	365	390	415	448	476	8.0%	7.1%
Banking Systems	518	563	599	630	667	704	8.7%	6.3%
Point-of-Sale Terminals	478	497	574	620	687	742	4.0%	9.2%
Cash Registers	9	5	3	2	1	1	(44.4%)	(35.6%)
Mailing, Letter Handling, Addressing	818	857	988	950	922	904	4.8%	2.0%
Other Specialized Terminals	333	336	340	358	385	411	0.9%	4.3%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 3a

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Facsimile	0	0	0	0	0	0	0
Video Teleconferencing	0	0	18	27	32	44	54
Telex	0	0	0	0	0	0	0
Videotex	0	0	0	0	0	0	0
Image & Text Communication Eqp.	0	0	18	27	32	44	54
300/1200 bps	203	242	258	205	88	70	58
2400 bps	165	191	230	283	207	226	238
4800 bps	170	190	210	220	145	113	96
9600 bps	277	303	339	401	650	622	597
14.4 Kbps	101	110	111	110	133	148	140
16.8 Kbps	0	4	8	10	13	13	14
19.2 Kbps	0	6	10	14	63	76	94
Modems	916	1,046	1,166	1,243	1,299	1,268	1,237
Statistical Multiplexers	245	289	303	319	258	193	184
Time-Division Multiplexers	0	0	0	0	0	0	0
T-1 Multiplexers	30	61	158	241	309	403	469
Front-End Processors	383	426	474	527	477	488	502
Data PBX	77	119	143	86	82	80	78
Data Network Management Sys.	0	0	0	43	61	0	0
DSU/CSU	36	70	72	86	101	119	136
Protocol Converters	75	140	154	160	161	164	164
Local Area Networks	150	326	593	913	1,630	2,580	3,774
Response	0	36	34	28	30	32	33
Modem Network Management	0	53	60	66	71	75	79
Matrix	0	50	58	62	64	68	71
Switch/Path	0	72	74	75	78	80	81
Analyzers	0	91	96	102	106	108	113
Nodes	63	112	149	201	238	297	340
PADs	19	30	42	42	47	43	47
Switch Concentrator	2	6	11	19	27	0	0
Private Packet Data Switching	84	148	202	262	312	340	387
Public Packet Data Switching	0	0	0	0	0	0	0
Data Communication Equipment	1,996	2,927	3,587	4,213	5,039	5,998	7,308

Source: Dataquest (August 1990)

Table 3b

North American Electronic Equipment Production
Communications Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Facsimile	0	0	0	0	0	0	NM	NM
Video Teleconferencing	54	78	109	131	141	150	44.4%	22.7%
Telex	0	0	0	0	0	0	NM	NM
Videotex	0	0	0	0	0	0	NM	NM
Image & Text Communication Eqp.	54	78	109	131	141	150	44.4%	22.7%
300/1200 bps	58	43	26	17	12	12	(25.9%)	(27.0%)
2400 bps	238	240	215	190	184	184	0.8%	(5.0%)
4800 bps	96	84	74	63	54	54	(12.5%)	(10.9%)
9600 bps	597	546	510	459	431	431	(8.5%)	(6.3%)
14.4 Kbps	140	124	96	71	49	49	(11.4%)	(18.9%)
16.8 Kbps	14	13	10	7	5	5	(7.1%)	(18.6%)
19.2 Kbps	94	89	81	71	60	60	(5.3%)	(8.6%)
Modems	1,237	1,139	1,012	878	795	795	(7.9%)	(8.5%)
Statistical Multiplexers	184	169	150	130	110	90	(8.2%)	(13.3%)
Time-Division Multiplexers	0	0	0	0	0	0	NM	NM
T-1 Multiplexers	469	554	627	694	750	800	18.1%	11.3%
Front-End Processors	502	548	578	598	637	666	9.2%	5.8%
Data PBX	78	76	75	70	68	68	(2.6%)	(2.7%)
Data Network Management Sys.	0	0	0	0	0	0	NM	NM
DSU/CSU	136	156	178	200	234	265	14.7%	14.3%
Protocol Converters	164	153	143	140	135	130	(6.7%)	(4.5%)
Local Area Networks	3,774	4,959	6,084	7,020	7,857	9,828	31.4%	21.1%
Response	33	32	30	29	28	27	(3.0%)	(3.9%)
Modem Network Management	79	76	71	66	61	56	(3.8%)	(6.7%)
Matrix	71	74	76	78	80	82	4.2%	2.9%
Switch/Path	81	78	72	65	60	55	(3.7%)	(7.5%)
Analyzers	113	119	126	136	144	153	5.3%	6.2%
Nodes	340	386	425	465	505	556	13.5%	10.3%
PADs	47	44	42	38	33	28	(6.4%)	(9.8%)
Switch Concentrator	0	0	0	0	0	0	NM	NM
Private Packet Data Switching	387	430	467	503	538	584	11.1%	8.6%
Public Packet Data Switching	0	0	0	0	0	0	NM	NM
Data Communication Equipment	7,308	8,563	9,689	10,607	11,497	13,599	17.2%	13.2%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 3c

North American Electronic Equipment Production Communications History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
1-40 Lines	93	97	97	130	139	147	150
41-100 Lines	425	447	461	495	529	536	551
101-400 Lines	703	732	727	800	777	800	792
401-1,000 Lines	495	548	564	553	546	535	522
>1,000 Lines	643	769	797	741	769	758	727
PBX Telephone Systems	2,359	2,593	2,646	2,719	2,760	2,776	2,742
Key Telephone Systems	1,304	1,293	1,101	984	866	810	808
Premise Switching Equipment	3,663	3,886	3,747	3,703	3,626	3,586	3,550
Voice Messaging	37	82	117	182	284	472	675
Interactive Voice Response Sys.	0	0	0	0	0	0	0
Call Accounting	182	193	201	243	243	268	282
Automatic Call Distributors	207	224	222	233	265	299	334
Call Processing Equipment	426	499	540	658	792	1,039	1,291
Telephones	0	0	285	200	168	126	82
Integrated Services Digital Network	0	0	0	0	0	0	0
Asynchronous	33	55	73	25	24	20	17
Synchronous	2	6	14	11	9	8	6
PC	6	6	62	23	1	1	0
Add-On	0	8	25	6	4	4	4
Integrated Voice/Data Workstations	41	75	174	65	38	33	27
Teleprinters	387	294	272	258	245	220	205
Answering Machines	0	0	0	0	0	0	0
Desktop Terminal Equipment	428	369	731	523	451	379	314
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517

Source: Dataquest (August 1990)

Table 3d

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
1-40 Lines	150	151	149	152	157	162	0.7%	1.6%
41-100 Lines	551	545	548	565	623	678	(1.1%)	4.2%
101-400 Lines	792	767	764	772	787	792	(3.2%)	0
401-1,000 Lines	522	519	502	502	502	502	(0.6%)	(0.8%)
>1,000 Lines	727	6 99	6 96	702	702	702	(3.9%)	(0.7%)
PBX Telephone Systems	2,742	2,681	2,659	2,693	2,771	2,836	(2.2%)	0.7%
Key Telephone Systems	808	780	754	731	710	690	(3.5%)	(3.1%)
Premise Switching Equipment	3,550	3,461	3,413	3,424	3,481	3,526	(2.5%)	(0.1%)
Voice Messaging	675	825	897	917	926	1,093	22.2%	10.1%
Interactive Voice Response System	0	0	0	0	0	0	NM	NM
Call Accounting	282	301	332	365	395	425	6.7%	8.5%
Automatic Call Distributors	334	383	431	488	548	620	14.7%	13.2%
Call Processing Equipment	1,291	1,509	1,660	1,770	1,869	2,138	16.9%	10.6%
Telephones	82	40	37	34	34	34	(51.2%)	(16.1%)
Integrated Services Digital Network	0	0	0	0	0	0	NM	NM
Asynchronous	17	15	13	11	9	7	(11.8%)	(16.3%)
Synchronous	6	5	4	3	2	1	(16.7%)	(30.1%)
PC	0	0	0	0	0	0	NM	NM
Add-On	4	5	5	6	6	7	25.0%	11.8%
Integrated Voice/Data Workstations	27	25	22	20	17	15	(7.4%)	(11.1%)
Teleprinters	205	190	172	130	98	68	(7.3%)	(19.8%)
Answering Machines	0	0	0	0	0	0	NM	NM
Desktop Terminal Equipment	314	255	231	184	149	117	(18.8%)	(17.9%)
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 3e

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Multiplex	658	727	812	912	942	1,377	1,507
Carrier System	1,088	1,217	1,372	1,431	1,555	1,689	1,843
Microwave Radio	339	368	404	438	482	480	482
Satellite Earth Station Eqp.	500	560	574	563	592	651	693
Satellite Communication Eqp.	500	560	574	563	592	651	693
Transmission Equipment	2,585	2,872	3,162	3,344	3,571	4,197	4,525
Central Office Switching Eqp.	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Digital Access Cross-Connect System	0	0	0	0	0	0	0
Public Switching Equipment	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Cellular Telephones	114	326	422	499	723	890	923
Paging Equipment	0	0	0	0	0	0	0
PMR	641	895	908	793	1,160	1,415	1,650
Cordless Telephony	755	1,221	1,330	1,292	1,883	2,305	2,573
Mobile Radio Base Station Eqp.	188	199	217	354	327	350	375
Mobile Radio System Equipment	943	1,420	1,547	1,646	2,210	2,655	2,948
Broadcast Radio Receivers, Transmitter	1,391	1,678	1,953	2,001	1,927	1,925	1,900
Amateur Radio	3	3	5	5	9	10	10
Citizen's Band; Mobile & Base	3	3	5	5	9	10	10
Portable Radio Receivers, Transmitters	536	717	648	779	921	1,050	1,200
Radio Checkout Monitor, Evaluation, etc.	242	252	241	277	317	335	350
Comm. Antenna <890 MHz	0	0	0	0	0	0	0
Microwave Antenna >890 MHz	0	0	0	0	0	0	0
Mobile Communication Equipment	3,118	4,073	4,399	4,712	5,392	5,985	6,418

Source: Dataquest (August 1990)

Table 3f

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Multiplex	1,507	1,577	1,653	1,757	1,998	2,144	4.6%	7.3%
Carrier System	1,843	2,010	2,200	2,415	2,664	2,912	9.1%	9.6%
Microwave Radio	482	491	505	527	539	550	1.9%	2.7%
Satellite Earth Station Eqp.	693	752	801	993	1,150	1,265	8.5%	12.8%
Satellite Communication Equipment	693	752	801	993	1,150	1,265	8.5%	12.8%
Transmission Equipment	4,525	4,830	5,159	5,692	6,351	6,871	6.7%	8.7%
Central Office Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Digital Access Cross-Connect System	0	0	0	0	0	0	N/M	N/M
Public Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Cellular Telephones	923	953	988	1,005	1,051	1,097	3.3%	3.5%
Paging Equipment	0	0	0	0	0	0	NM	NM
PMR	1,650	1,800	1,950	2,100	2,250	2,400	9.1%	7.8%
Cordless Telephony	2,573	2,753	2,938	3,105	3,301	3,497	7.0%	6.3%
Mobile Radio Base Station Eqp.	375	400	425	450	475	500	6.7%	5.9%
Mobile Radio System Equipment	2,948	3,153	3,363	3,555	3,776	3,997	7.0%	6.3%
Broadcast Radio Receivers, Transmitter	1,900	1,900	1,900	1,900	1,900	1,900	0	0
Amateur Radio	10	10	10	10	10	10	0	0
Citizen's Band; Mobile & Base	10	10	10	10	10	10	0	0
Portable Radio Receivers, Transmitters	1,200	1,300	1,400	1,500	1,600	1,700	8.3%	7.2%
Radio Checkout Monitor, Evaluation, etc.	350	375	400	425	450	475	7.1%	6.3%
Comm. Antenna <890 MHz	0	0	0	0	0	0	NM	NM
Microwave Antenna >890 MHz	0	0	0	0	0	0	NM	NM
Mobile Communication Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 3g

North American Electronic Equipment Production Communications History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Equipment	187	219	210	209	267	305	325
Video Equipment	461	496	509	527	641	710	800
Transmitters, RF Power Amps	111	107	135	122	124	125	125
Studio Transmitter Links	42	8	19	17	17	15	15
Cable TV Equipment	452	410	375	383	468	530	580
CCTV	99	109	125	141	165	180	200
Broadcast Transmitter Antenna	0	0	0	0	0	0	0
Other (Studio, Theater)	63	87	94	93	98	100	100
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Intercomm. Equip Elec. Ampl.	176	213	172	195	221	230	250
Fiber Optic	275	254	529	568	701	755	800
Other (Laser, Infrared)	137	461	485	309	290	275	260
Light Communication System	412	715	1,014	877	991	1,030	1,060
Telemetering Systems	304	246	358	370	329	340	350
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915

Source: Dataquest (August 1990)

Table 3h

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Equipment	325	350	375	400	425	450	7.7%	6.7%
Video Equipment	800	850	900	950	1,000	1,050	6.3%	5.6%
Transmitters, RF Power Amps	125	125	125	125	125	125	0	0
Studio Transmitter Links	15	15	15	15	15	15	0	0
Cable TV Equipment	580	650	700	750	800	850	12.1%	7.9%
CCTV	200	225	250	275	300	325	12.5%	10.2%
Broadcast Transmitter Antenna	0	0	0	0	0	0	NM	NM
Other (Studio, Theater)	100	100	100	100	100	100	0	0
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Intercomm. Equip Elec. Ampl.	250	270	290	310	330	350	8.0%	7.0%
Fiber Optic	800	850	900	950	1,000	1,050	6.3%	5.6%
Other (Laser, Infrared)	260	250	250	250	250	250	(3.8%)	(0.8%)
Light Communication System	1,060	1,100	1,150	1,200	1,250	1,300	3.8%	4.2%
Telemetering Systems	350	350	350	350	350	350	0	0
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 4a

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Intrusion Detection	516	568	590	679	781	878	930
Fire Detection	364	477	431	427	436	473	509
Alarm Systems	880	1,045	1,021	1,106	1,217	1,351	1,439
Discrete Devices	537	548	565	582	599	622	636
MPU Load Programmers	26	19	20	23	26	29	32
Computerized Engy. Ctl. Sys.	554	348	361	358	369	391	399
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Semiconductor Production	945	1,795	1,598	1,199	1,258	1,914	2,157
ATE	1,188	1,300	1,422	1,609	1,694	1,974	2,047
General	3,654	4,445	4,548	4,503	4,818	5,203	5,431
Test Equipment	4,842	5,745	5,970	6,112	6,512	7,177	7,478
Process Control Systems	1,803	1,969	2,129	2,279	2,413	2,648	2,875
Programmable Machine Tools	677	740	921	767	754	815	892
Mech. Assembly Equipment	243	397	391	360	361	376	401
Plastic Process Machinery	567	779	604	588	621	645	699
Assembly	36	67	95	66	52	67	73
Material Handling/Loading	51	79	112	81	81	88	95
Painting	32	54	60	52	37	39	29
Spot Welding	33	61	106	85	61	55	48
Arc Welding	31	57	63	58	59	60	60
Machining, Other	49	62	56	37	28	29	44
Robot Systems	232	380	492	379	318	338	349
Guided Vehicles	40	130	160	117	117	130	142
Programmable Conveyors	323	378	450	409	436	474	511
Storage/Retrieval Systems	166	182	208	255	265	309	355
Programmable Monorails	20	36	65	138	137	160	185
Warehousing	160	170	181	173	183	209	236
Other	9	11	13	5	5	5	6
Automated Material Handling	718	907	1,077	1,097	1,143	1,287	1,435
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286

Source: Dataquest (August 1990)

Table 4b

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Intrusion Detection	930	999	1,069	1,140	1,223	1,312	7.4%	7.1%
Fire Detection	509	544	585	617	649	683	6.9%	6.0%
Alarm Systems	1,439	1,543	1,654	1,757	1,872	1,995	7.2%	6.7%
Discrete Devices	636	655	675	715	749	785	3.0%	4.3%
MPU Load Programmers	32	36	43	46	50	54	12.5%	11.2%
Computerized Engy. Ctl. Sys.	399	405	450	502	532	564	1.5%	7.2%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Semiconductor Production	2,157	2,083	2,649	3,264	3,631	4,039	(3.4%)	13.4%
ATE	2,047	2,106	2,243	2,373	2,499	2,632	2.9%	5.2%
General	5,431	5,644	5,977	6,270	6,527	6,795	3.9%	4.6%
Test Equipment	7,478	7,750	8,220	8,643	9,026	9,426	3.6%	4.7%
Process Control Systems	2,875	3,090	3,345	3,612	3,952	4,324	7.5%	8.5%
Programmable Machine Tools	892	942	999	1,048	1,079	1,111	5.6%	4.5%
Mechanical Assembly Equipment	401	411	425	430	440	450	2.5%	2.3%
Plastic Process Machinery	699	744	785	831	882	936	6.4%	6.0%
Assembly	73	80	87	85	90	95	9.6%	5.5%
Material Handling/ Loading	95	102	108	114	120	126	7.4%	5.9%
Painting	29	31	32	34	35	36	6.9%	4.4%
Spot Welding	48	44	40	37	34	31	(8.3%)	(8.2%)
Arc Welding	60	61	62	63	64	65	1.7%	1.6%
Machining, Other	44	46	47	49	51	53	4.5%	3.8%
Robot Systems	349	364	376	382	394	407	4.3%	3.1%
Guided Vehicles	142	154	166	176	188	201	8.5%	7.2%
Programmable Conveyors	511	544	591	644	699	759	6.5%	8.2%
Storage/Retrieval Systems	355	403	450	494	549	610	13.5%	11.4%
Programmable Monorails	185	210	236	260	285	312	13.5%	11.0%
Warehousing	236	263	289	314	350	390	11.4%	10.6%
Other	6	7	7	8	9	10	16.7%	11.0%
Automated Material Handling	1,435	1,581	1,739	1,896	2,080	2,282	10.2%	9.7%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%

Source: Dataquest (August 1990)

Table 4c

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Integrating and Totalizing Meters for Gas & Liquids	449	493	547	557	601	651	649
Counting Devices	173	209	198	202	198	211	220
Digital Panel Meters	27	36	34	33	34	41	41
Analog Panel Meters	10	5	6	6	6	5	6
Panel Type	116	128	119	124	141	162	163
Elapsed-Time Meters	27	16	12	11	13	16	12
Portable Elec. Measuring Instr.	22	23	18	18	23	25	20
Electronic Recording Instr.	323	418	438	469	517	568	559
Physical Property Test, Inspection & Measure	564	652	678	690	750	820	870
Comm. Meteorological & Gen. Purpose Instruments	294	381	334	300	350	378	447
Nuclear Radiation Detection & Monitoring Instruments	503	495	514	543	526	558	580
Surveying & Drafting Instr.	246	327	368	390	461	487	511
Ultrasonic Cleaners, Drills	107	127	112	108	124	139	148
Metorological	79	86	112	140	167	181	197
Geophysical	228	316	313	266	285	306	328
Analytical & Scientific Intr.	2,439	2,749	2,768	2,713	2,984	3,226	3,371
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Automatic Blood Analyzer	744	724	715	787	865	952	1,047
CAT Scanner	510	666	513	457	416	407	387
Digital Radiography	55	60	57	63	68	81	87
Electrocardiographs	72	118	96	98	106	114	122
Electrencephalographs	15	20	13	15	16	18	20
Nuclear Magnetic Resonanc	69	81	155	264	385	500	590
Respiratory Analysis	16	17	15	15	16	16	16
Ultrasonic Scanners	376	294	187	168	182	208	218
X-Ray	711	656	685	719	751	788	805
Other Diagnostic	291	254	263	276	280	292	303
Diagnostic	2,859	2,890	2,699	2,862	3,085	3,376	3,595
Patient Monitoring	659	577	640	666	699	741	771
Hearing Aids	340	363	395	419	444	477	500
Prosthetic	340	363	395	419	444	477	500
Surgical Support	104	130	181	217	239	250	256
Defibrillators	86	91	104	111	117	126	130
Dialysis, Diatheray	73	65	71	74	78	85	87
Electrosurgical	64	81	80	79	83	89	95
Pacemakers	263	371	304	312	320	318	336
Ultrasonic Generators	18	32	27	25	27	30	34
Other Therapeutic	274	280	258	237	253	293	313
Therapeutic	778	920	844	838	878	941	995
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117

Source: Dataquest (August 1990)

Table 4d

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Integrating and Totalizing Meters for Gas & Liquids	649	634	685	720	748	777	(2.3%)	3.7%
Counting Devices	220	223	258	281	305	331	1.4%	8.5%
Digital Panel Meters	41	44	50	57	63	70	7.3%	11.2%
Analog Panel Meters	6	6	5	4	4	4	0	(7.8%)
Panel Type	163	196	214	222	235	249	20.2%	8.8%
Elapsed-Time Meters	12	13	15	18	20	22	8.3%	13.1%
Portable Elec. Measuring Instr.	20	21	22	27	30	33	5.0%	10.8%
Electronic Recording Instruments	559	584	656	689	723	759	4.5%	6.3%
Physical Property Test, Inspection & Measure	870	921	1,000	1,065	1,125	1,188	5.9%	6.4%
Comm. Meteorological & Gen. Purpose Instruments	447	470	506	530	565	602	5.1%	6.1%
Nuclear Radiation Detection & Monitoring Instruments	580	559	601	643	665	688	(3.6%)	3.5%
Surveying & Drafting Instruments	511	538	581	619	655	693	5.3%	6.3%
Ultrasonic Cleaners, Drills	148	159	172	187	202	218	7.4%	8.1%
Metorological	197	209	234	252	273	296	6.1%	8.5%
Geophysical	328	347	377	407	439	474	5.8%	7.6%
Analytical & Scientific Intruments	3,371	3,512	3,766	3,962	4,084	4,210	4.2%	4.5%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Automatic Blood Analyzer	1,047	1,152	1,267	1,361	1,475	1,599	10.0%	8.8%
CAT Scanner	387	360	331	315	297	280	(7.0%)	(6.3%)
Digital Radiography	87	97	110	119	130	142	11.5%	10.3%
Electrocardiographs	122	129	135	143	151	159	5.7%	5.5%
Electrencephalographs	20	23	26	28	31	34	15.0%	11.4%
Nuclear Magnetic Resonanc	590	649	714	771	846	928	10.0%	9.5%
Respiratory Analysis	16	17	18	19	20	21	6.3%	5.6%
Ultrasonic Scanners	218	243	257	269	284	300	11.5%	6.6%
X-Ray	805	841	877	896	921	947	4.5%	3.3%
Other Diagnostic	303	312	324	333	343	353	3.0%	3.1%
Diagnostic	3,595	3,823	4,059	4,254	4,498	4,764	6.3%	5.8%
Patient Monitoring	771	817	882	882	902	922	6.0%	3.7%
Hearing Aids	500	534	570	589	615	642	6.8%	5.1%
Prosthetic	500	534	570	589	615	642	6.8%	5.1%
Surgical Support	256	270	287	298	310	322	5.5%	4.7%
Defibrillators	130	135	142	149	156	163	3.8%	4.7%
Dialysis, Diatheray	87	89	92	99	105	111	2.3%	5.1%
Electrosurgical	95	98	105	113	121	130	3.2%	6.4%
Pacemakers	336	345	357	373	389	406	2.7%	3.8%
Ultrasonic Generators	34	36	37	40	44	48	5.9%	7.3%
Other Therapeutic	313	338	365	374	390	407	8.0%	5.4%
Therapeutic	995	1,041	1,098	1,148	1,205	1,265	4.6%	4.9%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%

Source: Dataquest (August 1990)

Table 4e

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	0	0	0	1,493	1,590	1,825	2,080
Space	0	0	0	2,911	2,693	2,470	2,818
Navigation/Communication	0	0	0	625	663	713	808
Aircraft Flight Systems	0	0	0	1,692	1,783	1,892	2,198
Simulation & Training	0	0	0	185	201	216	245
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Vending Machines	334	394	429	408	386	398	415
Laser Systems (Exc. Communications)	545	623	621	625	679	760	821
Power Supplies	815	964	1,131	1,338	1,580	1,881	2,052
Traffic Control	481	474	453	462	485	509	537
Particle Accelerator Elec.	34	29	19	17	20	23	25
Industrial & Scientific X-Ray	21	53	61	67	75	83	90
Laboratory & Scientific Apparatus	976	1,101	1,136	1,194	1,290	1,397	1,451
Teaching Machines and Aids	65	64	67	70	77	84	90
Scientific Not Elsewhere Classified	185	187	185	183	185	221	238
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899

Source: Dataquest (August 1990)

Table 4f

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	2,080	2,355	2,645	2,949	3,228	3,533	13.2%	11.2%
Space	2,818	3,330	3,865	4,456	5,145	5,941	18.2%	16.1%
Navigation/ Communication	808	910	1,074	1,185	1,298	1,422	12.6%	12.0%
Aircraft Flight Systems	2,198	2,536	2,892	3,245	3,559	3,903	15.4%	12.2%
Simulation & Training	245	280	331	393	464	548	14.3%	17.5%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Vending Machines	415	421	427	459	459	459	1.4%	2.0%
Laser Systems (Exc. Communications)	821	893	984	1,087	1,188	1,298	8.8%	9.6%
Power Supplies	2,052	2,205	2,432	2,613	2,843	3,093	7.5%	8.6%
Traffic Control	537	562	587	619	651	685	4.7%	5.0%
Particle Accelerator Electronic	25	24	25	26	27	28	(4.0%)	2.3%
Industrial & Scientific X-Ray	90	95	102	109	116	123	5.6%	6.5%
Laboratory & Scientific Apparatus	1,451	1,495	1,589	1,670	1,751	1,836	3.0%	4.8%
Teaching Machines and Aids	90	97	105	111	118	125	7.8%	6.9%
Scientific Not Elsewhere Classified	238	261	286	297	314	332	9.7%	6.9%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Industrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%

Source: Dataquest (August 1990)

Table 5a

North American Electronic Equipment Production
Consumer History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Amplifiers	23	16	17	16	14	11	12
Compact Disc Players	0	0	0	0	0	0	0
Radio	19	23	18	19	25	30	33
Stereo (Hi-Fi) Components	202	186	193	205	200	207	210
Stereo Headphone	0	0	0	0	0	0	0
Musical Instruments	11	10	13	15	17	18	19
Tape Recorders	15	11	11	14	13	13	11
Audio	270	246	252	269	269	279	285
Video Cameras	303	354	225	60	35	20	10
VTRs (VCRs)	20	58	78	105	157	184	205
Videodisc Players	0	3	5	6	8	9	9
Color Televisions	4,473	4,834	4,936	5,028	5,298	5,395	5,510
Black & White Televisions	173	59	40	33	24	20	15
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Games	959	383	236	137	141	132	130
Cameras	13	15	18	17	20	23	25
Watches	68	62	64	67	72	69	65
Clocks	8	13	13	14	16	17	19
Personal Electronics	1,048	473	331	235	249	241	239
Air Conditioners	873	991	1,286	1,140	1,140	1,200	1,250
Microwave Ovens	1,044	1,252	1,300	1,300	1,350	1,400	1,450
Washers & Dryers	1,876	2,079	2,168	2,700	3,400	3,350	3,350
Refrigerators	2,249	2,573	2,718	2,894	3,082	3,080	3,247
Dishwashers, Disposals	1,600	1,800	1,900	2,050	2,100	2,150	2,150
Ranges & Ovens	1,300	1,477	1,517	1,589	1,600	1,650	1,700
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Automatic Garage Door Openers	187	198	184	208	222	232	240
Consumer Elec. Equip. Not Elsewhere Classified	322	449	626	689	723	760	797
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457

Source: Dataquest (August 1990)

Table 5b

North American Electronic Equipment Production
Consumer Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Amplifiers	12	12	11	10	10	10	0	(3.6%)
Compact Disc Players	0	0	0	0	0	0	NM	NM
Radio	33	36	38	43	45	48	9.1%	7.8%
Stereo (Hi-Fi) Components	210	214	220	223	225	228	1.9%	1.7%
Stereo Headphone	0	0	0	0	0	0	NM	NM
Musical Instruments	19	20	21	22	23	24	5.3%	4.8%
Tape Recorders	11	10	9	8	8	8	(9.1%)	(6.2%)
Audio	285	292	299	306	311	318	2.5%	2.2%
Video Cameras	10	0	0	0	0	0	(100.0%)	(100.0%)
VTRs (VCRs)	205	200	200	200	200	200	(2.4%)	(0.5%)
Videodisc Players	9	8	7	8	8	8	(11.1%)	(2.3%)
Color Televisions	5,510	5,646	5,807	5,998	6,224	6,500	2.5%	3.4%
Black & White Televisions	15	10	0	0	0	0	(33.3%)	(100.0%)
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Games	130	130	130	130	130	130	0	0
Cameras	25	26	26	24	24	24	4.0%	(0.8%)
Watches	65	61	59	57	57	57	(6.2%)	(2.6%)
Clocks	19	23	26	28	28	28	21.1%	8.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Air Conditioners	1,250	1,300	1,350	1,400	1,450	1,500	4.0%	3.7%
Microwave Ovens	1,450	1,500	1,550	1,600	1,650	1,700	3.4%	3.2%
Washers & Dryers	3,350	3,400	3,450	3,500	3,550	3,600	1.5%	1.4%
Refrigerators	3,247	3,312	3,468	3,617	3,700	3,750	2.0%	2.9%
Dishwashers, Disposals	2,150	2,250	2,300	2,350	2,400	2,450	4.7%	2.6%
Ranges & Ovens	1,700	1,750	1,800	1,850	1,900	1,950	2.9%	2.8%
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Automatic Garage Door Openers	240	246	257	272	257	257	2.5%	1.4%
Consumer Elec. Equip. Not Elsewhere Classified	797	832	869	899	900	900	4.4%	2.5%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 6a

North American Electronic Equipment Production
Military History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	NA	NA	NA	6,911	6,945	6,521	6,456
Sonar	NA	NA	NA	2,754	2,875	2,984	2,870
Missile/Weapon	NA	NA	NA	5,937	6,228	6,385	6,461
Space	NA	NA	NA	5,025	5,281	5,148	5,552
Navigation	NA	NA	NA	1,465	1,537	1,606	1,602
Communications	NA	NA	NA	4,388	4,616	4,791	4,944
Electronic Warfare	NA	NA	NA	3,250	3,029	3,044	3,021
Reconnaissance	NA	NA	NA	2,314	2,422	2,495	2,550
Aircraft Systems	NA	NA	NA	4,330	4,555	4,327	4,312
Computer Systems	NA	NA	NA	1,983	2,112	2,207	2,308
Simulation & Training	NA	NA	NA	632	671	744	845
Misc. Equipment	NA	NA	NA	10,381	10,661	10,811	10,806
Military	NA	NA	47,300	49,370	50,932	51,063	51,727

NA = Not available
Source: Dataquest (August 1990)

Table 6b

North American Electronic Equipment Production
Military Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	6,456	6,552	6,650	6,783	7,089	7,435	1.5%	2.9%
Sonar	2,870	3,050	3,172	3,270	3,405	3,558	6.3%	4.4%
Missile/Weapon	6,461	6,450	6,665	6,895	7,120	7,298	(0.2%)	2.5%
Space	5,552	5,898	6,329	6,760	7,220	7,718	6.2%	6.8%
Navigation	1,602	1,635	1,686	1,740	1,794	1,849	2.1%	2.9%
Communications	4,944	5,118	5,245	5,409	5,580	5,750	3.5%	3.1%
Electronic Warfare	3,021	3,112	3,235	3,335	3,458	3,565	3.0%	3.4%
Reconnaissance	2,550	2,615	2,696	2,796	2,893	2,962	2.5%	3.0%
Aircraft Systems	4,312	4,337	4,411	4,624	4,929	5,302	0.6%	4.2%
Computer Systems	2,308	2,421	2,545	2,708	2,892	3,088	4.9%	6.0%
Simulation & Training	845	946	1,054	1,170	1,328	1,495	12.0%	12.1%
Misc. Equipment	10,806	10,784	10,575	10,355	10,158	9,978	(0.2%)	(1.6%)
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%

Source: Dataquest (August 1990)

Table 7a

North American Electronic Equipment Production Transportation History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Entertainment	1,549	2,142	2,380	2,647	2,780	2,876	2,968
Body Controls	777	1,060	1,261	1,513	1,640	1,772	1,912
Driver Information	798	1,060	1,237	1,458	1,583	1,708	1,839
Powertrain	1,933	2,473	2,782	3,007	3,155	3,259	3,351
Safety & Convenience	490	706	820	955	1,041	1,129	1,222
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292

Source: Dataquest (August 1990)

Table 7b

North American Electronic Equipment Production Transportation Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Entertainment	2,968	3,028	3,192	3,338	3,468	3,548	2.0%	3.6%
Body Controls	1,912	2,075	2,415	2,704	2,903	3,052	8.5%	9.8%
Driver Information	1,839	1,959	2,170	2,381	2,545	2,658	6.5%	7.6%
Powertrain	3,351	3,441	3,595	3,724	3,839	3,933	2.7%	3.3%
Safety & Convenience	1,222	1,325	1,525	1,805	2,081	2,258	8.4%	13.1%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%

Source: Dataquest (August 1990)

Semiconductor Capital Spending

INTRODUCTION

Knowledge of aggregate capital spending plans of semiconductor manufacturers is important for strategic and tactical planning, both in the semiconductor industry itself and for users of semiconductors. Forecasts of capital spending help semiconductor users align themselves with vendors who are planning ahead for the right markets at the right time.

This section provides a forecast of capital spending, including captives, for the period 1988 to 1992, as well as historical figures from 1980 to 1987. It also includes a discussion of the forces that drive capital spending, especially pertaining to the competitive relationship between the Japanese and U.S. semiconductor industries.

Methodology

A new feature of our capital spending analysis is that we will report capital spending by regional companies and also by geographical areas. The regional companies' report will consist of worldwide semiconductor merchant capital spending and semiconductor merchant revenue by Asia-Pacific, European, Japanese, and U.S. companies. We will also report capital spending and production for the captive manufacturers.

Spending by region will include capital spending within a given geographical area by all companies, including captives. Thus, for example, regional European capital spending will include all capital spending by Asia-Pacific, European, Japanese, U.S., and captive companies in Europe. It will exclude all spending by European companies on facilities outside of Europe.

Associated with regional capital spending will be a history and forecast of regional production. Regional production, which is different from regional consumption, is an estimate of the final market value of devices fabricated within a given region. A device is classified as produced within a region if it is fabricated within that region, even though it may be tested and assembled in, and shipped from, another region. Thus, for example, regional European production will include all production by Asia-Pacific, European, Japanese, U.S., and captive companies in Europe, and will exclude all production by European companies outside of Europe.

Our new capital spending and revenue forecast for companies is shown in Table 1. Our new regional capital spending and production forecast is shown in Table 2.

Table 1
Capital Spending and Revenue
by Regional Companies
(Millions of Dollars)

	1987	1988	1989	1990	1991	1992	CAGR (1987-1992)
Asia Pacific							
Revenue	$ 656	$ 938	$ 1,247	$ 1,434	$ 2,079	$ 3,160	37%
Percent Change	54%	43%	33%	15%	45%	52%	
Capital Spending	$ 355	$ 451	$ 541	$ 730	$ 949	$ 1,139	26%
Percent Change	30%	27%	20%	35%	30%	20%	
Capital Spending/ Revenue	54%	48%	43%	51%	46%	36%	
Captive Revenue	$ 3,357	$ 3,779	$ 4,522	$ 5,215	$ 6,072	$ 7,071	16%
Percent Change	16%	13%	20%	15%	16%	16%	
Capital Spending	$ 883	$ 1,110	$ 1,232	$ 1,380	$ 1,594	$ 1,980	18%
Percent Change	10%	26%	11%	12%	15%	24%	
Capital Spending/ Revenue	20%	20%	16%	16%	15%	16%	
North America	$ 1,834	$ 2,566	$ 2,752	$ 2,477	$ 3,155	$ 4,294	19%
Japan	$ 2,340	$ 3,662	$ 3,918	$ 3,879	$ 5,236	$ 7,069	25%
Europe	$ 724	$ 730	$ 861	$ 973	$ 1,245	$ 1,432	15%
Asia-Pacific	$ 355	$ 451	$ 541	$ 730	$ 949	$ 1,139	26%
Captive	883	$ 1,110	$ 1,232	$ 1,380	$ 1,594	$ 1,980	18%
Total Worldwide Capital Spending	$ 6,136	$ 8,518	$ 9,304	$ 9,438	$12,179	$15,914	21%
Percent Change	18.6%	38.8%	9.2%	1.4%	29.0%	30.7%	
North America	$13,890	$17,084	$17,938	$17,669	$20,780	$24,992	12%
Japan	$17,938	$22,560	$24,927	$24,290	$27,392	$32,468	13%
Europe	$ 4,015	$ 4,761	$ 5,452	$ 5,639	$ 6,443	$ 8,249	15%
Asia-Pacific	$ 656	$ 938	$ 1,247	$ 1,434	$ 2,079	$ 3,160	37%
Captive	$ 3,357	$ 3,779	$ 4,522	$ 5,215	$ 6,072	$ 7,071	16%
Total Worldwide Production Revenue	$39,855	$49,122	$54,086	$54,247	$62,767	$75,939	14%
Percent Change	21.6%	23.3%	10.1%	0.3%	15.7%	21.0%	

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1989

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Table 2

Capital Spending and Production by Regions (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	CAGR (1987-1992)
Asia Pacific							
Production	$ 796	$ 1,076	$ 1,364	$ 1,433	$ 2,104	$ 3,188	32%
Percent Change	46%	35%	27%	5%	47%	51%	
Capital Spending	$ 380	$ 468	$ 545	$ 655	$ 900	$ 1,096	24%
Percent Change	27%	23%	16%	20%	37%	22%	
Capital Spending/ Production	48%	44%	40%	46%	43%	34%	
North America	$ 2,473	$ 3,332	$ 3,654	$ 3,729	$ 4,640	$ 6,054	20%
Japan	$ 2,440	$ 3,796	$ 4,044	$ 3,919	$ 5,238	$ 7,056	24%
Europe	$ 843	$ 923	$ 1,061	$ 1,135	$ 1,402	$ 1,706	15%
Asia-Pacific	$ 380	$ 468	$ 545	$ 655	$ 900	$ 1,096	24%
Total Worldwide Capital Spending	$ 6,136	$ 8,518	$ 9,304	$ 9,438	$12,179	$15,914	21%
Percent Change	18.6%	38.8%	9.2%	1.4%	29.0%	30.7%	
North America	$15,791	$19,219	$20,858	$21,914	$24,939	$31,136	15%
Japan	$18,504	$23,274	$25,565	$24,454	$27,471	$32,538	12%
Europe	$ 4,765	$ 5,553	$ 6,299	$ 6,446	$ 7,253	$ 9,078	14%
Asia-Pacific	$ 796	$ 1,076	$ 1,364	$ 1,433	$ 2,104	$ 3,188	32%
Total Worldwide Production Revenue	$39,855	$49,122	$54,086	$54,247	$62,767	$75,939	14%
Percent Change	21.6%	23.3%	10.1%	0.3%	15.7%	21.0%	

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1989

Semiconductor Capital Spending

1988

Buoyed by a generally expanding economy and growing end-use markets, semiconductor production has continued to expand. For this reason, we believe that the 1988 spending level will be approximately equal to that of 1984 ($8.8 billion in 1984 versus $8.5 billion in 1988). Because of the continuing high demand for devices, capacity utilization is now at about 80 percent industry-wide. Capacity utilization rates for devices with smaller geometries, however, are generally more than 80 percent; in some cases, such as DRAMs and 32-bit microprocessors, demand exceeds available supply. Semiconductor manufacturers, though spending for more capacity, will remain cautious; they prefer to increase equipment availability and to increase yields before adding capacity. Dataquest does not, therefore, expect 1988 growth to be anywhere near the 1984 level.

Capital spending will be driven not only by increases in the level of demand, but also by the continuing need for equipment upgrades. The goals of equipment upgrades are both technological and economic. Upgrades are technologically necessary in order to manufacture increasingly complex devices with ever smaller geometries. They are economically necessary in order to increase equipment productivity in an increasingly fierce competitive environment.

We expect Japanese companies to increase capital spending by 56 percent in dollars over 1987. Measured in yen, the spending increase will not be quite so abrupt (41 percent). Measured in yen or in dollars, this is healthy and welcome growth.

In 1988, U.S. companies increased their spending by 40 percent over 1987. Spending by Asia-Pacific companies reached $451 million in 1988, a 27 percent growth over 1987. Spending by captives also saw a healthy increase in 1988. We expect captive capital spending to grow to $1.1 billion, an increase of 26 percent.

Spending by European companies was relatively weak in 1988, rising only 1 percent to $730 million. This relative flat spending has two causes. The first is that European companies like Philips and Siemens had strong spending plans that they carried through in spite of the recent downturn. These spending programs are now complete and the facilities they generated (Philips at Einhoven, The Netherlands, and Siemens at Regensburg, West Germany), are now going into volume production. Consequently, we can expect both Philips and Siemens to moderate their spending plans somewhat. The second reason for the slowdown is the recent merger of SGS and Thomson into SGS/Thomson. This new world-class manufacturer is now taking time to step back, examine, restructure, and rationalize its operations.

Semiconductor Capital Spending

Beyond 1988

In 1989, we expect to see a slowdown in the growth of semiconductor production and, consequently, in the growth of capital spending. This is because we expect the U.S. economy (and therefore the end markets that semiconductors serve) to undergo a slight recession in the latter part of 1989.

Growth in production and capital spending should, therefore, be much stronger in the first half of 1989 than in the second half. We expect to see some decline in both production and capital spending in the second half of 1989. We foresee that semiconductor production will grow 10 percent on an annual basis in 1989, and capital spending will grow 9 percent on an annual basis.

The negative growth rate in the second half of 1989 will likely continue into the first half of 1990. However, growth should resume in the second half of 1990. As a result of a continuing decline in the first half of 1990, followed by the beginnings of a recovery will be that, for 1990, both production and capital spending will be flat on an annual basis.

After 1990, however, we expect a resumption of vigorous growth. Overall, for the period 1987 to 1992, capital spending will grow at a compound annual growth rate (CAGR) of 21 percent. Spending in this period will be led by the Japanese companies that, by 1992, will be spending more than $7 billion on capital equipment.

Spending worldwide after 1990 will be driven by the need for equipment upgrades that will be necessary for new generations of devices, and for the added capacity that will be necessary for a growing world economy. Capital spending will also be driven by the need for companies to replenish the capital stock that they brought on-stream in 1984.

The need to replenish 1984's and 1985's capital stock is especially important for Japanese companies, which more than doubled their installed base between 1983 and 1986. Consequently, 1984's and 1985's capital stock will represent a very large part of Japanese companies' installed base, and a large part of their spending will be dedicated to replacing it. Spending in dollars by Japanese companies between 1987 and 1992 will grow at a CAGR of 25 percent in dollars. In yen, the growth rate will be somewhat lower—22 percent.

By 1992, U.S. merchant spending will be $4.2 billion. The growth rate of U.S. company spending will be at a CAGR of 19 percent from 1987 to 1992.

Capital spending by European companies between 1987 and 1992 will grow the least of any other region, with a CAGR of 15 percent. However, after 1988, spending growth in Europe will resume at an above average rate. Spending by European companies will equal $1.4 billion in 1992.

Semiconductor Capital Spending

Capital spending by Asia-Pacific companies continues to grow faster than spending by any other region in the world. Their CAGR for 1987 to 1992 is forecast at 26 percent. In 1987, spending by Asia-Pacific companies was 62 percent of European companies. By 1992, we expect this figure to rise to 80 percent of the European level.

JAPAN AND THE UNITED STATES: NO WINNER IN SIGHT

Measured in dollars, Japan increased its 1988 capital spending at a much faster rate than U.S. merchant companies (56 percent versus 40 percent). For the 1987 to 1992 forecast period, the story is similar: a CAGR of 25 percent for Japanese companies versus 19 percent for U.S. merchant companies. In 1992, Japanese company capital spending will stand at more than $7 billion, while the U.S. merchants will spend a mere $4.3 billion. Measured in dollars, it appears that the Japanese merchant semiconductor industry will tower over that of the United States merchants. If capital spending by the U.S. captives is added to that of the U.S. merchants, we estimate that Japanese company capital spending in 1992 will still be 13 percent greater than the combined U.S. merchants and captives ($7.1 billion versus $6.3 billion).

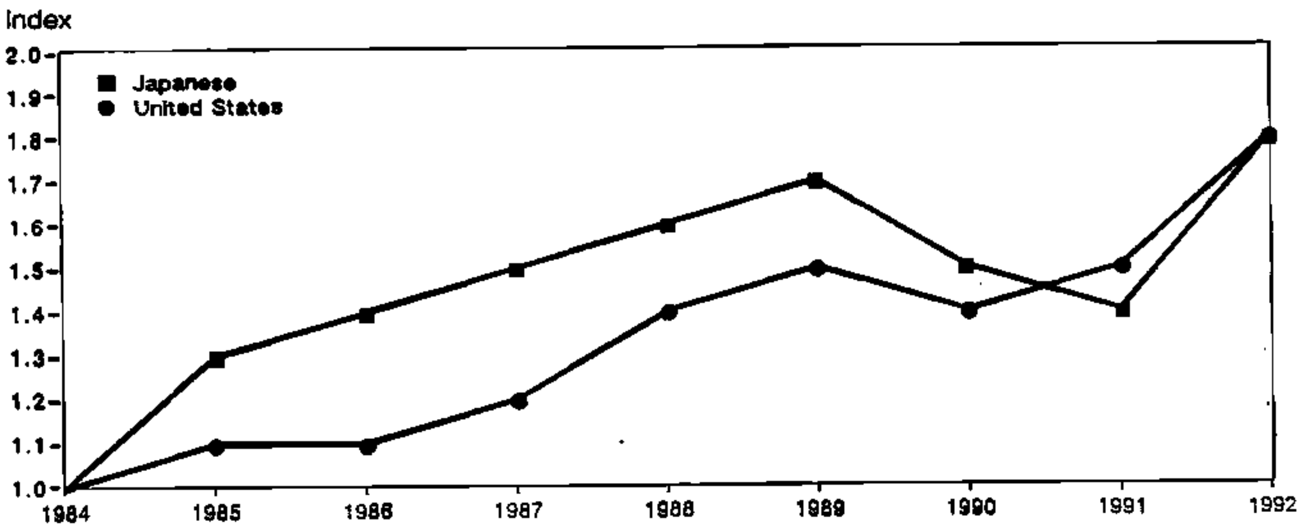
However, measured in local currencies, (i.e., measuring growth rates and installed bases in yen for Japanese companies and dollars for U.S. merchant companies), the story is quite different. In 1988, Japanese companies increased their spending by 41 percent in yen, as opposed to 40 percent for U.S. merchant companies—essentially the same percentage growth. Japanese capital spending in 1988 was 55 percent of Japanese capital spending in 1984. U.S. merchant capital spending in 1988 was 84 percent of U.S. merchant capital spending in 1984.

An even more telling comparison is for the period 1984 to 1992. 1984 was the peak year for capital spending for both Japanese and U.S. merchant companies. In our forecast horizon, 1992 is the peak year. The growth rate of capital spending for Japanese companies from 1984 to 1992 is 1 percent in yen. That of U.S. merchant companies is 4 percent in dollars.

Figure 1 shows the growth of Japanese and U.S. merchant companies' installed base of property, plants, and equipment. The growth of each industry's installed base is indexed to 1984 (the year that the Japanese industry achieved parity with the U.S. merchant industry). If, in 1984, the installed base of each industry was essentially the same size, then, in 1985, the Japanese installed base surpassed that of the U.S. merchants by a large margin. However, in 1990, when a substantial amount of the Japanese company installed base from 1984 will be retired, the installed base of U.S. merchant companies will likely surpass that of Japanese companies. By 1992, we expect the size of the installed base of Japanese companies and U.S. merchant companies to be about equal. If the installed base of the U.S. captives is added to that of the U.S. merchants, then, measured in local currencies, the combined U.S. installed base is substantially larger than the installed base of the Japanese industry.

Figure 1

Japanese and U.S. Installed Base



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Source: Dataquest
January 1989

NORTH AMERICAN COMPANY CAPITAL SPENDING

Dataquest surveys the major North American semiconductor manufacturers several times a year to track their capital spending plans. We have noted a strengthening of optimism as 1988 progressed. Table 3 provides a summary of the history of capital spending in the United States by company and the change in spending from 1987 to 1988.

In 1985, capacity utilization for all U.S. companies fell to an all-time low of 51 percent. In 1988, capacity utilization rose to 88 percent. Capacity utilization for leading-edge devices is even higher, and, in some cases, demand exceeds supply. Due to these increasing rates of utilization, the percent of capital spending devoted to property and plant is the highest since 1985 (see Figure 2).

Continuing the trend which began in 1987, most U.S. companies are planning to increase their capital spending. Intel, Motorola, and Texas Instruments will each spend more than $400 million on property, plant, and equipment. Micron Technology will increase its spending by more than 700 percent as it adds a new fab to its manufacturing inventory.

Individual U.S. company capital spending-to-revenue ratios for the period 1975 through 1987 are given in Table 4.

Table 3

U.S. Company Capital Spending
(Millions of Dollars)

Company	1980	1981	1982	1983	1984
Advanced Micro Devices	$ 49	$ 58	$ 67	$ 121	$ 308
Analog Devices	19	16	19	24	58
Fairchild	83	140	156	125	195
General Electric	N/A	N/A	N/A	64	107
General Instruments	N/A	N/A	N/A	N/A	9
Harris	45	45	35	31	47
IDT	N/A	N/A	N/A	2	4
Intel	156	157	138	146	388
LSI Logic	N/A	N/A	6	30	82
Thomson-Mostek	85	98	47	78	123
Monolithic Memories	6	20	25	N/A	N/A
Micron Technology	N/A	N/A	5	29	58
Motorola	177	184	160	174	412
National Semiconductor	199	245	238	245	495
Texas Instruments	300	145	140	232	472
Others	312	265	251	324	577
Total	$1,347	$1,233	$1,131	$1,499	$3,139

Company	1985	1986	1987	1988	Percent Change 1987-88
Advanced Micro Devices	$ 243	$ 102	$ 138	$ 180	30%
Analog Devices	62	37	50	50	(1%)
Fairchild	135	135	N/A	N/A	N/A
General Electric	81	50	45	50	11%
General Instrument	12	8	12	20	67%
Harris	52	37	30	30	0
IDT	25	18	18	37	103%
Intel	214	155	302	450	49%
LSI Logic	40	71	135	60	(56%)
Thomson-Mostek	N/A	N/A	N/A	N/A	N/A
Monolithic Memories	N/A	N/A	N/A	N/A	N/A
Micron Technology	32	11	14	120	769%
Motorola	330	250	350	430	23%
National Semiconductor	319	223	157	200	27%
Texas Instruments	281	217	231	410	77%
Others	374	266	352	530	51%
Total	$2,065	$1,445	$1,834	$2,566	40%

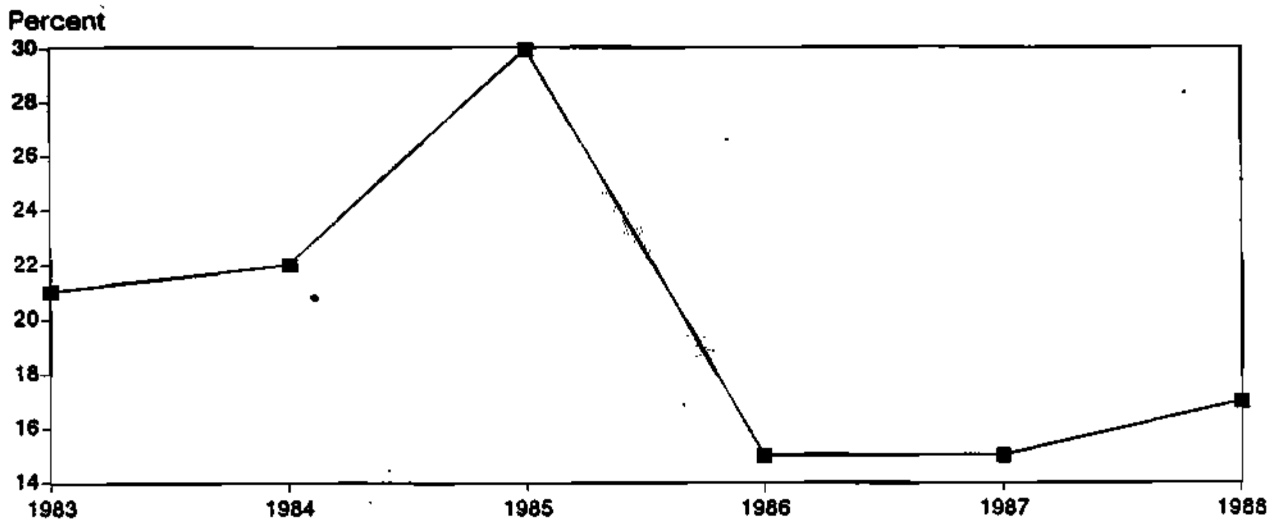
*Columns may not add to totals shown because of rounding.

N/A = Not Applicable

Source: Dataquest
January 1989

Figure 2

U.S. Property and Plant Capital Spending as a Percent of Total Capital Spending



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Source: Dataquest
January 1989

Table 4

U.S. Company Capital Spending as a Percent of Revenue

Company	1980	1981	1982	1983	1984	1985	1986	1987
AMD	17.2%	20.8%	20.4%	19.0%	27.1%	30.9%	12.1%	13.6%
Analog Devices	24.9%	18.5%	18.3%	16.6%	26.7%	27.6%	15.3%	18.4%
Fairchild	14.7%	30.3%	38.0%	27.5%	29.3%	27.4%	N/A	N/A
General Electric	N/A	N/A	N/A	13.0%	17.0%	16.0%	9.6%	7.9%
General Instrument	N/A	N/A	N/A	N/A	3.1%	5.5%	3.4%	4.4%
Harris	24.3%	27.3%	22.4%	17.8%	18.2%	21.1%	20.0%	13.4%
IDT	N/A	N/A	N/A	22.5%	12.9%	8.0%	25.3%	18.6%
Intel	27.1%	29.9%	22.1%	18.8%	32.3%	21.0%	15.6%	20.1%
LSI Logic	N/A	N/A	98.3%	93.7%	97.9%	28.5%	36.6%	51.9%
Thomson-Mostek	25.8%	46.7%	21.4%	24.8%	33.2%	35.5%	6.5%	N/A
Micron Technology	N/A	N/A	103.5%	119.0%	49.4%	90.1%	18.0%	12.0%
Monolithic Memories	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Motorola	15.9%	15.5%	13.1%	10.6%	17.8%	18.0%	12.3%	14.3%
National Semi	15.2%	20.3%	21.3%	17.9%	26.4%	22.5%	16.4%	11.0%
Texas Instruments	19.0%	11.2%	10.7%	14.2%	19.0%	16.1%	11.9%	10.9%
Total	16.7%	17.7%	15.6%	16.1%	22.9%	19.7%	14.2%	12.9%

N/A = Not Applicable

Source: Dataquest
January 1989

Semiconductor Capital Spending

JAPANESE COMPANY CAPITAL SPENDING

Japanese company capital spending increased 41 percent to ¥476 billion in calendar year 1988, after a 14 percent increase in 1987. Toshiba, Hitachi, and NEC alone will account for 35 percent of the total Japanese capital spending. Fujitsu planned to double its spending from ¥20 billion to ¥40 billion in 1988 (see Tables 5 and 6). Capital spending as a percent of revenue is shown in Table 7.

Table 5

Japanese Calendar Year Capital Spending
(Billions of Yen)

Company	1980	1981	1982	1983	1984	1985	1986	1987	1988	Percent Change 1987-88
Fuji Electric	0	0	¥ 4	¥ 6	¥ 12	¥ 12	¥ 5	¥ 3	¥ 5	67%
Fujitsu	¥ 25	¥ 32	35	53	115	72	16	20	40	100%
Hitachi	21	33	36	62	120	92	22	30	55	83%
Nihon Semi	0	0	0	0	0	0	5	15	3	(80%)
Matsushita	20	19	9	21	110	60	25	22	30	36%
Mitsubishi	8	13	20	31	65	62	20	15	25	67%
NEC	30	38	42	58	129	123	30	30	50	67%
NJRC	N/A	N/A	2	2	4	5	5	2	5	108%
NMB	0	0	0	0	14	14	5	10	10	0
Oki Electric	12	12	11	11	26	26	10	25	37	48%
Rohm	0	0	2	3	6	9	8	12	10	(17%)
Sanken Electric	0	0	2	3	6	6	4	5	10	100%
Sanyo Electric	8	12	10	12	32	47	18	25	29	16%
Sharp	9	10	8	16	26	36	22	20	26	30%
Shindengen	0	0	1	1	3	3	1	1	2	100%
Seiko Epson	0	0	5	9	18	8	5	6	7	17%
Sony	0	0	5	9	14	36	16	16	32	100%
Toshiba	11	16	28	86	136	123	65	60	60	0
Other	0	0	9	16	34	32	13	20	40	100%
Total	¥144	¥185	¥229	¥399	¥870	¥766	¥295	¥337	¥476	41%

*Columns may not add to totals shown because of rounding.

N/A = Not Available

Source: Dataquest
January 1989

Table 6

Japanese Calendar Year Capital Spending
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987	1988	Percent Change 1987-88
Fuji Electric	0	0	$ 16	$ 26	$ 51	$ 50	$ 30	$ 21	$ 38	85%
Fujitsu	$111	$145	141	226	485	303	96	139	308	122%
Hitachi	93	149	145	264	506	387	132	208	423	103%
Japan Semi	0	0	0	0	0	0	30	104	23	(78%)
Matsushita	89	86	36	89	464	252	150	153	231	51%
Mitsubishi	36	59	80	132	274	261	120	104	192	85%
NEC	133	172	169	247	544	517	180	208	385	85%
NJRC	0	0	8	9	17	21	30	17	38	131%
NMB	0	0	0	0	59	59	30	69	77	11%
Oki Electric	53	54	44	47	110	109	60	174	285	64%
Rohm	0	0	8	13	25	38	48	83	77	(8%)
Sanken Electric	0	0	8	13	25	25	24	35	77	122%
Sanyo Electric	36	54	40	51	135	197	108	174	223	29%
Sharp	38	43	32	68	110	151	132	139	200	44%
Shindengen	0	0	4	4	13	13	6	7	15	122%
Seiko Epson	0	0	20	38	76	34	30	42	54	29%
Sony	0	0	20	38	59	151	96	111	246	122%
Toshiba	49	72	113	366	574	517	389	417	462	11%
Other	0	0	36	68	143	134	78	139	308	122%
Total	$638	$834	$921	$1,698	$3,671	$3,219	$1,766	$2,345	$3,662	56%

*Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1989

Table 7

Japanese Company Capital Spending as a Percent of Revenue

Company	1980	1981	1982	1983	1984	1985	1986	1987
Fuji Electric	N/A	N/A	16%	21%	29%	32%	15%	8%
Fujitsu	40%	39%	30%	34%	41%	30%	7%	7%
Hitachi	15%	18%	16%	21%	25%	23%	6%	7%
Japan Semi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Matsushita	28%	18%	8%	15%	50%	28%	12%	10%
Mitsubishi	14%	18%	24%	26%	28%	39%	11%	7%
NEC	17%	17%	16%	17%	24%	26%	7%	7%
NJRC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NMB	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oki Electric	N/A	55%	34%	20%	30%	36%	14%	27%
Rohm	N/A	N/A	8%	8%	10%	15%	13%	17%
Sanken Electronics	N/A	N/A	9%	12%	16%	16%	11%	12%
Sanyo Electric	19%	24%	17%	15%	30%	43%	18%	22%
Sharp	N/A	27%	17%	24%	33%	46%	30%	23%
Seiko Epson	N/A	N/A	N/A	N/A	66%	36%	18%	20%
Sony	N/A	N/A	N/A	30%	35%	60%	21%	20%
Toshiba	8%	9%	16%	37%	37%	35%	175%	14%
Others	N/A	N/A	6%	9%	30%	31%	14%	20%
Total	17%	16%	17%	22%	32%	32%	12%	13%

N/A = Not Applicable

Source: Dataquest
January 1989

Semiconductor Capital Spending

As a further, and final, note to the discussion above regarding the size of Japanese and U.S. industries, Dataquest notes that not one of the top five Japanese semiconductor manufacturers (NEC, Toshiba, Hitachi, Fujitsu, or Mitsubishi) will have capital expenditures at a level anywhere near those they attained in 1984. By contrast, two of the five U.S. manufacturer (Intel and Motorola) will exceed 1984's levels, and Texas Instruments will come very close to attaining its 1984 level of capital spending.

PRODUCTION AND CAPITAL SPENDING

Production is one of the basic forces that shapes capital spending, which is a derived demand. If the semiconductor end users do not have a strong demand for their products, then the demand for semiconductors, and consequently for capital equipment, will be weak. While we expect that the long-term growth of semiconductor production will remain vigorous, it will not be quite as vigorous as before.

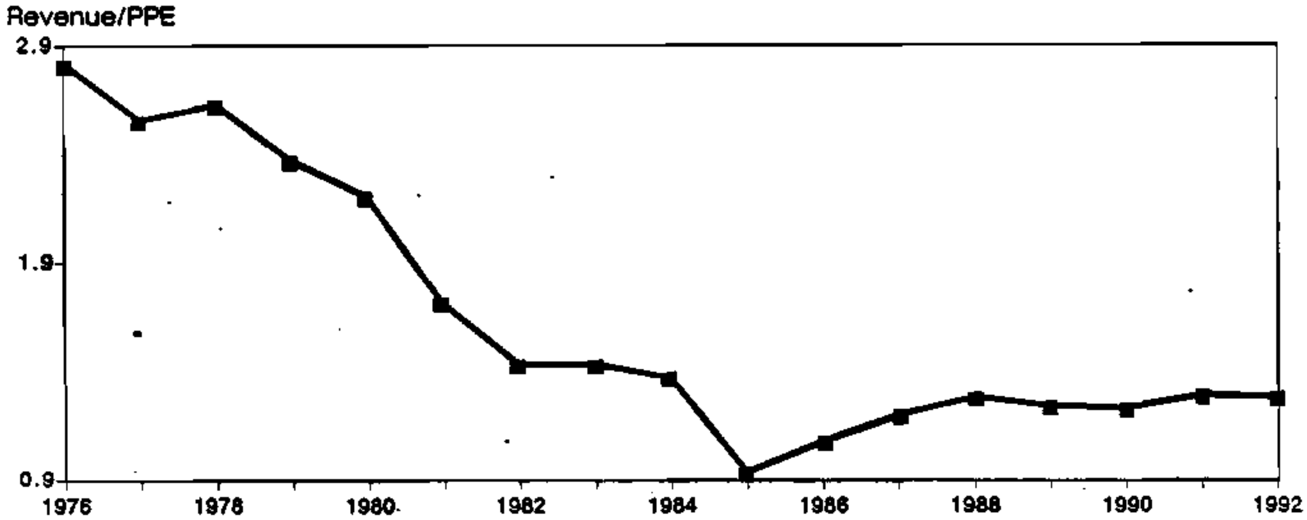
From 1975 to 1981, semiconductor production grew at a 25 percent CAGR. For the 1982 to 1986 period, this growth rate slowed to 18 percent. Dataquest now expects semiconductor production to grow even more slowly, at a 15 percent rate, from 1986 to 1992. This new, lower, long-term growth rate is due to the absence of a new "hula-hoop," such as the PC, to drive the industry as it did from 1982 to 1984. It is also due to the success of the industry. Since semiconductors are now found throughout the economy, they, therefore, will be increasingly influenced by the secular trends of the economy.

Another reason for the slowdown in the CAGR of capital spending is that of increasing productivity of capital. Capital productivity is the amount of revenue that is generated with a given installed base of property, plant, and equipment (PPE). Historically, this is a ratio that has declined. We believe, however, that capital productivity has begun to rise (see Figure 3). There are several reasons for this. Computer-integrated manufacturing (CIM) will allow manufacturers to schedule many different product mixes and maintain line balance while increasing equipment utilization. We estimate that equipment utilization is in the neighborhood of 40 percent presently. We expect that manufacturers will increase their yields because automation will remove people from clean rooms and because of lower particulate from semiconductor equipment and materials.

Figure 4 shows the effects of increasing capital productivity. Until 1985, the percentage change in capital spending exceeded that of the percentage change of production in every year but one. From 1985 to 1992, we expect the percentage change in capital spending to exceed that of production only twice, and by much less substantial margins than in the previous period.

Figure 3

The Productivity of Capital



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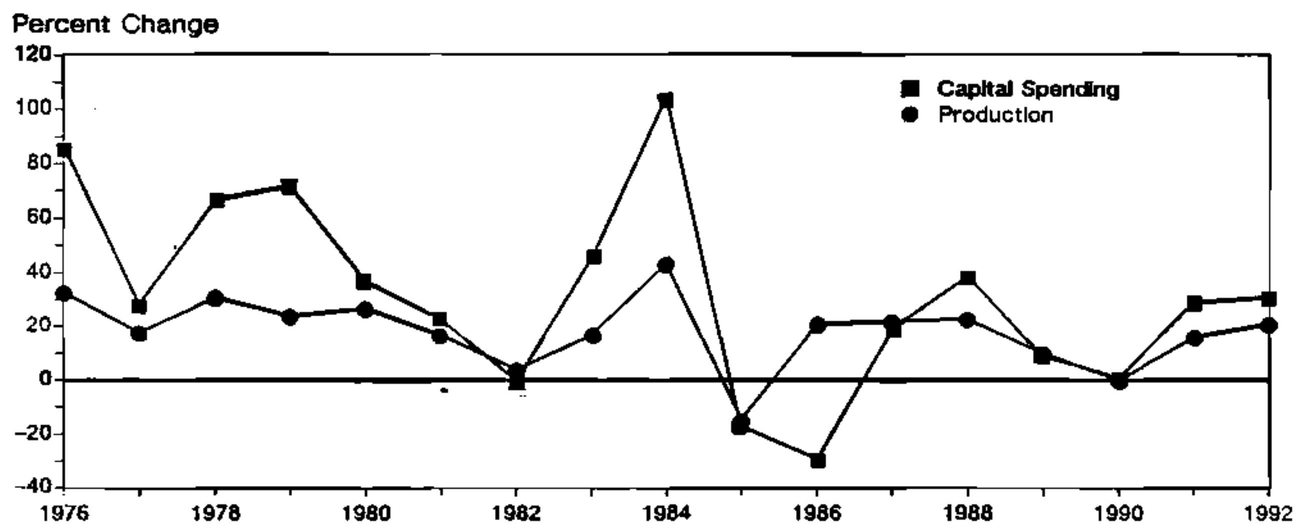
Source: Dataquest
January 1989

Figure 4

Percent Change in Capital Spending Production



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Source: Dataquest
January 1989

Thus, although we are in the midst of a boom, growth in capital spending will be slower than it has been in the past. It will also be steadier because the semiconductor industry itself is becoming more mature, which results in a less uneven growth. Therefore, capacity additions will be better planned than in the past.

Dataquest consequently does not expect skyrocketing capital spending growth such as that which occurred in 1984. We also do not expect the devastating descents that occurred in 1985 and 1986. The peaks may not be as high, but the ride will be smoother and more sustainable.

USER PERSPECTIVE

The capital expenditure trends that are expected through 1989 and beyond give users a good chance to reassess both their U.S. and Japanese semiconductor vendors. Based on past history, users can determine where key vendors have put resources and where the overall regional trends are forecast. If a vendor is out of synch with the overall trend, it may indicate a long-term plan to over or under capitalize in order to meet financial goals. Under capitalization in this increasingly costly environment is analogous to a slow-acting poison that will gradually result in competitive failure.

As the capital expenditures closely track the ebb and flow of the electronic industry demand cycle, astute users can track their key vendors to see whether they have kept up with the industry. More importantly, users can check whether their vendors have the wherewithal to support them in the future.

wide

Final Worldwide Semiconductor Market Share Estimates

May 1990

Dataquest

a company of
The Dun & Bradstreet Corporation

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Table of Contents

This booklet is divided into two major sections.

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Chapter 1

Final Worldwide Semiconductor Market Share Estimates

These market share estimates provide our final estimates of 1989. The tables cover history for the period 1987 to 1989 for the major categories of semiconductors.

Background

An integral part of Dataquest's Semiconductor Industry Service database is analyzing the semiconductor markets by estimating each manufacturer's market share. These analyses provide insights into semiconductor markets and reinforce estimates of consumption, production, and company revenue that were made using other data. An index of all tables is included for easy reference. Information on further product detail may be requested through the client inquiry privilege.

The semiconductor market is divided among North American companies, Japanese companies, European companies, and Asia/Pacific companies, based on the location of their main offices. All of the major companies are included in this database.

The totals given for each company reflect worldwide production. For example, although Texas Instruments manufactures semiconductors in many parts of the world, its entire production is included under the North American companies market share section. In contrast, some, but not all, foreign-owned subsidiaries are included in the North American totals and not in the total of the parent company location. For example, Exar, a subsidiary of the Japanese company Rohm, is included as a North American company. On the other hand, revenue for Signetics is included under Philips, a European company. The total for North American companies, therefore, is not the same as for North American semiconductor production.

Merchant versus Captive Consumption

Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes totally captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

Hybrid Circuits

Hybrid integrated circuits, while primarily a special packaging arrangement, are included in Table 15, under Analog ICs. Only those hybrids are included that are made in the division or other organization whose primary product is semiconductors. Several major manufacturers also manufacture hybrids in other divisions; where we have identified these manufacturers, they are excluded. A split between monolithics and hybrid analog circuits is available through the client inquiry service.

Exchange Rate Conventions

Estimates of Japanese consumption or factory shipments use the exchange rate (dollar/yen) for the given year. Refer to Table 0 for the exchange rates used. In viewing the year-to-year Japanese market growth rate, one must consider the different exchange rates in effect during the year. For the European market, the value of shipments is estimated directly in dollars.

Data Sources

In both the United States and Europe, there is no official body—government organization, industry association, or trade publication—that maintains complete or even near-complete statistics on the semiconductor industry. In Japan, some statistics are kept by MITI. We believe that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data presented in the tables are as follows:

- Revenue published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons

- Government data or trade association data such as those from WSTS, MITI, and EIA
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

Need for Careful Interpretation

Construction of the tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses average exchange rates for each year and, as far as possible, the estimates are prepared in terms of local currencies before conversion to U.S. dollars or yen.

Despite the care taken in gathering and analyzing the available data and in attempting to categorize those data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in these tables. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between these data and those provided by others.

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Exchange Rates	0
Total Semiconductor	1
Total Integrated Circuit	2
Bipolar Digital	3
TTL/Other	4
ECL	5
Memory	6
Logic	7
MOS Digital	8
N/PMOS	9
CMOS	10
BiCMOS	11
Memory	12
Microcomponents	13
Logic	14
Analog	15
Total Discrete	16
Total Optoelectronic	17

Yen per U.S. Dollar Exchange Rates

Year	Exchange Rate
1987	144
1988	130
1989	138

Source: International Monetary Fund
Far Eastern Economic Review
Dataquest
May 1990

Notes to Market Share Tables

1. ABB-HAFO was formerly known as ASEA Brown Boveri.
2. ABB-IXYS was formerly the West German-based power semiconductor division of ASEA Brown Boveri.
3. Ericsson was known as Rifa prior to March 1, 1988.
4. Harris revenue includes GE Solid State revenue from 1989 onward.
5. Inmos revenue is included in SGS-Thomson revenue from 1989 onward.
6. Matra MHS was formerly known as Matra-Harris Semiconducteurs.
7. Philips revenue includes Signetics revenue.
8. Plessey revenue includes Ferranti revenue from 1987 onward.
9. SGS-Thomson revenue includes Inmos revenue from 1989 onward.
10. Thomson Composants Militaires et Spatiaux (TMS) revenue was formerly included in SGS-Thomson (30 percent) and the Other European Companies category (70 percent).
11. VQSI was formerly known as Varo.
12. Micro Quality Semiconductor was formerly known as VQSI.
13. In 1989 AT&T revenue, previously classified as MOS logic, has been reclassified as microcomponent.
14. In 1989, Rockwell revenue previously classified as MOS logic has been reclassified as analog.
15. Prior to 1989, Sanyo revenue was understated.
16. Collection of BiCMOS revenue data began in 1987.

Table 1

Worldwide Semiconductor Market
Total Semiconductor Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	38,251	50,859	57,213	100.0%	100.0%	100.0%
North American Companies	14,930	18,586	19,978	39.0%	36.5%	34.9%
Acrian	15	21	26	0	0	0
Actel	NA	NA	7	NA	NA	0
Advanced Micro Devices	986	1,084	1,100	2.6%	2.1%	1.9%
Altera	21	37	59	0.1%	0.1%	0.1%
Analog Devices	292	360	357	0.8%	0.7%	0.6%
Applied Micro Circuits Corp.	27	28	22	0.1%	0.1%	0
AT&T	802	859	873	2.1%	1.7%	1.5%
Atmel	NA	NA	94	NA	NA	0.2%
Bipolar Integrated Technology	2	6	1	0	0	0
Brooktree	NA	NA	52	NA	NA	0.1%
Burr-Brown	120	144	141	0.3%	0.3%	0.2%
California Micro Devices	24	28	30	0.1%	0.1%	0.1%
Catalyst	2	5	31	0	0	0.1%
Cherry Semiconductor	29	33	32	0.1%	0.1%	0.1%
Chips & Technologies	112	160	240	0.3%	0.3%	0.4%
Cirrus Logic	NA	NA	29	NA	NA	0.1%
Comlinear	NA	NA	10	NA	NA	0
Crystal	NA	NA	12	NA	NA	0
Cypress Semiconductor	76	135	196	0.2%	0.3%	0.3%
Elantec	NA	NA	12	NA	NA	0
Exar	44	47	49	0.1%	0.1%	0.1%
General Electric	520	555	0	1.4%	1.1%	0
General Instrument	160	164	170	0.4%	0.3%	0.3%
Gennum	NA	NA	20	NA	NA	0
Gould AMI	85	101	117	0.2%	0.2%	0.2%
GTE Microcircuits	24	0	0	0.1%	0	0
Harris	275	329	830	0.7%	0.6%	1.5%
Hewlett-Packard	243	270	269	0.6%	0.5%	0.5%
Holt	9	9	9	0	0	0
Honeywell	187	182	56	0.5%	0.4%	0.1%
Hughes	43	47	37	0.1%	0.1%	0.1%
IC Sensors	NA	NA	7	NA	NA	0
IMI	13	15	15	0	0	0
Inova	NA	NA	21	NA	NA	0
Integrated CMOS Systems	NA	NA	11	NA	NA	0

(Continued)

Table 1 (Continued)
Worldwide Semiconductor Market
Total Semiconductor Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Integrated Device Technology	98	171	204	0.3%	0.3%	0.4%
Intel	1,491	2,350	2,430	3.9%	4.6%	4.2%
International CMOS Technology	NA	NA	9	NA	NA	0
Int'l. Microelectronic Prod.	42	47	53	0.1%	0.1%	0.1%
International Rectifier	151	192	190	0.4%	0.4%	0.3%
ITT	357	360	390	0.9%	0.7%	0.7%
Kulite	NA	NA	25	NA	NA	0
Lattice	13	22	31	0	0	0.1%
Linear Technology	43	59	70	0.1%	0.1%	0.1%
LSI Logic	262	375	512	0.7%	0.7%	0.9%
Macronix	NA	NA	31	NA	NA	0.1%
Maxim	22	35	43	0.1%	0.1%	0.1%
Micro Linear	12	24	28	0	0	0
Micro Power Systems	23	26	21	0.1%	0.1%	0
Micro Quality Semiconductor	0	0	2	0	0	0
Microchip Technology	89	111	124	0.2%	0.2%	0.2%
Micron Technology	115	331	395	0.3%	0.7%	0.7%
Mitel	39	43	54	0.1%	0.1%	0.1%
MOSel	1	12	20	0	0	0
Motorola	2,434	3,035	3,319	6.4%	6.0%	5.8%
National Semiconductor	1,506	1,650	1,618	3.9%	3.2%	2.8%
NCR	116	132	120	0.3%	0.3%	0.2%
Optek	NA	NA	77	NA	NA	0.1%
Performance Semiconductor	NA	NA	32	NA	NA	0.1%
Powerex	106	115	105	0.3%	0.2%	0.2%
Precision Monolithics	78	85	88	0.2%	0.2%	0.2%
Quality Technologies	NA	40	38	NA	0.1%	0.1%
Raytheon	89	99	96	0.2%	0.2%	0.2%
Rockwell	172	174	165	0.4%	0.3%	0.3%
Saratoga Semiconductor	4	10	10	0	0	0
SEEQ Technology	50	60	53	0.1%	0.1%	0.1%
Sierra Semiconductor	24	47	55	0.1%	0.1%	0.1%
Silicon General	25	35	36	0.1%	0.1%	0.1%
Silicon Systems	88	125	112	0.2%	0.2%	0.2%
Siliconix	115	131	121	0.3%	0.3%	0.2%
Sipex	NA	NA	22	NA	NA	0
Solitron	47	46	37	0.1%	0.1%	0.1%
Sprague	109	120	137	0.3%	0.2%	0.2%

(Continued)

Table 1 (Continued)

Worldwide Semiconductor Market
Total Semiconductor Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Standard Microsystems	41	41	42	0.1%	0.1%	0.1%
Supertex	19	21	23	0	0	0
Teledyne	33	35	23	0.1%	0.1%	0
Texas Instruments	2,127	2,741	2,787	5.6%	5.4%	4.9%
TRW	117	61	27	0.3%	0.1%	0
Unitrode	69	113	109	0.2%	0.2%	0.2%
Universal	8	10	13	0	0	0
Vitelic	10	40	66	0	0.1%	0.1%
VLSI Technology	172	221	286	0.4%	0.4%	0.5%
VQSI	21	21	0	0.1%	0	0
VTC Inc.	44	46	44	0.1%	0.1%	0.1%
WaferScale Integration	20	35	35	0.1%	0.1%	0.1%
Weitek	21	35	49	0.1%	0.1%	0.1%
Western Digital	70	100	135	0.2%	0.2%	0.2%
Xicor	63	90	90	0.2%	0.2%	0.2%
Xilinx	11	27	44	0	0.1%	0.1%
Zilog	75	90	99	0.2%	0.2%	0.2%
ZyMOS	26	27	37	0.1%	0.1%	0.1%
Other North American Companies	151	151	261	0.4%	0.3%	0.5%
Japanese Companies	18,450	25,942	29,809	48.2%	51.0%	52.1%
Fuji Electric	252	346	362	0.7%	0.7%	0.6%
Fujitsu	1,801	2,607	2,963	4.7%	5.1%	5.2%
Hitachi	2,618	3,506	3,974	6.8%	6.9%	6.9%
Matsushita	1,457	1,883	1,882	3.8%	3.7%	3.3%
Mitsubishi	1,492	2,312	2,579	3.9%	4.5%	4.5%
NEC	3,368	4,543	5,015	8.8%	8.9%	8.8%
New JRC	130	169	171	0.3%	0.3%	0.3%
NMB Semiconductor	104	199	247	0.3%	0.4%	0.4%
Oki Semiconductor	651	947	1,154	1.7%	1.9%	2.0%
Ricoh	65	85	91	0.2%	0.2%	0.2%
Rohm	518	721	740	1.4%	1.4%	1.3%
Sanken	294	383	387	0.8%	0.8%	0.7%
Sanyo	851	1,083	1,365	2.2%	2.1%	2.4%
Seiko-Epson	245	311	368	0.6%	0.6%	0.6%
Sharp	590	1,036	1,230	1.5%	2.0%	2.1%
Sony	571	950	1,077	1.5%	1.9%	1.9%

(Continued)

Table 1 (Continued)

Worldwide Semiconductor Market
Total Semiconductor Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies (Continued)						
Toshiba	3,029	4,395	4,930	7.9%	8.6%	8.6%
Yamaha	116	151	143	0.3%	0.3%	0.2%
Other Japanese Companies	298	315	1,131	0.8%	0.6%	2.0%
European Companies	4,200	4,917	5,443	11.0%	9.7%	9.5%
ABB-HAFO	103	113	37	0.3%	0.2%	0.1%
ABB-IXYS	0	0	50	0	0	0.1%
Austria Mikro Systeme	32	44	56	0.1%	0.1%	0.1%
Ericsson	41	52	54	0.1%	0.1%	0.1%
European Silicon Structures	7	13	18	0	0	0
Eurosil	25	29	30	0.1%	0.1%	0.1%
Fagor	NA	27	29	NA	0.1%	0.1%
Inmos	91	110	0	0.2%	0.2%	0
Matra MHS	48	71	85	0.1%	0.1%	0.1%
MEDL	47	51	60	0.1%	0.1%	0.1%
Mietec	32	42	52	0.1%	0.1%	0.1%
Philips	1,602	1,738	1,716	4.2%	3.4%	3.0%
Plessey	222	284	240	0.6%	0.6%	0.4%
Semikron	79	91	95	0.2%	0.2%	0.2%
SGS-Thomson	859	1,087	1,301	2.2%	2.1%	2.3%
Siemens	657	784	1,194	1.7%	1.5%	2.1%
STC	12	22	19	0	0	0
TAG	21	23	22	0.1%	0	0
Telefunken Electronic	273	289	299	0.7%	0.6%	0.5%
TMS	NA	NA	45	NA	NA	0.1%
Other European Companies	49	47	41	0.1%	0.1%	0.1%
Asia/Pacific Companies	671	1,414	1,983	1.8%	2.8%	3.5%
Daewoo	1	7	10	0	0	0
ERSO	30	0	0	0.1%	0	0
Hyundai	30	106	210	0.1%	0.2%	0.4%
Korean Electronic Co.	78	95	105	0.2%	0.2%	0.2%
Samsung	328	905	1,260	0.9%	1.8%	2.2%
United Microelectronics	91	106	210	0.2%	0.2%	0.4%
Other Asia/Pacific Companies	44	58	40	0.1%	0.1%	0.1%

NA = Not available

Source: Dataquest
May 1990

Table 2

Worldwide Semiconductor Market
Total Integrated Circuit Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	29,887	41,068	46,924	100.0%	100.0%	100.0%
North American Companies	12,496	15,990	17,400	41.8%	38.9%	37.1%
Actel	NA	NA	7	NA	NA	0
Advanced Micro Devices	986	1,084	1,100	3.3%	2.6%	2.3%
Altera	21	37	59	0.1%	0.1%	0.1%
Analog Devices	292	360	357	1.0%	0.9%	0.8%
Applied Micro Circuits Corp.	27	28	22	0.1%	0.1%	0
AT&T	595	688	716	2.0%	1.7%	1.5%
Atmel	NA	NA	94	NA	NA	0.2%
Bipolar Integrated Technology	2	6	1	0	0	0
Brooktree	NA	NA	52	NA	NA	0.1%
Burr-Brown	120	144	141	0.4%	0.4%	0.3%
California Micro Devices	24	28	30	0.1%	0.1%	0.1%
Catalyst	2	5	31	0	0	0.1%
Cherry Semiconductor	29	33	32	0.1%	0.1%	0.1%
Chips & Technologies	112	160	240	0.4%	0.4%	0.5%
Cirrus Logic	NA	NA	29	NA	NA	0.1%
Comlinear	NA	NA	10	NA	NA	0
Crystal	NA	NA	12	NA	NA	0
Cypress Semiconductor	76	135	196	0.3%	0.3%	0.4%
Elantec	NA	NA	12	NA	NA	0
Exar	44	47	49	0.1%	0.1%	0.1%
General Electric	358	389	0	1.2%	0.9%	0
Gennum	NA	NA	20	NA	NA	0
Gould AMI	85	101	117	0.3%	0.2%	0.2%
GTE Microcircuits	24	0	0	0.1%	0	0
Harris	275	329	692	0.9%	0.8%	1.5%
Holt	9	9	9	0	0	0
Honeywell	147	142	25	0.5%	0.3%	0.1%
Hughes	43	47	37	0.1%	0.1%	0.1%
IC Sensors	NA	NA	7	NA	NA	0
IMI	13	15	15	0	0	0
Inova	NA	NA	21	NA	NA	0
Integrated CMOS Systems	NA	NA	11	NA	NA	0
Integrated Device Technology	98	171	204	0.3%	0.4%	0.4%
Intel	1,491	2,350	2,430	5.0%	5.7%	5.2%
International CMOS Technology	NA	NA	9	NA	NA	0

(Continued)

Table 2 (Continued)

Worldwide Semiconductor Market
Total Integrated Circuit Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Int'l. Microelectronic Prod.	42	47	53	0.1%	0.1%	0.1%
International Rectifier	0	0	3	0	0	0
ITT	197	214	235	0.7%	0.5%	0.5%
Kulite	NA	NA	25	NA	NA	0.1%
Lattice	13	22	31	0	0.1%	0.1%
Linear Technology	43	59	70	0.1%	0.1%	0.1%
LSI Logic	262	375	512	0.9%	0.9%	1.1%
Macronix	NA	NA	31	NA	NA	0.1%
Maxim	22	35	43	0.1%	0.1%	0.1%
Micro Linear	12	24	28	0	0.1%	0.1%
Micro Power Systems	23	26	21	0.1%	0.1%	0
Microchip Technology	89	111	124	0.3%	0.3%	0.3%
Micron Technology	115	331	395	0.4%	0.8%	0.8%
Mitel	39	43	54	0.1%	0.1%	0.1%
MOSel	1	12	20	0	0	0
Motorola	1,758	2,259	2,519	5.9%	5.5%	5.4%
National Semiconductor	1,431	1,575	1,548	4.8%	3.8%	3.3%
NCR	116	132	120	0.4%	0.3%	0.3%
Performance Semiconductor	NA	NA	32	NA	NA	0.1%
Precision Monolithics	78	85	88	0.3%	0.2%	0.2%
Raytheon	77	84	82	0.3%	0.2%	0.2%
Rockwell	172	174	165	0.6%	0.4%	0.4%
Saratoga Semiconductor	4	10	10	0	0	0
SEEQ Technology	50	60	53	0.2%	0.1%	0.1%
Sierra Semiconductor	24	47	55	0.1%	0.1%	0.1%
Silicon General	25	35	36	0.1%	0.1%	0.1%
Silicon Systems	88	125	112	0.3%	0.3%	0.2%
Siliconix	70	70	54	0.2%	0.2%	0.1%
Sipex	NA	NA	22	NA	NA	0
Solitron	13	13	10	0	0	0
Sprague	92	102	114	0.3%	0.2%	0.2%
Standard Microsystems	41	41	42	0.1%	0.1%	0.1%
Supertex	10	11	15	0	0	0
Teledyne	33	35	23	0.1%	0.1%	0
Texas Instruments	2,024	2,637	2,691	6.8%	6.4%	5.7%
TRW	25	25	27	0.1%	0.1%	0.1%
Unitrode	23	51	50	0.1%	0.1%	0.1%

(Continued)

Table 2 (Continued)

Worldwide Semiconductor Market
Total Integrated Circuit Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Universal	8	10	13	0	0	0
Vitelic	10	40	66	0	0.1%	0.1%
VLSI Technology	172	221	286	0.6%	0.5%	0.6%
VTC Inc.	44	46	44	0.1%	0.1%	0.1%
WaferScale Integration	20	35	35	0.1%	0.1%	0.1%
Weitek	21	35	49	0.1%	0.1%	0.1%
Western Digital	70	100	135	0.2%	0.2%	0.3%
Xicor	63	90	90	0.2%	0.2%	0.2%
Xilinx	11	27	44	0	0.1%	0.1%
Zilog	75	90	99	0.3%	0.2%	0.2%
ZyMOS	26	27	37	0.1%	0.1%	0.1%
Other North American Companies	91	91	202	0.3%	0.2%	0.4%
Japanese Companies	13,981	20,375	23,800	46.8%	49.6%	50.7%
Fuji Electric	42	64	74	0.1%	0.2%	0.2%
Fujitsu	1,660	2,420	2,738	5.6%	5.9%	5.8%
Hitachi	1,946	2,729	3,218	6.5%	6.6%	6.9%
Matsushita	994	1,328	1,244	3.3%	3.2%	2.7%
Mitsubishi	1,239	1,975	2,185	4.1%	4.8%	4.7%
NEC	2,795	3,884	4,321	9.4%	9.5%	9.2%
New JRC	109	146	154	0.4%	0.4%	0.3%
NMB Semiconductor	104	199	247	0.3%	0.5%	0.5%
Oki Semiconductor	619	902	1,111	2.1%	2.2%	2.4%
Ricoh	65	85	91	0.2%	0.2%	0.2%
Rohm	248	325	343	0.8%	0.8%	0.7%
Sanken	119	157	156	0.4%	0.4%	0.3%
Sanyo	556	811	975	1.9%	2.0%	2.1%
Seiko-Epson	245	311	368	0.8%	0.8%	0.8%
Sharp	367	751	902	1.2%	1.8%	1.9%
Sony	361	621	732	1.2%	1.5%	1.6%
Toshiba	2,194	3,316	3,774	7.3%	8.1%	8.0%
Yamaha	116	151	143	0.4%	0.4%	0.3%
Other Japanese Companies	202	200	1,024	0.7%	0.5%	2.2%
European Companies	2,845	3,429	3,915	9.5%	8.3%	8.3%
ABB-HAFO	26	28	23	0.1%	0.1%	0
Austria Mikro Systeme	32	44	56	0.1%	0.1%	0.1%

(Continued)

Table 2 (Continued)

Worldwide Semiconductor Market
Total Integrated Circuit Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies (Continued)						
Ericsson	39	52	54	0.1%	0.1%	0.1%
European Silicon Structures	7	13	18	0	0	0
Eurosil	25	29	30	0.1%	0.1%	0.1%
Inmos	91	110	0	0.3%	0.3%	0
Matra MHS	48	71	85	0.2%	0.2%	0.2%
MEDL	27	29	39	0.1%	0.1%	0.1%
Mietec	32	42	52	0.1%	0.1%	0.1%
Philips	1,186	1,281	1,250	4.0%	3.1%	2.7%
Plessey	183	237	240	0.6%	0.6%	0.5%
SGS-Thomson	646	833	1,019	2.2%	2.0%	2.2%
Siemens	354	483	847	1.2%	1.2%	1.8%
STC	12	21	17	0	0.1%	0
Telefunken Electronic	110	124	126	0.4%	0.3%	0.3%
TMS	NA	NA	33	NA	NA	0.1%
Other European Companies	27	32	26	0.1%	0.1%	0.1%
	565	1,274	1,809	1.9%	3.1%	3.9%
Asia/Pacific Companies						
Daewoo	1	7	10	0	0	0
ERSO	30	0	0	0.1%	0	0
Goldstar	68	136	147	0.2%	0.3%	0.3%
Hyundai	30	106	210	0.1%	0.3%	0.4%
Korean Electronic Co.	20	25	24	0.1%	0.1%	0.1%
Samsung	291	850	1,182	1.0%	2.1%	2.5%
United Microelectronics	91	106	210	0.3%	0.3%	0.4%
Other Asia/Pacific Companies	34	44	26	0.1%	0.1%	0.1%

NA = Not available

Source: Dataquest
May 1990

Table 3

Worldwide Semiconductor Market
Bipolar Digital Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	4,760	5,200	4,510	100.0%	100.0%	100.0%
North American Companies	2,589	2,761	2,221	54.4%	53.1%	49.2%
Advanced Micro Devices	500	536	474	10.5%	10.3%	10.5%
Applied Micro Circuits Corp.	27	27	20	0.6%	0.5%	0.4%
AT&T	79	61	56	1.7%	1.2%	1.2%
Atmel	NA	NA	8	NA	NA	0.2%
Bipolar Integrated Technology	2	6	1	0	0.1%	0
Chips & Technologies	25	30	24	0.5%	0.6%	0.5%
Harris	30	62	50	0.6%	1.2%	1.1%
Honeywell	44	27	0	0.9%	0.5%	0
Intel	18	22	10	0.4%	0.4%	0.2%
Motorola	429	435	369	9.0%	8.4%	8.2%
National Semiconductor	521	550	458	10.9%	10.6%	10.2%
Raytheon	51	55	55	1.1%	1.1%	1.2%
Teledyne	1	2	3	0	0	0.1%
Texas Instruments	854	940	671	17.9%	18.1%	14.9%
TRW	0	0	7	0	0	0.2%
Other North American Companies	8	8	15	0.2%	0.2%	0.3%
Japanese Companies	1,540	1,791	1,755	32.4%	34.4%	38.9%
Fujitsu	495	653	617	10.4%	12.6%	13.7%
Hitachi	463	501	479	9.7%	9.6%	10.6%
Matsushita	26	30	14	0.5%	0.6%	0.3%
Mitsubishi	122	127	125	2.6%	2.4%	2.8%
NEC	247	292	302	5.2%	5.6%	6.7%
New JRC	1	1	1	0	0	0
Oki Semiconductor	32	38	48	0.7%	0.7%	1.1%
Sanyo	29	41	67	0.6%	0.8%	1.5%
Toshiba	125	108	102	2.6%	2.1%	2.3%
European Companies	594	598	502	12.5%	11.5%	11.1%
Ericsson	12	0	0	0.3%	0	0
Matra MHS	3	0	0	0.1%	0	0
Philips	405	413	306	8.5%	7.9%	6.8%
Plessey	68	94	122	1.4%	1.8%	2.7%
SGS-Thomson	20	20	7	0.4%	0.4%	0.2%
Siemens	63	36	54	1.3%	0.7%	1.2%

(Continued)

Table 3 (Continued)

Worldwide Semiconductor Market
Bipolar Digital Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies (Continued)						
STC	0	7	4	0	0.1%	0.1%
Telefunken Electronic	15	19	5	0.3%	0.4%	0.1%
Other European Companies	8	9	4	0.2%	0.2%	0.1%
	37	50	32	0.8%	1.0%	0.7%
Asia/Pacific Companies						
Goldstar	22	32	32	0.5%	0.6%	0.7%
Other Asia/Pacific Companies	15	18	0	0.3%	0.3%	0

NA = Not available

Source: Dataquest
May 1990

Table 4

Worldwide Semiconductor Market
TTL/Other Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	3,791	4,071	3,402	100.0%	100.0%	100.0%
North American Companies	2,230	2,359	1,791	58.8%	57.9%	52.6%
Advanced Micro Devices	495	524	401	13.1%	12.9%	11.8%
AT&T	62	48	44	1.6%	1.2%	1.3%
Chips & Technologies	25	30	24	0.7%	0.7%	0.7%
Harris	30	62	50	0.8%	1.5%	1.5%
Intel	18	22	10	0.5%	0.5%	0.3%
Motorola	250	233	184	6.6%	5.7%	5.4%
National Semiconductor	449	450	357	11.8%	11.1%	10.5%
Raytheon	46	48	47	1.2%	1.2%	1.4%
Teledyne	1	2	3	0	0	0.1%
Texas Instruments	854	940	671	22.5%	23.1%	19.7%
Japanese Companies	1,075	1,208	1,176	28.4%	29.7%	34.6%
Fujitsu	233	317	294	6.1%	7.8%	8.6%
Hitachi	356	376	357	9.4%	9.2%	10.5%
Matsushita	19	21	10	0.5%	0.5%	0.3%
Mitsubishi	122	127	125	3.2%	3.1%	3.7%
NEC	160	184	195	4.2%	4.5%	5.7%
New JRC	1	1	1	0	0	0
NMB Semiconductor	1	1	0	0	0	0
Oki Semiconductor	29	35	43	0.8%	0.9%	1.3%
Sanyo	29	41	67	0.8%	1.0%	2.0%
Toshiba	125	105	84	3.3%	2.6%	2.5%
European Companies	451	454	403	11.9%	11.2%	11.8%
Ericsson	12	0	0	0.3%	0	0
Matra MHS	3	0	0	0.1%	0	0
Philips	380	393	290	10.0%	9.7%	8.5%
Plessey	5	8	82	0.1%	0.2%	2.4%
SGS-Thomson	19	20	7	0.5%	0.5%	0.2%
Siemens	11	8	16	0.3%	0.2%	0.5%
Telefunken Electronic	15	19	5	0.4%	0.5%	0.1%
Other European Companies	6	6	3	0.2%	0.1%	0.1%
Asia/Pacific Companies	35	50	32	0.9%	1.2%	0.9%
Goldstar	20	32	32	0.5%	0.8%	0.9%
Other Asia/Pacific Companies	15	18	0	0.4%	0.4%	0

Source: Dataquest
May 1990

Table 5

Worldwide Semiconductor Market
ECL Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	970	1,130	1,108	100.0%	100.0%	100.0%
North American Companies	359	402	430	37.0%	35.6%	38.8%
Advanced Micro Devices	5	12	73	0.5%	1.1%	6.6%
Applied Micro Circuits Corp.	27	27	20	2.8%	2.4%	1.8%
AT&T	17	13	12	1.8%	1.2%	1.1%
Atmel	NA	NA	8	NA	NA	0.7%
Bipolar Integrated Technology	2	6	1	0.2%	0.5%	0.1%
Honeywell	44	27	0	4.5%	2.4%	0
Motorola	179	202	185	18.5%	17.9%	16.7%
National Semiconductor	72	100	101	7.4%	8.8%	9.1%
Raytheon	5	7	8	0.5%	0.6%	0.7%
TRW	0	0	7	0	0	0.6%
Other North American Companies	8	8	15	0.8%	0.7%	1.4%
Japanese Companies	466	584	579	48.0%	51.7%	52.3%
Fujitsu	262	336	323	27.0%	29.7%	29.2%
Hitachi	107	125	122	11.0%	11.1%	11.0%
Matsushita	7	9	4	0.7%	0.8%	0.4%
NEC	87	108	107	9.0%	9.6%	9.7%
Oki Semiconductor	3	3	5	0.3%	0.3%	0.5%
Toshiba	0	3	18	0	0.3%	1.6%
European Companies	143	144	99	14.7%	12.7%	8.9%
Philips	25	20	16	2.6%	1.8%	1.4%
Plessey	63	86	40	6.5%	7.6%	3.6%
SGS-Thomson	1	0	0	0.1%	0	0
Siemens	52	28	38	5.4%	2.5%	3.4%
STC	0	7	4	0	0.6%	0.4%
Other European Companies	2	3	1	0.2%	0.3%	0.1%
Asia/Pacific Companies	2	0	0	0.2%	0	0
Goldstar	2	0	0	0.2%	0	0

NA = Not available

Source: Dataquest
May 1990

Table 6

Worldwide Semiconductor Market
Bipolar Digital Memory Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	621	689	540	100.0%	100.0%	100.0%
North American Companies	246	213	167	39.6%	30.9%	30.9%
Advanced Micro Devices	120	104	85	19.3%	15.1%	15.7%
AT&T	1	0	0	0.2%	0	0
Harris	6	3	0	1.0%	0.4%	0
Motorola	10	7	4	1.6%	1.0%	0.7%
National Semiconductor	45	35	56	7.2%	5.1%	10.4%
Raytheon	14	14	12	2.3%	2.0%	2.2%
Texas Instruments	50	50	10	8.1%	7.3%	1.9%
Japanese Companies	306	417	326	49.3%	60.5%	60.4%
Fujitsu	178	254	190	28.7%	36.9%	35.2%
Hitachi	95	119	111	15.3%	17.3%	20.6%
NEC	33	44	25	5.3%	6.4%	4.6%
European Companies	69	59	47	11.1%	8.6%	8.7%
Matra MHS	3	0	0	0.5%	0	0
Philips	61	58	47	9.8%	8.4%	8.7%
Siemens	4	0	0	0.6%	0	0
Other European Companies	1	1	0	0.2%	0.1%	0

Source: Dataquest
May 1990

Table 7

Worldwide Semiconductor Market
Bipolar Digital Logic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	4,139	4,511	3,970	100.0%	100.0%	100.0%
North American Companies	2,343	2,548	2,054	56.6%	56.5%	51.7%
Advanced Micro Devices	380	432	389	9.2%	9.6%	9.8%
Applied Micro Circuits Corp.	27	27	20	0.7%	0.6%	0.5%
AT&T	78	61	56	1.9%	1.4%	1.4%
Atmel	NA	NA	8	NA	NA	0.2%
Bipolar Integrated Technology	2	6	1	0	0.1%	0
Chips & Technologies	25	30	24	0.6%	0.7%	0.6%
Harris	24	59	50	0.6%	1.3%	1.3%
Honeywell	44	27	0	1.1%	0.6%	0
Intel	18	22	10	0.4%	0.5%	0.3%
Motorola	419	428	365	10.1%	9.5%	9.2%
National Semiconductor	476	515	402	11.5%	11.4%	10.1%
Raytheon	37	41	43	0.9%	0.9%	1.1%
Teledyne	1	2	3	0	0	0.1%
Texas Instruments	804	890	661	19.4%	19.7%	16.6%
TRW	0	0	7	0	0	0.2%
Other North American Companies	8	8	15	0.2%	0.2%	0.4%
Japanese Companies	1,234	1,374	1,429	29.8%	30.5%	36.0%
Fujitsu	317	399	427	7.7%	8.8%	10.8%
Hitachi	368	382	368	8.9%	8.5%	9.3%
Matsushita	26	30	14	0.6%	0.7%	0.4%
Mitsubishi	122	127	125	2.9%	2.8%	3.1%
NEC	214	248	277	5.2%	5.5%	7.0%
New JRC	1	1	1	0	0	0
Oki Semiconductor	32	38	48	0.8%	0.8%	1.2%
Sanyo	29	41	67	0.7%	0.9%	1.7%
Toshiba	125	108	102	3.0%	2.4%	2.6%
European Companies	525	539	455	12.7%	11.9%	11.5%
Ericsson	12	0	0	0.3%	0	0
Philips	344	355	259	8.3%	7.9%	6.5%
Plessey	68	94	122	1.6%	2.1%	3.1%
SGS-Thomson	20	20	7	0.5%	0.4%	0.2%
Siemens	59	36	54	1.4%	0.8%	1.4%

(Continued)

Table 7 (Continued)

Worldwide Semiconductor Market
Bipolar Digital Logic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies (Continued)						
STC	0	7	4	0	0.2%	0.1%
Telefunken Electronic	15	19	5	0.4%	0.4%	0.1%
Other European Companies	7	8	4	0.2%	0.2%	0.1%
	37	50	32	0.9%	1.1%	0.8%
Asia/Pacific Companies						
Goldstar	22	32	32	0.5%	0.7%	0.8%
Other Asia/Pacific Companies	15	18	0	0.4%	0.4%	0

NA = Not available

Source: Dataquest
May 1990

Table 8

Worldwide Semiconductor Market
MOS Digital Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	17,473	26,988	33,024	100.0%	100.0%	100.0%
North American Companies	6,880	9,754	11,277	39.4%	36.1%	34.1%
Actel	NA	NA	7	NA	NA	0
Advanced Micro Devices	414	482	549	2.4%	1.8%	1.7%
Altera	21	37	59	0.1%	0.1%	0.2%
Analog Devices	12	20	20	0.1%	0.1%	0.1%
Applied Micro Circuits Corp.	0	1	2	0	0	0
AT&T	300	380	411	1.7%	1.4%	1.2%
Atmel	NA	NA	73	NA	NA	0.2%
California Micro Devices	4	5	8	0	0	0
Catalyst	2	5	31	0	0	0.1%
Chips & Technologies	87	130	216	0.5%	0.5%	0.7%
Cirrus Logic	NA	NA	29	NA	NA	0.1%
Cypress Semiconductor	76	135	196	0.4%	0.5%	0.6%
Exar	6	7	3	0	0	0
General Electric	233	269	0	1.3%	1.0%	0
Gould AMI	85	101	101	0.5%	0.4%	0.3%
GTE Microcircuits	4	0	0	0	0	0
Harris	106	121	362	0.6%	0.4%	1.1%
Honeywell	77	88	4	0.4%	0.3%	0
Hughes	43	47	37	0.2%	0.2%	0.1%
IMI	13	15	15	0.1%	0.1%	0
Inova	NA	NA	21	NA	NA	0.1%
Integrated CMOS Systems	NA	NA	11	NA	NA	0
Integrated Device Technology	98	171	203	0.6%	0.6%	0.6%
Intel	1,473	2,328	2,420	8.4%	8.6%	7.3%
International CMOS Technology	NA	NA	9	NA	NA	0
Int'l. Microelectronic Prod.	42	47	33	0.2%	0.2%	0.1%
ITT	146	150	185	0.8%	0.6%	0.6%
Lattice	13	22	31	0.1%	0.1%	0.1%
LSI Logic	262	375	512	1.5%	1.4%	1.6%
Macronix	NA	NA	31	NA	NA	0.1%
Microchip Technology	89	111	124	0.5%	0.4%	0.4%
Micron Technology	115	331	395	0.7%	1.2%	1.2%
MOSel	1	12	20	0	0	0.1%
Motorola	990	1,399	1,705	5.7%	5.2%	5.2%

(Continued)

Table 8 (Continued)

Worldwide Semiconductor Market
MOS Digital Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
National Semiconductor	415	485	532	2.4%	1.8%	1.6%
NCR	116	132	94	0.7%	0.5%	0.3%
Performance Semiconductor	NA	NA	32	NA	NA	0.1%
Raytheon	1	2	0	0	0	0
Rockwell	172	174	42	1.0%	0.6%	0.1%
Saratoga Semiconductor	4	10	10	0	0	0
SEEQ Technology	50	60	53	0.3%	0.2%	0.2%
Sierra Semiconductor	12	24	27	0.1%	0.1%	0.1%
Siliconix	7	3	0	0	0	0
Sprague	14	16	16	0.1%	0.1%	0
Standard Microsystems	41	41	42	0.2%	0.2%	0.1%
Teledyne	2	0	0	0	0	0
Texas Instruments	784	1,271	1,603	4.5%	4.7%	4.9%
TRW	7	5	5	0	0	0
Universal	6	6	9	0	0	0
Vitelic	10	40	66	0.1%	0.1%	0.2%
VLSI Technology	172	221	286	1.0%	0.8%	0.9%
VTC Inc.	17	19	17	0.1%	0.1%	0.1%
WaferScale Integration	20	35	35	0.1%	0.1%	0.1%
Weitek	21	35	49	0.1%	0.1%	0.1%
Western Digital	70	100	135	0.4%	0.4%	0.4%
Xicor	60	87	87	0.3%	0.3%	0.3%
Xilinx	11	27	44	0.1%	0.1%	0.1%
Zilog	75	90	99	0.4%	0.3%	0.3%
ZyMOS	26	27	37	0.1%	0.1%	0.1%
Other North American Companies	55	55	134	0.3%	0.2%	0.4%
Japanese Companies	8,921	14,494	18,006	51.1%	53.7%	54.5%
Fuji Electric	14	31	31	0.1%	0.1%	0.1%
Fujitsu	1,014	1,616	1,958	5.8%	6.0%	5.9%
Hitachi	1,173	1,885	2,407	6.7%	7.0%	7.3%
Matsushita	592	875	854	3.4%	3.2%	2.6%
Mitsubishi	812	1,453	1,676	4.6%	5.4%	5.1%
NEC	2,006	3,123	3,604	11.5%	11.6%	10.9%
New JRC	13	27	34	0.1%	0.1%	0.1%
NMB Semiconductor	104	199	247	0.6%	0.7%	0.7%

(Continued)

Table 8 (Continued)

Worldwide Semiconductor Market
MOS Digital Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies (Continued)						
Oki Semiconductor	566	841	1,028	3.2%	3.1%	3.1%
Ricoh	65	85	91	0.4%	0.3%	0.3%
Rohm	13	54	66	0.1%	0.2%	0.2%
Sanyo	150	299	378	0.9%	1.1%	1.1%
Seiko-Epson	231	296	354	1.3%	1.1%	1.1%
Sharp	312	682	837	1.8%	2.5%	2.5%
Sony	144	235	371	0.8%	0.9%	1.1%
Toshiba	1,593	2,639	3,100	9.1%	9.8%	9.4%
Yamaha	116	151	130	0.7%	0.6%	0.4%
Other Japanese Companies	3	3	840	0	0	2.5%
European Companies	1,250	1,684	2,135	7.2%	6.2%	6.5%
ABB-HAFO	26	28	23	0.1%	0.1%	0.1%
Austria Mikro Systeme	29	40	47	0.2%	0.1%	0.1%
Ericsson	11	6	7	0.1%	0	0
European Silicon Structures	7	13	18	0	0	0.1%
Eurosil	25	29	30	0.1%	0.1%	0.1%
Inmos	91	110	0	0.5%	0.4%	0
Matra MHS	43	71	85	0.2%	0.3%	0.3%
MEDL	27	29	35	0.2%	0.1%	0.1%
Mietec	32	42	52	0.2%	0.2%	0.2%
Philips	342	402	422	2.0%	1.5%	1.3%
Plessey	51	76	83	0.3%	0.3%	0.3%
SGS-Thomson	344	461	619	2.0%	1.7%	1.9%
Siemens	171	327	641	1.0%	1.2%	1.9%
STC	12	10	8	0.1%	0	0
Telefunken Electronic	23	20	20	0.1%	0.1%	0.1%
TMS	NA	NA	26	NA	NA	0.1%
Other European Companies	16	20	19	0.1%	0.1%	0.1%
Asia/Pacific Companies	422	1,056	1,606	2.4%	3.9%	4.9%
ERSO	29	0	0	0.2%	0	0
Goldstar	20	63	106	0.1%	0.2%	0.3%
Hyundai	30	106	210	0.2%	0.4%	0.6%
Samsung	242	765	1,066	1.4%	2.8%	3.2%
United Microelectronics	91	106	210	0.5%	0.4%	0.6%
Other Asia/Pacific Companies	10	14	14	0.1%	0.1%	0

NA = Not available

Source: Dataquest
May 1990

Table 9

Worldwide Semiconductor Market
N/PMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	8,482	10,196	10,843	100.0%	100.0%	100.0%
North American Companies	3,289	3,997	3,766	38.8%	39.2%	34.7%
Advanced Micro Devices	389	407	327	4.6%	4.0%	3.0%
AT&T	40	52	56	0.5%	0.5%	0.5%
Gould AMI	21	25	101	0.2%	0.2%	0.9%
Harris	15	2	13	0.2%	0	0.1%
Hughes	2	1	1	0	0	0
Intel	1,122	1,251	1,276	13.2%	12.3%	11.8%
Int'l. Microelectronic Prod.	3	4	5	0	0	0
ITT	81	80	80	1.0%	0.8%	0.7%
Macronix	NA	NA	31	NA	NA	0.3%
Microchip Technology	64	68	55	0.8%	0.7%	0.5%
Micron Technology	115	253	298	1.4%	2.5%	2.7%
Motorola	337	450	212	4.0%	4.4%	2.0%
National Semiconductor	90	126	55	1.1%	1.2%	0.5%
NCR	50	57	14	0.6%	0.6%	0.1%
Rockwell	132	136	42	1.6%	1.3%	0.4%
SEEQ Technology	33	34	11	0.4%	0.3%	0.1%
Sprague	7	7	4	0.1%	0.1%	0
Standard Microsystems	36	34	10	0.4%	0.3%	0.1%
Texas Instruments	604	845	1,048	7.1%	8.3%	9.7%
VLSI Technology	25	15	0	0.3%	0.1%	0
Xicor	57	77	68	0.7%	0.8%	0.6%
Zilog	61	68	55	0.7%	0.7%	0.5%
Other North American Companies	5	5	4	0.1%	0	0
Japanese Companies	4,403	5,120	5,886	51.9%	50.2%	54.3%
Fujitsu	735	535	606	8.7%	5.2%	5.6%
Hitachi	471	721	800	5.6%	7.1%	7.4%
Matsushita	312	371	333	3.7%	3.6%	3.1%
Mitsubishi	613	808	908	7.2%	7.9%	8.4%
NEC	1,327	1,140	1,202	15.6%	11.2%	11.1%
Oki Semiconductor	199	304	341	2.3%	3.0%	3.1%
Ricoh	39	40	37	0.5%	0.4%	0.3%
Rohm	0	1	1	0	0	0
Sanyo	37	63	26	0.4%	0.6%	0.2%

(Continued)

Table 9 (Continued)

Worldwide Semiconductor Market
N/PMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies (Continued)						
Sharp	93	187	212	1.1%	1.8%	2.0%
Sony	30	42	52	0.4%	0.4%	0.5%
Toshiba	522	875	926	6.2%	8.6%	8.5%
Yamaha	23	31	43	0.3%	0.3%	0.4%
Other Japanese Companies	2	2	399	0	0	3.7%
	573	708	666	6.8%	6.9%	6.1%
European Companies						
Austria Mikro Systeme	6	8	11	0.1%	0.1%	0.1%
Inmos	11	5	0	0.1%	0	0
Matra MHS	2	4	0	0	0	0
Mietec	0	7	7	0	0.1%	0.1%
Philips	178	175	105	2.1%	1.7%	1.0%
Plessey	10	13	12	0.1%	0.1%	0.1%
SGS-Thomson	187	239	237	2.2%	2.3%	2.2%
Siemens	146	228	260	1.7%	2.2%	2.4%
STC	5	2	2	0.1%	0	0
Telefunken Electronic	23	20	20	0.3%	0.2%	0.2%
TMS	NA	NA	5	NA	NA	0
Other European Companies	5	7	7	0.1%	0.1%	0.1%
	217	371	525	2.6%	3.6%	4.8%
Asia/Pacific Companies						
ERSO	2	0	0	0	0	0
Goldstar	4	7	32	0	0.1%	0.3%
Hyundai	9	33	1	0.1%	0.3%	0
Samsung	173	301	422	2.0%	3.0%	3.9%
United Microelectronics	29	30	70	0.3%	0.3%	0.6%

NA = Not available

Source: Dataquest
May 1990

Table 10

Worldwide Semiconductor Market
CMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	8,938	16,584	21,449	100.0%	100.0%	100.0%
North American Companies	3,556	5,595	7,326	39.8%	33.7%	34.2%
Actel	NA	NA	7	NA	NA	0
Advanced Micro Devices	25	75	222	0.3%	0.5%	1.0%
Altera	21	37	59	0.2%	0.2%	0.3%
Analog Devices	12	20	20	0.1%	0.1%	0.1%
AT&T	260	328	355	2.9%	2.0%	1.7%
Atmel	NA	NA	73	NA	NA	0.3%
California Micro Devices	4	5	8	0	0	0
Catalyst	2	5	31	0	0	0.1%
Chips & Technologies	87	130	216	1.0%	0.8%	1.0%
Cirrus Logic	NA	NA	29	NA	NA	0.1%
Cypress Semiconductor	76	135	195	0.9%	0.8%	0.9%
Exar	6	7	3	0.1%	0	0
General Electric	227	262	0	2.5%	1.6%	0
Gould AMI	64	76	0	0.7%	0.5%	0
GTE Microcircuits	4	0	0	0	0	0
Harris	91	119	340	1.0%	0.7%	1.6%
Honeywell	77	88	4	0.9%	0.5%	0
Hughes	41	46	36	0.5%	0.3%	0.2%
IMI	13	15	15	0.1%	0.1%	0.1%
Integrated CMOS Systems	NA	NA	11	NA	NA	0.1%
Integrated Device Technology	98	171	202	1.1%	1.0%	0.9%
Intel	351	1,077	1,144	3.9%	6.5%	5.3%
International CMOS Technology	NA	NA	9	NA	NA	0
Int'l. Microelectronic Prod.	39	43	28	0.4%	0.3%	0.1%
ITT	65	70	105	0.7%	0.4%	0.5%
Lattice	13	22	31	0.1%	0.1%	0.1%
LSI Logic	262	374	507	2.9%	2.3%	2.4%
Microchip Technology	5	3	3	0.1%	0	0
Micron Technology	0	0	97	0	0	0.5%
MOSel	1	12	20	0	0.1%	0.1%
Motorola	653	949	1,490	7.3%	5.7%	6.9%
National Semiconductor	325	350	447	3.6%	2.1%	2.1%
NCR	66	75	80	0.7%	0.5%	0.4%
Performance Semiconductor	NA	NA	32	NA	NA	0.1%

(Continued)

Table 10 (Continued)

Worldwide Semiconductor Market
CMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Raytheon	1	2	0	0	0	0
Rockwell	40	38	0	0.4%	0.2%	0
SEEQ Technology	17	26	42	0.2%	0.2%	0.2%
Sierra Semiconductor	12	24	27	0.1%	0.1%	0.1%
Siliconix	7	3	0	0.1%	0	0
Sprague	7	9	4	0.1%	0.1%	0
Standard Microsystems	5	7	32	0.1%	0	0.1%
Teledyne	2	0	0	0	0	0
Texas Instruments	180	415	539	2.0%	2.5%	2.5%
TRW	7	5	5	0.1%	0	0
Universal	6	6	9	0.1%	0	0
Vitelic	10	40	66	0.1%	0.2%	0.3%
VLSI Technology	147	206	286	1.6%	1.2%	1.3%
VTC Inc.	17	19	17	0.2%	0.1%	0.1%
WaferScale Integration	20	35	35	0.2%	0.2%	0.2%
Weitek	21	35	49	0.2%	0.2%	0.2%
Western Digital	70	100	135	0.8%	0.6%	0.6%
Xicor	3	10	19	0	0.1%	0.1%
Xilinx	11	27	44	0.1%	0.2%	0.2%
Zilog	14	22	44	0.2%	0.1%	0.2%
ZyMOS	26	27	37	0.3%	0.2%	0.2%
Other North American Companies	45	45	117	0.5%	0.3%	0.5%
Japanese Companies	4,514	9,348	11,623	50.5%	56.4%	54.2%
Fuji Electric	13	30	25	0.1%	0.2%	0.1%
Fujitsu	279	1,081	1,241	3.1%	6.5%	5.8%
Hitachi	699	1,157	1,454	7.8%	7.0%	6.8%
Matsushita	280	504	521	3.1%	3.0%	2.4%
Mitsubishi	199	645	768	2.2%	3.9%	3.6%
NEC	679	1,965	2,314	7.6%	11.8%	10.8%
New JRC	13	27	34	0.1%	0.2%	0.2%
NMB Semiconductor	104	199	247	1.2%	1.2%	1.2%
Oki Semiconductor	367	537	623	4.1%	3.2%	2.9%
Ricoh	26	45	53	0.3%	0.3%	0.2%
Rohm	13	53	65	0.1%	0.3%	0.3%
Sanyo	113	236	352	1.3%	1.4%	1.6%

(Continued)

Table 10 (Continued)

Worldwide Semiconductor Market
CMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies (Continued)						
Seiko-Epson	231	296	354	2.6%	1.8%	1.7%
Sharp	219	495	625	2.5%	3.0%	2.9%
Sony	114	193	319	1.3%	1.2%	1.5%
Toshiba	1,071	1,764	2,100	12.0%	10.6%	9.8%
Yamaha	93	120	87	1.0%	0.7%	0.4%
Other Japanese Companies	1	1	441	0	0	2.1%
European Companies	663	956	1,433	7.4%	5.8%	6.7%
ABB-HAFO	26	28	23	0.3%	0.2%	0.1%
Austria Mikro Systeme	23	32	36	0.3%	0.2%	0.2%
Ericsson	11	6	7	0.1%	0	0
European Silicon Structures	7	13	18	0.1%	0.1%	0.1%
Eurosil	25	29	30	0.3%	0.2%	0.1%
Inmos	80	105	0	0.9%	0.6%	0
Matra MHS	41	67	85	0.5%	0.4%	0.4%
MEDL	27	29	35	0.3%	0.2%	0.2%
Mietec	18	17	22	0.2%	0.1%	0.1%
Philips	164	227	317	1.8%	1.4%	1.5%
Plessey	41	63	71	0.5%	0.4%	0.3%
SGS-Thomson	157	222	372	1.8%	1.3%	1.7%
Siemens	25	99	381	0.3%	0.6%	1.8%
STC	7	6	3	0.1%	0	0
TMS	NA	NA	21	NA	NA	0.1%
Other European Companies	11	13	12	0.1%	0.1%	0.1%
Asia/Pacific Companies	205	685	1,067	2.3%	4.1%	5.0%
Daewoo	0	2	0	0	0	0
ERSO	27	0	0	0.3%	0	0
Goldstar	16	56	74	0.2%	0.3%	0.3%
Hyundai	21	73	209	0.2%	0.4%	1.0%
Samsung	69	464	644	0.8%	2.8%	3.0%
United Microelectronics	62	76	140	0.7%	0.5%	0.7%
Other Asia/Pacific Companies	10	14	0	0.1%	0.1%	0

NA = Not available

Source: Dataquest
May 1990

Table 11

Worldwide Semiconductor Market
BiCMOS Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	53	208	732	100.0%	100.0%	100.0%
North American Companies	35	162	185	66.0%	77.9%	25.3%
Applied Micro Circuits Corp.	0	1	2	0	0.5%	0.3%
Cypress Semiconductor	0	0	1	0	0	0.1%
General Electric	6	7	0	11.3%	3.4%	0
Harris	0	0	9	0	0	1.2%
Inova	NA	NA	21	NA	NA	2.9%
Integrated Device Technology	0	0	1	0	0	0.1%
LSI Logic	0	1	5	0	0.5%	0.7%
Microchip Technology	20	40	66	37.7%	19.2%	9.0%
Micron Technology	0	78	0	0	37.5%	0
Motorola	0	0	3	0	0	0.4%
National Semiconductor	0	9	30	0	4.3%	4.1%
Saratoga Semiconductor	4	10	10	7.5%	4.8%	1.4%
Sprague	0	0	8	0	0	1.1%
Texas Instruments	0	11	16	0	5.3%	2.2%
Other North American Companies	5	5	13	9.4%	2.4%	1.8%
Japanese Companies	4	26	497	7.5%	12.5%	67.9%
Fuji Electric	1	1	6	1.9%	0.5%	0.8%
Fujitsu	0	0	111	0	0	15.2%
Hitachi	3	7	153	5.7%	3.4%	20.9%
NEC	0	18	88	0	8.7%	12.0%
Oki Semiconductor	0	0	64	0	0	8.7%
Ricoh	0	0	1	0	0	0.1%
Toshiba	0	0	74	0	0	10.1%
European Companies	14	20	36	26.4%	9.6%	4.9%
Mietec	14	18	23	26.4%	8.7%	3.1%
SGS-Thomson	0	0	10	0	0	1.4%
STC	0	2	3	0	1.0%	0.4%
Asia/Pacific Companies	0	0	14	0	0	1.9%
Other Asia/Pacific Companies	0	0	14	0	0	1.9%

NA = Not available

Source: Dataquest
May 1990

Table 12

Worldwide Semiconductor Market
MOS Memory Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	6,056	11,692	16,361	100.0%	100.0%	100.0%
North American Companies	1,701	2,836	3,688	28.1%	24.3%	22.5%
Advanced Micro Devices	155	207	258	2.6%	1.8%	1.6%
AT&T	25	24	13	0.4%	0.2%	0.1%
Atmel	NA	NA	47	NA	NA	0.3%
Catalyst	2	5	31	0	0	0.2%
Cypress Semiconductor	57	94	149	0.9%	0.8%	0.9%
Exar	2	3	0	0	0	0
General Electric	23	29	0	0.4%	0.2%	0
Gould AMI	8	15	25	0.1%	0.1%	0.2%
Harris	36	26	37	0.6%	0.2%	0.2%
Honeywell	5	14	2	0.1%	0.1%	0
Hughes	2	0	0	0	0	0
Inova	NA	NA	21	NA	NA	0.1%
Integrated Device Technology	85	135	158	1.4%	1.2%	1.0%
Intel	326	392	433	5.4%	3.4%	2.6%
International CMOS Technology	NA	NA	6	NA	NA	0
Int'l. Microelectronic Prod.	0	0	17	0	0	0.1%
ITT	0	0	10	0	0	0.1%
Lattice	4	2	0	0.1%	0	0
Macronix	NA	NA	31	NA	NA	0.2%
Microchip Technology	59	82	94	1.0%	0.7%	0.6%
Micron Technology	115	331	395	1.9%	2.8%	2.4%
MOSel	1	12	20	0	0.1%	0.1%
Motorola	89	236	407	1.5%	2.0%	2.5%
National Semiconductor	80	135	138	1.3%	1.2%	0.8%
NCR	6	6	8	0.1%	0.1%	0
Performance Semiconductor	NA	NA	16	NA	NA	0.1%
Saratoga Semiconductor	4	10	10	0.1%	0.1%	0.1%
SEEQ Technology	37	46	40	0.6%	0.4%	0.2%
Texas Instruments	445	834	1,095	7.3%	7.1%	6.7%
Vitelic	10	40	66	0.2%	0.3%	0.4%
VLSI Technology	23	16	23	0.4%	0.1%	0.1%
WaferScale Integration	12	25	28	0.2%	0.2%	0.2%
Xicor	60	87	87	1.0%	0.7%	0.5%
Other North American Companies	30	30	23	0.5%	0.3%	0.1%

(Continued)

Table 12 (Continued)

Worldwide Semiconductor Market
MOS Memory Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies	3,909	7,597	10,558	64.5%	65.0%	64.5%
Fujitsu	634	1,067	1,265	10.5%	9.1%	7.7%
Hitachi	576	1,114	1,534	9.5%	9.5%	9.4%
Matsushita	91	230	370	1.5%	2.0%	2.3%
Mitsubishi	492	966	1,161	8.1%	8.3%	7.1%
NEC	838	1,490	1,739	13.8%	12.7%	10.6%
NMB Semiconductor	104	199	247	1.7%	1.7%	1.5%
Oki Semiconductor	193	353	473	3.2%	3.0%	2.9%
Ricoh	18	26	31	0.3%	0.2%	0.2%
Rohm	0	8	10	0	0.1%	0.1%
Sanyo	27	87	130	0.4%	0.7%	0.8%
Seiko-Epson	71	94	141	1.2%	0.8%	0.9%
Sharp	130	344	476	2.1%	2.9%	2.9%
Sony	56	103	228	0.9%	0.9%	1.4%
Toshiba	679	1,516	1,918	11.2%	13.0%	11.7%
Other Japanese Companies	0	0	835	0	0	5.1%
European Companies	235	464	786	3.9%	4.0%	4.8%
Austria Mikro Systeme	2	4	0	0	0	0
Inmos	43	53	0	0.7%	0.5%	0
Matra MHS	13	28	31	0.2%	0.2%	0.2%
MEDL	5	5	7	0.1%	0	0
Philips	18	35	60	0.3%	0.3%	0.4%
Plessey	0	0	3	0	0	0
SGS-Thomson	95	185	269	1.6%	1.6%	1.6%
Siemens	52	150	416	0.9%	1.3%	2.5%
STC	6	2	0	0.1%	0	0
Other European Companies	1	2	0	0	0	0
Asia/Pacific Companies	211	795	1,329	3.5%	6.8%	8.1%
ERSO	5	0	0	0.1%	0	0
Goldstar	0	27	82	0	0.2%	0.5%
Hyundai	30	106	210	0.5%	0.9%	1.3%
Samsung	170	650	935	2.8%	5.6%	5.7%
United Microelectronics	6	12	102	0.1%	0.1%	0.6%

NA = Not available

Source: Dataquest
May 1990

Table 13

Worldwide Semiconductor Market
MOS Microcomponents Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	5,108	7,144	8,202	100.0%	100.0%	100.0%
North American Companies	2,663	3,872	4,526	52.1%	54.2%	55.2%
Advanced Micro Devices	178	183	172	3.5%	2.6%	2.1%
Analog Devices	12	20	20	0.2%	0.3%	0.2%
AT&T[1]	50	39	141	1.0%	0.5%	1.7%
California Micro Devices	1	1	8	0	0	0.1%
Chips & Technologies	87	130	216	1.7%	1.8%	2.6%
Cirrus Logic	NA	NA	29	NA	NA	0.4%
Cypress Semiconductor	0	7	11	0	0.1%	0.1%
General Electric	41	48	0	0.8%	0.7%	0
GTE Microcircuits	1	0	0	0	0	0
Harris	44	62	115	0.9%	0.9%	1.4%
Hughes	2	2	2	0	0	0
IMI	0	1	0	0	0	0
Integrated Device Technology	5	15	13	0.1%	0.2%	0.2%
Intel	1,087	1,835	1,929	21.3%	25.7%	23.5%
ITT	21	15	25	0.4%	0.2%	0.3%
LSI Logic	0	18	67	0	0.3%	0.8%
Microchip Technology	19	18	18	0.4%	0.3%	0.2%
Motorola	520	699	803	10.2%	9.8%	9.8%
National Semiconductor	140	150	172	2.7%	2.1%	2.1%
NCR	8	6	22	0.2%	0.1%	0.3%
Performance Semiconductor	NA	NA	13	NA	NA	0.2%
Rockwell	46	51	42	0.9%	0.7%	0.5%
Sierra Semiconductor	1	1	1	0	0	0
Standard Microsystems	36	34	34	0.7%	0.5%	0.4%
Texas Instruments	169	234	252	3.3%	3.3%	3.1%
TRW	0	0	5	0	0	0.1%
VLSI Technology	18	54	94	0.4%	0.8%	1.1%
WaferScale Integration	0	0	2	0	0	0
Weitek	21	35	49	0.4%	0.5%	0.6%
Western Digital	70	100	135	1.4%	1.4%	1.6%
Zilog	75	90	99	1.5%	1.3%	1.2%
ZyMOS	4	17	30	0.1%	0.2%	0.4%
Other North American Companies	7	7	7	0.1%	0.1%	0.1%

(Continued)

Table 13 (Continued)

Worldwide Semiconductor Market
MOS Microcomponents Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies	2,096	2,817	3,190	41.0%	39.4%	38.9%
Fujitsu	146	202	211	2.9%	2.8%	2.6%
Hitachi	402	525	554	7.9%	7.3%	6.8%
Matsushita	199	230	217	3.9%	3.2%	2.6%
Mitsubishi	267	381	435	5.2%	5.3%	5.3%
NEC	566	790	937	11.1%	11.1%	11.4%
Oki Semiconductor	101	134	149	2.0%	1.9%	1.8%
Ricoh	14	19	22	0.3%	0.3%	0.3%
Rohm	3	16	16	0.1%	0.2%	0.2%
Sanyo	53	70	70	1.0%	1.0%	0.9%
Seiko-Epson	6	12	12	0.1%	0.2%	0.1%
Sharp	34	54	112	0.7%	0.8%	1.4%
Sony	21	37	47	0.4%	0.5%	0.6%
Toshiba	283	346	407	5.5%	4.8%	5.0%
Other Japanese Companies	1	1	1	0	0	0
European Companies	310	401	433	6.1%	5.6%	5.3%
Eurosil	3	2	2	0.1%	0	0
Inmos	48	57	0	0.9%	0.8%	0
Matra MHS	19	21	28	0.4%	0.3%	0.3%
MEDL	1	1	3	0	0	0
Philips	100	114	131	2.0%	1.6%	1.6%
Plessey	0	0	3	0	0	0
SGS-Thomson	95	118	161	1.9%	1.7%	2.0%
Siemens	44	88	92	0.9%	1.2%	1.1%
TMS	NA	NA	13	NA	NA	0.2%
Asia/Pacific Companies	39	54	53	0.8%	0.8%	0.6%
ERSO	2	0	0	0	0	0
Goldstar	1	4	2	0	0.1%	0
Samsung	8	15	8	0.2%	0.2%	0.1%
United Microelectronics	28	35	43	0.5%	0.5%	0.5%

NA = Not available

[1]AT&T's 1989 revenue for microcomponents includes approximately $100 million previously classified as MOS logic. Microperipheral products consumed internally account for the bulk of this revenue. AT&T's commercial microcomponents revenue was approximately $21 million.

Source: Dataquest
May 1990

Table 14

Worldwide Semiconductor Market
MOS Logic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	6,309	8,152	8,461	100.0%	100.0%	100.0%
North American Companies	2,516	3,046	3,063	39.9%	37.4%	36.2%
Actel	NA	NA	7	NA	NA	0.1%
Advanced Micro Devices	81	92	119	1.3%	1.1%	1.4%
Altera	21	37	59	0.3%	0.5%	0.7%
Applied Micro Circuits Corp.	0	1	2	0	0	0
AT&T	225	317	257	3.6%	3.9%	3.0%
Atmel	NA	NA	26	NA	NA	0.3%
California Micro Devices	3	4	0	0	0	0
Cypress Semiconductor	19	34	36	0.3%	0.4%	0.4%
Exar	4	4	3	0.1%	0	0
General Electric	169	192	0	2.7%	2.4%	0
Gould AMI	77	86	76	1.2%	1.1%	0.9%
GTE Microcircuits	3	0	0	0	0	0
Harris	26	33	210	0.4%	0.4%	2.5%
Honeywell	72	74	2	1.1%	0.9%	0
Hughes	39	45	35	0.6%	0.6%	0.4%
IMI	13	14	15	0.2%	0.2%	0.2%
Integrated CMOS Systems	NA	NA	11	NA	NA	0.1%
Integrated Device Technology	8	21	32	0.1%	0.3%	0.4%
Intel	60	101	58	1.0%	1.2%	0.7%
International CMOS Technology	NA	NA	3	NA	NA	0
Int'l. Microelectronic Prod.	42	47	16	0.7%	0.6%	0.2%
ITT	125	135	150	2.0%	1.7%	1.8%
Lattice	9	20	31	0.1%	0.2%	0.4%
LSI Logic	262	357	445	4.2%	4.4%	5.3%
Microchip Technology	11	11	12	0.2%	0.1%	0.1%
Motorola	381	464	495	6.0%	5.7%	5.9%
National Semiconductor	195	200	222	3.1%	2.5%	2.6%
NCR	102	120	64	1.6%	1.5%	0.8%
Performance Semiconductor	NA	NA	3	NA	NA	0
Raytheon	1	2	0	0	0	0
Rockwell	126	123	0	2.0%	1.5%	0
SEEQ Technology	13	14	13	0.2%	0.2%	0.2%
Sierra Semiconductor	11	23	26	0.2%	0.3%	0.3%
Siliconix	7	3	0	0.1%	0	0

(Continued)

Table 14 (Continued)

Worldwide Semiconductor Market
MOS Logic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Sprague	14	16	16	0.2%	0.2%	0.2%
Standard Microsystems	5	7	8	0.1%	0.1%	0.1%
Teledyne	2	0	0	0	0	0
Texas Instruments	170	203	256	2.7%	2.5%	3.0%
TRW	7	5	0	0.1%	0.1%	0
Universal	6	6	9	0.1%	0.1%	0.1%
VLSI Technology	131	151	169	2.1%	1.9%	2.0%
VTC Inc.	17	19	17	0.3%	0.2%	0.2%
WaferScale Integration	8	10	5	0.1%	0.1%	0.1%
Xilinx	11	27	44	0.2%	0.3%	0.5%
ZyMOS	22	10	7	0.3%	0.1%	0.1%
Other North American Companies	18	18	104	0.3%	0.2%	1.2%
Japanese Companies	2,916	4,080	4,258	46.2%	50.0%	50.3%
Fuji Electric	14	31	31	0.2%	0.4%	0.4%
Fujitsu	234	347	482	3.7%	4.3%	5.7%
Hitachi	195	246	319	3.1%	3.0%	3.8%
Matsushita	302	415	267	4.8%	5.1%	3.2%
Mitsubishi	53	106	80	0.8%	1.3%	0.9%
NEC	602	843	928	9.5%	10.3%	11.0%
New JRC	13	27	34	0.2%	0.3%	0.4%
Oki Semiconductor	272	354	406	4.3%	4.3%	4.8%
Ricoh	33	40	38	0.5%	0.5%	0.4%
Rohm	10	30	40	0.2%	0.4%	0.5%
Sanyo	70	142	178	1.1%	1.7%	2.1%
Seiko-Epson	154	190	201	2.4%	2.3%	2.4%
Sharp	148	284	249	2.3%	3.5%	2.9%
Sony	67	95	96	1.1%	1.2%	1.1%
Toshiba	631	777	775	10.0%	9.5%	9.2%
Yamaha	116	151	130	1.8%	1.9%	1.5%
Other Japanese Companies	2	2	4	0	0	0
European Companies	705	819	916	11.2%	10.0%	10.8%
ABB-HAFO	26	28	23	0.4%	0.3%	0.3%
Austria Mikro Systeme	27	36	47	0.4%	0.4%	0.6%
Ericsson	11	6	7	0.2%	0.1%	0.1%

(Continued)

Table 14 (Continued)

Worldwide Semiconductor Market
MOS Logic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies (Continued)						
European Silicon Structures	7	13	18	0.1%	0.2%	0.2%
Eurosil	22	27	28	0.3%	0.3%	0.3%
Matra MHS	11	22	26	0.2%	0.3%	0.3%
MEDL	21	23	25	0.3%	0.3%	0.3%
Mietec	32	42	52	0.5%	0.5%	0.6%
Philips	224	253	231	3.6%	3.1%	2.7%
Plessey	51	76	77	0.8%	0.9%	0.9%
SGS-Thomson	154	158	189	2.4%	1.9%	2.2%
Siemens	75	89	133	1.2%	1.1%	1.6%
STC	6	8	8	0.1%	0.1%	0.1%
Telefunken Electronic	23	20	20	0.4%	0.2%	0.2%
TMS	NA	NA	13	NA	NA	0.2%
Other European Companies	15	18	19	0.2%	0.2%	0.2%
	172	207	224	2.7%	2.5%	2.6%
Asia/Pacific Companies						
Daewoo	0	2	0	0	0	0
ERSO	22	0	0	0.3%	0	0
Goldstar	19	32	22	0.3%	0.4%	0.3%
Samsung	64	100	123	1.0%	1.2%	1.5%
United Microelectronics	57	59	65	0.9%	0.7%	0.8%
Other Asia/Pacific Companies	10	14	14	0.2%	0.2%	0.2%

NA = Not available

Source: Dataquest
May 1990

Table 15

Worldwide Semiconductor Market
Analog Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	7,654	8,880	9,390	100.0%	100.0%	100.0%
North American Companies	3,027	3,475	3,902	39.5%	39.1%	41.6%
Advanced Micro Devices	72	66	77	0.9%	0.7%	0.8%
Analog Devices	280	340	337	3.7%	3.8%	3.6%
AT&T	216	247	249	2.8%	2.8%	2.7%
Atmel	NA	NA	13	NA	NA	0.1%
Brooktree	NA	NA	52	NA	NA	0.6%
Burr-Brown	120	144	141	1.6%	1.6%	1.5%
California Micro Devices	20	23	22	0.3%	0.3%	0.2%
Cherry Semiconductor	29	33	32	0.4%	0.4%	0.3%
Comlinear	NA	NA	10	NA	NA	0.1%
Crystal	NA	NA	12	NA	NA	0.1%
Elantec	NA	NA	12	NA	NA	0.1%
Exar	38	40	46	0.5%	0.5%	0.5%
General Electric	125	120	0	1.6%	1.4%	0
Gennum	NA	NA	20	NA	NA	0.2%
Gould AMI	0	0	16	0	0	0.2%
GTE Microcircuits	20	0	0	0.3%	0	0
Harris	139	146	280	1.8%	1.6%	3.0%
Holt	9	9	9	0.1%	0.1%	0.1%
Honeywell	26	27	21	0.3%	0.3%	0.2%
IC Sensors	NA	NA	7	NA	NA	0.1%
Integrated Device Technology	0	0	1	0	0	0
Int'l. Microelectronic Prod.	0	0	20	0	0	0.2%
International Rectifier	0	0	3	0	0	0
ITT	51	64	50	0.7%	0.7%	0.5%
Kulite	NA	NA	25	NA	NA	0.3%
Linear Technology	43	59	70	0.6%	0.7%	0.7%
Maxim	22	35	43	0.3%	0.4%	0.5%
Micro Linear	12	24	28	0.2%	0.3%	0.3%
Micro Power Systems	23	26	21	0.3%	0.3%	0.2%
Mitel	39	43	54	0.5%	0.5%	0.6%
Motorola	339	425	445	4.4%	4.8%	4.7%
National Semiconductor	495	540	558	6.5%	6.1%	5.9%
NCR	0	0	26	0	0	0.3%
Precision Monolithics	78	85	88	1.0%	1.0%	0.9%

(Continued)

Table 15 (Continued)

Worldwide Semiconductor Market
Analog Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
North American Companies (Continued)						
Raytheon	25	27	27	0.3%	0.3%	0.3%
Rockwell	0	0	123	0	0	1.3%
Sierra Semiconductor	12	23	28	0.2%	0.3%	0.3%
Silicon General	25	35	36	0.3%	0.4%	0.4%
Silicon Systems	88	125	112	1.1%	1.4%	1.2%
Siliconix	63	67	54	0.8%	0.8%	0.6%
Sipex	NA	NA	22	NA	NA	0.2%
Solitron	13	13	10	0.2%	0.1%	0.1%
Sprague	78	86	98	1.0%	1.0%	1.0%
Supertex	10	11	15	0.1%	0.1%	0.2%
Teledyne	30	33	20	0.4%	0.4%	0.2%
Texas Instruments	386	426	417	5.0%	4.8%	4.4%
TRW	18	20	15	0.2%	0.2%	0.2%
Unitrode	23	51	50	0.3%	0.6%	0.5%
Universal	2	4	4	0	0	0
VTC Inc.	27	27	27	0.4%	0.3%	0.3%
Xicor	3	3	3	0	0	0
Other North American Companies	28	28	53	0.4%	0.3%	0.6%
Japanese Companies	3,520	4,090	4,039	46.0%	46.1%	43.0%
Fuji Electric	28	33	43	0.4%	0.4%	0.5%
Fujitsu	151	151	163	2.0%	1.7%	1.7%
Hitachi	310	343	332	4.1%	3.9%	3.5%
Matsushita	376	423	376	4.9%	4.8%	4.0%
Mitsubishi	305	395	384	4.0%	4.4%	4.1%
NEC	542	469	415	7.1%	5.3%	4.4%
New JRC	95	118	119	1.2%	1.3%	1.3%
Oki Semiconductor	21	23	35	0.3%	0.3%	0.4%
Rohm	235	271	277	3.1%	3.1%	2.9%
Sanken	119	157	156	1.6%	1.8%	1.7%
Sanyo	377	471	530	4.9%	5.3%	5.6%
Seiko-Epson	14	15	14	0.2%	0.2%	0.1%
Sharp	55	69	65	0.7%	0.8%	0.7%
Sony	217	386	361	2.8%	4.3%	3.8%
Toshiba	476	569	572	6.2%	6.4%	6.1%
Yamaha	0	0	13	0	0	0.1%
Other Japanese Companies	199	197	184	2.6%	2.2%	2.0%

(Continued)

Table 15 (Continued)

Worldwide Semiconductor Market
Analog Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies	1,001	1,147	1,278	13.1%	12.9%	13.6%
Austria Mikro Systeme	3	4	9	0	0	0.1%
Ericsson	16	46	47	0.2%	0.5%	0.5%
Matra MHS	2	0	0	0	0	0
MEDL	0	0	4	0	0	0
Philips	439	466	522	5.7%	5.2%	5.6%
Plessey	64	67	35	0.8%	0.8%	0.4%
SGS-Thomson	282	352	393	3.7%	4.0%	4.2%
Siemens	120	120	152	1.6%	1.4%	1.6%
STC	0	4	5	0	0	0.1%
Telefunken Electronic	72	85	101	0.9%	1.0%	1.1%
TMS	NA	NA	7	NA	NA	0.1%
Other European Companies	3	3	3	0	0	0
	106	168	171	1.4%	1.9%	1.8%
Asia/Pacific Companies						
Daewoo	1	5	10	0	0.1%	0.1%
ERSO	1	0	0	0	0	0
Goldstar	26	41	9	0.3%	0.5%	0.1%
Korean Electronic Co.	20	25	24	0.3%	0.3%	0.3%
Samsung	49	85	116	0.6%	1.0%	1.2%
Other Asia/Pacific Companies	9	12	12	0.1%	0.1%	0.1%

NA = Not available

Source: Dataquest
May 1990

Table 16

Worldwide Semiconductor Market
Total Discrete Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	6,655	7,612	7,662	100.0%	100.0%	100.0%
North American Companies	2,051	2,171	2,120	30.8%	28.5%	27.7%
Acrian	15	21	26	0.2%	0.3%	0.3%
AT&T	200	161	147	3.0%	2.1%	1.9%
General Electric	146	145	0	2.2%	1.9%	0
General Instrument	132	164	170	2.0%	2.2%	2.2%
Harris	0	0	120	0	0	1.6%
Hewlett-Packard	57	57	56	0.9%	0.7%	0.7%
Honeywell	10	10	0	0.2%	0.1%	0
International Rectifier	151	192	187	2.3%	2.5%	2.4%
ITT	160	146	155	2.4%	1.9%	2.0%
Micro Quality Semiconductor	0	0	2	0	0	0
Motorola	652	752	775	9.8%	9.9%	10.1%
National Semiconductor	75	75	70	1.1%	1.0%	0.9%
Powerex	106	115	105	1.6%	1.5%	1.4%
Raytheon	12	15	14	0.2%	0.2%	0.2%
Siliconix	45	61	67	0.7%	0.8%	0.9%
Solitron	34	33	27	0.5%	0.4%	0.4%
Sprague	17	18	23	0.3%	0.2%	0.3%
Supertex	9	10	8	0.1%	0.1%	0.1%
Texas Instruments	64	63	60	1.0%	0.8%	0.8%
TRW	49	0	0	0.7%	0	0
Unitrode	46	62	59	0.7%	0.8%	0.8%
VQSI	21	21	0	0.3%	0.3%	0
Other North American Companies	50	50	49	0.8%	0.7%	0.6%
Japanese Companies	3,376	4,056	4,091	50.7%	53.3%	53.4%
Fuji Electric	206	279	287	3.1%	3.7%	3.7%
Fujitsu	70	82	109	1.1%	1.1%	1.4%
Hitachi	625	707	690	9.4%	9.3%	9.0%
Matsushita	318	377	332	4.8%	5.0%	4.3%
Mitsubishi	227	310	364	3.4%	4.1%	4.8%
NEC	518	571	574	7.8%	7.5%	7.5%
New JRC	10	8	4	0.2%	0.1%	0.1%
Oki Semiconductor	7	9	10	0.1%	0.1%	0.1%
Rohm	200	287	301	3.0%	3.8%	3.9%

(Continued)

Table 16 (Continued)

Worldwide Semiconductor Market
Total Discrete Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Japanese Companies (Continued)						
Sanken	162	207	213	2.4%	2.7%	2.8%
Sanyo	210	210	230	3.2%	2.8%	3.0%
Sony	72	112	96	1.1%	1.5%	1.3%
Toshiba	703	864	848	10.6%	11.4%	11.1%
Other Japanese Companies	48	33	33	0.7%	0.4%	0.4%
European Companies	1,125	1,250	1,284	16.9%	16.4%	16.8%
ABB-HAFO	69	76	5	1.0%	1.0%	0.1%
ABB-IXYS	0	0	50	0	0	0.7%
Fagor	NA	27	29	NA	0.4%	0.4%
MEDL	20	22	21	0.3%	0.3%	0.3%
Philips	390	432	442	5.9%	5.7%	5.8%
Plessey	22	25	0	0.3%	0.3%	0
Semikron	79	91	95	1.2%	1.2%	1.2%
SGS-Thomson	213	254	282	3.2%	3.3%	3.7%
Siemens	218	201	232	3.3%	2.6%	3.0%
STC	0	1	2	0	0	0
TAG	21	23	22	0.3%	0.3%	0.3%
Telefunken Electronic	86	91	95	1.3%	1.2%	1.2%
TMS	NA	NA	2	NA	NA	0
Other European Companies	7	7	7	0.1%	0.1%	0.1%
Asia/Pacific Companies	103	135	167	1.5%	1.8%	2.2%
Goldstar	1	1	1	0	0	0
Korean Electronic Co.	55	65	74	0.8%	0.9%	1.0%
Samsung	37	55	78	0.6%	0.7%	1.0%
Other Asia/Pacific Companies	10	14	14	0.2%	0.2%	0.2%

NA = Not available

Source: Dataquest
May 1990

Table 17

Worldwide Semiconductor Market
Total Optoelectronic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
Total Market	1,709	2,179	2,627	100.0%	100.0%	100.0%
North American Companies	383	425	458	22.4%	19.5%	17.4%
AT&T	7	10	10	0.4%	0.5%	0.4%
General Electric	16	21	0	0.9%	1.0%	0
General Instrument	28	0	0	1.6%	0	0
Harris	0	0	18	0	0	0.7%
Hewlett-Packard	186	213	213	10.9%	9.8%	8.1%
Honeywell	30	30	31	1.8%	1.4%	1.2%
Motorola	24	24	25	1.4%	1.1%	1.0%
Optek	NA	NA	77	NA	NA	2.9%
Quality Technologies	NA	40	38	NA	1.8%	1.4%
Texas Instruments	39	41	36	2.3%	1.9%	1.4%
TRW	43	36	0	2.5%	1.7%	0
Other North American Companies	10	10	10	0.6%	0.5%	0.4%
Japanese Companies	1,093	1,511	1,918	64.0%	69.3%	73.0%
Fuji Electric	4	3	1	0.2%	0.1%	0
Fujitsu	71	105	116	4.2%	4.8%	4.4%
Hitachi	47	70	66	2.8%	3.2%	2.5%
Matsushita	145	178	306	8.5%	8.2%	11.6%
Mitsubishi	26	27	30	1.5%	1.2%	1.1%
NEC	55	88	120	3.2%	4.0%	4.6%
New JRC	11	15	13	0.6%	0.7%	0.5%
Oki Semiconductor	25	36	33	1.5%	1.7%	1.3%
Rohm	70	109	96	4.1%	5.0%	3.7%
Sanken	13	19	18	0.8%	0.9%	0.7%
Sanyo	85	62	160	5.0%	2.8%	6.1%
Sharp	223	285	328	13.0%	13.1%	12.5%
Sony	138	217	249	8.1%	10.0%	9.5%
Toshiba	132	215	308	7.7%	9.9%	11.7%
Other Japanese Companies	48	82	74	2.8%	3.8%	2.8%
European Companies	230	238	244	13.5%	10.9%	9.3%
ABB-HAFO	8	9	9	0.5%	0.4%	0.3%
Ericsson	2	0	0	0.1%	0	0
Philips	26	25	24	1.5%	1.1%	0.9%
Plessey	17	22	0	1.0%	1.0%	0

(Continued)

Table 17 (Continued)

Worldwide Semiconductor Market
Total Optoelectronic Market Share Estimates
Sales by Manufacturers
(Millions of Dollars)

	Revenue			Market Share		
	1987	1988	1989	1987	1988	1989
European Companies (Continued)						
Siemens	85	100	115	5.0%	4.6%	4.4%
Telefunken Electronic	77	74	78	4.5%	3.4%	3.0%
TMS	NA	NA	10	NA	NA	0.4%
Other European Companies	15	8	8	0.9%	0.4%	0.3%
	3	5	7	0.2%	0.2%	0.3%
Asia/Pacific Companies						
Korean Electronic Co.	3	5	7	0.2%	0.2%	0.3%

NA = Not available

Source: Dataquest
May 1990

Chapter 2

Final Worldwide Semiconductor Market Share Rankings

These market share rankings provide our final estimates for 1989. The tables rank the top 20 companies in 12 semiconductor categories for 1988 and 1989.

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Table 1

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Total Semiconductor
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	4,543	5,015	10%	8.8%
2	2	Toshiba	4,395	4,930	12%	8.6%
3	3	Hitachi	3,506	3,974	13%	6.9%
4	4	Motorola	3,035	3,319	9%	5.8%
5	6	Fujitsu	2,607	2,963	14%	5.2%
6	5	Texas Instruments	2,741	2,787	2%	4.9%
7	8	Mitsubishi	2,312	2,579	12%	4.5%
8	7	Intel	2,350	2,430	3%	4.2%
9	9	Matsushita	1,883	1,882	0	3.3%
10	10	Philips	1,738	1,716	(1%)	3.0%
11	11	National Semiconductor	1,650	1,618	(2%)	2.8%
12	14	Sanyo[1]	1,083	1,365	NM	2.4%
13	12	SGS-Thomson	1,087	1,301	20%	2.3%
14	18	Samsung	905	1,260	39%	2.2%
15	15	Sharp	1,036	1,230	19%	2.1%
16	20	Siemens	784	1,194	52%	2.1%
17	17	Oki Semiconductor	947	1,154	22%	2.0%
18	13	Advanced Micro Devices	1,084	1,100	1%	1.9%
19	16	Sony	950	1,077	13%	1.9%
20	19	AT&T	859	873	2%	1.5%
		All Others	11,364	13,446	18%	23.5%
		North American Companies	18,586	19,978	7%	34.9%
		Japanese Companies	25,942	29,809	15%	52.1
		European Companies	4,917	5,443	11%	9.5
		Asia/Pacific Companies	1,414	1,983	40%	3.5
		Total Market	50,859	57,213	12%	100.0%

[1]Prior to 1989, Sanyo revenue was understated.
NM = Not meaningful

Source: Dataquest
May 1990

Table 2

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Total Integrated Circuit
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,884	4,321	11%	9.2%
2	2	Toshiba	3,316	3,774	14%	8.0%
3	3	Hitachi	2,729	3,218	18%	6.9%
4	5	Fujitsu	2,420	2,738	13%	5.8%
5	4	Texas Instruments	2,637	2,691	2%	5.7%
6	7	Motorola	2,259	2,519	12%	5.4%
7	6	Intel	2,350	2,430	3%	5.2%
8	8	Mitsubishi	1,975	2,185	11%	4.7%
9	9	National Semiconductor	1,575	1,548	(2%)	3.3%
10	11	Philips	1,281	1,250	(2%)	2.7%
11	10	Matsushita	1,328	1,244	(6%)	2.7%
12	14	Samsung	850	1,182	39%	2.5%
13	13	Oki Semiconductor	902	1,111	23%	2.4%
14	12	Advanced Micro Devices	1,084	1,100	1%	2.3%
15	15	SGS-Thomson	833	1,019	22%	2.2%
16	16	Sanyo	811	975	20%	2.1%
17	17	Sharp	751	902	20%	1.9%
18	20	Siemens	483	847	75%	1.8%
19	19	Sony	621	732	18%	1.6%
20	18	AT&T	688	716	4%	1.5%
		All Others	8,291	10,422	26%	22.2%
		North American Companies	15,990	17,400	9%	37.1%
		Japanese Companies	20,375	23,800	17%	50.7
		European Companies	3,429	3,915	14%	8.3
		Asia/Pacific Companies	1,274	1,809	42%	3.9
		Total Market	41,068	46,924	14%	100.0%

Source: Dataquest
May 1990

Table 3

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Bipolar Digital
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Texas Instruments	940	671	(29%)	14.9%
2	2	Fujitsu	653	617	(6%)	13.7%
3	5	Hitachi	501	479	(4%)	10.6%
4	4	Advanced Micro Devices	536	474	(12%)	10.5%
5	3	National Semiconductor	550	458	(17%)	10.2%
6	6	Motorola	435	369	(15%)	8.2%
7	7	Philips	413	306	(26%)	6.8%
8	8	NEC	292	302	3%	6.7%
9	9	Mitsubishi	127	125	(2%)	2.8%
10	11	Plessey	94	122	30%	2.7%
11	10	Toshiba	108	102	(6%)	2.3%
12	15	Sanyo	41	67	63%	1.5%
13	13	AT&T	61	56	(8%)	1.2%
14	14	Raytheon	55	55	0	1.2%
15	17	Siemens	36	54	50%	1.2%
16	12	Harris	62	50	(19%)	1.1%
17	16	Oki Semiconductor	38	48	26%	1.1%
18	18	Goldstar	32	32	0	0.7%
19	20	Chips & Technologies	30	24	(20%)	0.5%
20	22	Applied Micro Circuits Corp.	27	20	(26%)	0.4%
		All Others	169	79	(53%)	1.8%
		North American Companies	2,761	2,221	(20%)	49.2%
		Japanese Companies	1,791	1,755	(2%)	38.9
		European Companies	598	502	(16%)	11.1
		Asia/Pacific Companies	50	32	(36%)	0.7
		Total Market	5,200	4,510	(13%)	100.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest May 1990

Table 4

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Bipolar Digital Memory
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Fujitsu	254	190	(25%)	35.2%
2	2	Hitachi	119	111	(7%)	20.6%
3	3	Advanced Micro Devices	104	85	(18%)	15.7%
4	7	National Semiconductor	35	56	60%	10.4%
5	4	Philips	58	47	(19%)	8.7%
6	6	NEC	44	25	(43%)	4.6%
7	8	Raytheon	14	12	(14%)	2.2%
8	5	Texas Instruments	50	10	(80%)	1.9%
9	9	Motorola	7	4	(43%)	0.7%
NM	10	Harris	3	0	NM	0
		All Others	1	0	(100%)	0
		North American Companies	213	167	(22%)	30.9%
		Japanese Companies	417	326	(22%)	60.4
		European Companies	59	47	(20%)	8.7
		Asia/Pacific Companies	0	0	NM	0
		Total Market	689	540	(22%)	100.0%

NM = Not meaningful

Source: Dataquest
May 1990

Table 5

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Bipolar Digital Logic
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Texas Instruments	890	661	(26%)	16.6%
2	5	Fujitsu	399	427	7%	10.8%
3	2	National Semiconductor	515	402	(22%)	10.1%
4	3	Advanced Micro Devices	432	389	(10%)	9.8%
5	6	Hitachi	382	368	(4%)	9.3%
6	4	Motorola	428	365	(15%)	9.2%
7	8	NEC	248	277	12%	7.0%
8	7	Philips	355	259	(27%)	6.5%
9	9	Mitsubishi	127	125	(2%)	3.1%
10	11	Plessey	94	122	30%	3.1%
11	10	Toshiba	108	102	(6%)	2.6%
12	14	Sanyo	41	67	63%	1.7%
13	12	AT&T	61	56	(8%)	1.4%
14	17	Siemens	36	54	50%	1.4%
15	13	Harris	59	50	(15%)	1.3%
16	16	Oki Semiconductor	38	48	26%	1.2%
17	15	Raytheon	41	43	5%	1.1%
18	18	Goldstar	32	32	0	0.8%
19	20	Chips & Technologies	30	24	(20%)	0.6%
20	22	Applied Micro Circuits Corp.	27	20	(26%)	0.5%
		All Others	168	79	(53%)	2.0%
		North American Companies	2,548	2,054	(19%)	51.7%
		Japanese Companies	1,374	1,429	4%	36.0
		European Companies	539	455	(16%)	11.5
		Asia/Pacific Companies	50	32	(36%)	0.8
		Total Market	4,511	3,970	(12%)	100.0%

Source: Dataquest
May 1990

Table 6

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
MOS Digital
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	3,123	3,604	15%	10.9%
2	2	Toshiba	2,639	3,100	17%	9.4%
3	3	Intel	2,328	2,420	4%	7.3%
4	4	Hitachi	1,885	2,407	28%	7.3%
5	5	Fujitsu	1,616	1,958	21%	5.9%
6	7	Motorola	1,399	1,705	22%	5.2%
7	6	Mitsubishi	1,453	1,676	15%	5.1%
8	8	Texas Instruments	1,271	1,603	26%	4.9%
9	11	Samsung	765	1,066	39%	3.2%
10	10	Oki Semiconductor	841	1,028	22%	3.1%
11	9	Matsushita	875	854	(2%)	2.6%
12	12	Sharp	682	837	23%	2.5%
13	20	Siemens	327	641	96%	1.9%
14	15	SGS-Thomson	461	619	34%	1.9%
15	14	Advanced Micro Devices	482	549	14%	1.7%
16	13	National Semiconductor	485	532	10%	1.6%
17	18	LSI Logic	375	512	37%	1.6%
18	16	Philips	402	422	5%	1.3%
19	17	AT&T	380	411	8%	1.2%
20	19	Micron Technology	331	395	19%	1.2%
		All Others	4,868	6,685	37%	20.2%
		North American Companies	9,754	11,277	16%	34.1%
		Japanese Companies	14,494	18,006	24%	54.5
		European Companies	1,684	2,135	27%	6.5
		Asia/Pacific Companies	1,056	1,606	52%	4.9
		Total Market	26,988	33,024	22%	100.0%

Source: Dataquest
May 1990

Table 7

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
MOS Memory
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	1,516	1,918	27%	11.7%
2	2	NEC	1,490	1,739	17%	10.6%
3	3	Hitachi	1,114	1,534	38%	9.4%
4	4	Fujitsu	1,067	1,265	19%	7.7%
5	5	Mitsubishi	966	1,161	20%	7.1%
6	6	Texas Instruments	834	1,095	31%	6.7%
7	7	Samsung	650	935	44%	5.7%
8	10	Sharp	344	476	38%	2.9%
9	9	Oki Semiconductor	353	473	34%	2.9%
10	8	Intel	392	433	10%	2.6%
11	17	Siemens	150	416	177%	2.5%
12	12	Motorola	236	407	72%	2.5%
13	11	Micron Technology	331	395	19%	2.4%
14	13	Matsushita	230	370	61%	2.3%
15	16	SGS-Thomson	185	269	45%	1.6%
16	14	Advanced Micro Devices	207	258	25%	1.6%
17	15	NMB Semiconductor	199	247	24%	1.5%
18	21	Sony	103	228	121%	1.4%
19	20	Hyundai	106	210	98%	1.3%
20	19	Integrated Device Technology	135	158	17%	1.0%
		All Others[1]	1,084	2,374	119%	14.5%
		North American Companies	2,836	3,688	30%	22.5%
		Japanese Companies	7,597	10,558	39%	64.5
		European Companies	464	786	69%	4.8
		Asia/Pacific Companies	795	1,329	67%	8.1
		Total Market	11,692	16,361	40%	100.0%

[1]In 1989, All Others includes additional revenue not counted in 1988.
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
May 1990

Table 8

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
MOS Microcomponents
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Intel	1,835	1,929	5%	23.5%
2	2	NEC	790	937	19%	11.4%
3	3	Motorola	699	803	15%	9.8%
4	4	Hitachi	525	554	6%	6.8%
5	5	Mitsubishi	381	435	14%	5.3%
6	6	Toshiba	346	407	18%	5.0%
7	7	Texas Instruments	234	252	8%	3.1%
8	8	Matsushita	230	217	(6%)	2.6%
9	13	Chips & Technologies	130	216	66%	2.6%
10	9	Fujitsu	202	211	4%	2.6%
11	10	Advanced Micro Devices	183	172	(6%)	2.1%
11	11	National Semiconductor	150	172	15%	2.1%
13	14	SGS-Thomson	118	161	36%	2.0%
14	12	Oki Semiconductor	134	149	11%	1.8%
15	26	AT&T[1]	39	141	262%	1.7%
16	16	Western Digital	100	135	35%	1.6%
17	15	Philips	114	131	15%	1.6%
18	20	Harris[2]	62	115	85%	1.4%
19	23	Sharp	54	112	107%	1.4%
20	17	Zilog	90	99	10%	1.2%
		All Others	728	854	17%	10.4%
		North American Companies	3,872	4,526	17%	55.2%
		Japanese Companies	2,817	3,190	13%	38.9
		European Companies	401	433	8%	5.3
		Asia/Pacific Companies	54	53	(2%)	0.6
		Total Market	7,144	8,202	15%	100.0%

[1]In 1989, AT&T revenue previously classified as MOS logic has been reclassified as microcomponent.
[2]In 1989, Harris revenue includes GE Solid State revenue.

Source: Dataquest
May 1990

Table 9

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
MOS Logic
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	NEC	843	928	10%	11.0%
2	2	Toshiba	777	775	0	9.2%
3	3	Motorola	464	495	7%	5.9%
4	7	Fujitsu	347	482	39%	5.7%
5	5	LSI Logic	357	445	25%	5.3%
6	6	Oki Semiconductor	354	406	15%	4.8%
7	11	Hitachi	246	319	30%	3.8%
8	4	Matsushita	415	267	(36%)	3.2%
9	8	AT&T[1]	317	257	(19%)	3.0%
10	12	Texas Instruments	203	256	26%	3.0%
11	9	Sharp	284	249	(12%)	2.9%
12	10	Philips	253	231	(9%)	2.7%
13	13	National Semiconductor	200	222	11%	2.6%
14	40	Harris[2]	33	210	536%	2.5%
15	15	Seiko Epson	190	201	6%	2.4%
16	16	SGS-Thomson	158	189	20%	2.2%
17	19	Sanyo	142	178	25%	2.1%
18	18	VLSI Technology	151	169	12%	2.0%
19	20	ITT	135	150	11%	1.8%
20	28	Siemens	89	133	49%	1.6%
		All Others	2,194	1,899	(13%)	22.4%
		North American Companies	3,046	3,063	1%	36.2%
		Japanese Companies	4,080	4,258	4%	50.3
		European Companies	819	916	12%	10.8
		Asia.Pacific Companies	207	224	8%	2.6
		Total Market	8,152	8,461	4%	100.0%

[1]In 1989, AT&T revenue previously classified as MOS logic has been reclassified as microcomponent.
[2]In 1989, Harris revenue includes GE Solid State revenue.
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
May 1990

Table 10

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Analog
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	569	572	1%	6.1%
2	2	National Semiconductor	540	558	3%	5.9%
3	3	Sanyo	471	530	13%	5.6%
4	5	Philips	466	522	12%	5.6%
5	7	Motorola	425	445	5%	4.7%
6	6	Texas Instruments	426	417	(2%)	4.4%
7	4	NEC	469	415	(12%)	4.4%
8	11	SGS-Thomson	352	393	12%	4.2%
9	9	Mitsubishi	395	384	(3%)	4.1%
10	8	Matsushita	423	376	(11%)	4.0%
11	10	Sony	386	361	(6%)	3.8%
12	13	Analog Devices	340	337	(1%)	3.6%
13	12	Hitachi	343	332	(3%)	3.5%
14	18	Harris[1]	146	280	92%	3.0%
15	14	Rohm	271	277	2%	2.9%
16	15	AT&T	247	249	1%	2.7%
17	17	Fujitsu	151	163	8%	1.7%
18	16	Sanken	157	156	(1%)	1.7%
19	21	Siemens	120	152	27%	1.6%
20	19	Burr-Brown	144	141	(2%)	1.5%
		All Others	2,039	2,330	14%	24.8%
		North American Companies	3,475	3,902	12%	41.6%
		Japanese Companies	4,090	4,039	(1%)	43.0
		European Companies	1,147	1,278	11%	13.6
		Asia/Pacific Companies	168	171	2%	1.8
		Total Market	8,880	9,390	6%	100.0%

[1]In 1989, Harris revenue includes GE Solid State revenue.

Source: Dataquest
May 1990

Table 11

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Total Discrete
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Toshiba	864	848	(2%)	11.1%
2	2	Motorola	752	775	3%	10.1%
3	3	Hitachi	707	690	(2%)	9.0%
4	4	NEC	571	574	1%	7.5%
5	5	Philips	432	442	2%	5.8%
6	7	Mitsubishi	310	364	17%	4.8%
7	6	Matsushita	377	332	(12%)	4.3%
8	8	Rohm	287	301	5%	3.9%
9	9	Fuji Electric	279	287	3%	3.7%
10	10	SGS-Thomson	254	282	11%	3.7%
11	13	Siemens	201	232	15%	3.0%
12	11	Sanyo	210	230	10%	3.0%
13	12	Sanken	207	213	3%	2.8%
14	14	International Rectifier	192	187	(3%)	2.4%
15	15	General Instrument	164	170	4%	2.2%
16	17	ITT	146	155	6%	2.0%
17	16	AT&T	161	147	(9%)	1.9%
18	NM	Harris[1]	0	120	NM	1.6%
19	23	Fujitsu	82	109	33%	1.4%
20	19	Powerex	115	105	(9%)	1.4%
		All Others	1,301	1,099	(16%)	14.3%
		North American Companies	2,171	2,120	(2%)	27.7%
		Japanese Companies	4,056	4,091	1%	53.4
		European Companies	1,250	1,284	3%	16.8
		Asia/Pacific Companies	135	167	24%	2.2
		Total Market	7,612	7,662	1%	100.0%

[1]In 1989, Harris revenue includes GE Solid State revenue.
NM = Not meaningful
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
May 1990

Table 12

Final Estimated 1989
Worldwide Semiconductor Market Share Rankings
Total Optoelectronic
(Millions of Dollars)

1989 Rank	1988 Rank		1988 Revenue	1989 Revenue	Percent Change	1989 Market Share
1	1	Sharp	285	328	15%	12.5%
2	3	Toshiba	215	308	43%	11.7%
3	5	Matsushita	178	306	72%	11.6%
4	2	Sony	217	249	15%	9.5%
5	4	Hewlett-Packard	213	213	0%	8.1%
6	12	Sanyo[1]	62	160	NM[1]	6.1%
7	9	NEC	88	120	36%	4.6%
8	7	Fujitsu	105	116	10%	4.4%
9	8	Siemens	100	115	15%	4.4%
10	6	Rohm	109	96	(12%)	3.7%
11	10	Telefunken Electronic	74	78	5%	3.0%
12	NM	Optek	0	77	NM	2.9%
13	11	Hitachi	70	66	(6%)	2.5%
14	14	Quality Technologies	40	38	(5%)	1.4%
15	13	Texas Instruments	41	36	(12%)	1.4%
16	16	Oki Semiconductor	36	33	(8%)	1.3%
17	17	Honeywell	30	31	3%	1.2%
18	18	Mitsubishi	27	30	11%	1.1%
19	20	Motorola	24	25	4%	1.0%
20	19	Philips	25	24	(4%)	0.9%
		All Others	240	178	(26%)	6.8%
		North American Companies	425	458	8%	17.4%
		Japanese Companies	1,511	1,918	27%	73.0
		European Companies	238	244	3%	9.3
		Asia/Pacific Companies	5	7	40%	0.3
		Total Market	2,179	2,627	21%	100.0%

[1]Prior to 1989, Sanyo revenue was understated.
NM = Not meaningful

Source: Dataquest
May 1990

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Semiconductor Shipments

INTRODUCTION

Semiconductor shipment data comprise a set of detailed tables that estimate the size of the semiconductor total available market (TAM) worldwide and for four major geographical regions for the years 1979 through 1994 and 1999. Semiconductor shipment tables contain both historical data and forecasts. Historical data begin with 1979 and end with 1988, while forecast data provide annual market size estimates for 1989 through 1994, with additional estimates for 1999. Below is a list of tables detailing the type of data, region, time period, and units of measure.

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Table	Region Covered	Years	Units
0	Japan and Western Europe Exchange Rates	1970-1989	Various
1a	Worldwide Market	1979-1983	Dollars
1b	Worldwide Market	1984-1989	Dollars
1c	Worldwide Market	1990-1994; 1999	Dollars
1d	Worldwide Market	1979-1983	Percent
1e	Worldwide Market	1984-1989	Percent
1f	Worldwide Market	1990-1994	Percent
1g	Worldwide Market	1979-1999	Percent
2a	North American Market	1979-1983	Dollars
2b	North American Market	1984-1989	Dollars
2c	North American Market	1990-1994; 1999	Dollars
2d	North American Market	1979-1983	Percent
2e	North American Market	1984-1989	Percent
2f	North American Market	1990-1994	Percent
2g	North American Market	1979-1999	Percent
3a	Japanese Market	1979-1983	Dollars
3b	Japanese Market	1984-1989	Percent
3c	Japanese Market	1990-1994; 1999	Dollars
3d	Japanese Market	1979-1983	Percent
3e	Japanese Market	1984-1989	Percent
3f	Japanese Market	1990-1994	Percent
3g	Japanese Market	1979-1999	Percent
4a	Japanese Market	1979-1983	Yen
4b	Japanese Market	1984-1989	Yen
4c	Japanese Market	1990-1994; 1999	Yen
4d	Japanese Market	1979-1983	Percent
4e	Japanese Market	1984-1989	Percent

(Continued)

LIST OF TABLES (Continued)

Table	Region Covered	Years	Units
4f	Japanese Market	1990-1994	Percent
4g	Japanese Market	1979-1999	Percent
5a	Western European Market	1979-1983	Dollars
5b	Western European Market	1984-1989	Dollars
5c	Western European Market	1990-1994; 1999	Dollars
5d	Western European Market	1979-1983	Percent
5e	Western European Market	1984-1989	Percent
5f	Western European Market	1990-1994	Percent
5g	Western European Market	1979-1999	Percent
6a	Rest of World Market	1979-1983	Dollars
6b	Rest of World Market	1984-1989	Dollars
6c	Rest of World Market	1990-1994; 1999	Dollars
6d	Rest of World Market	1979-1983	Percent
6e	Rest of World Market	1984-1989	Percent
6f	Rest of World Market	1990-1994	Percent
6g	Rest of World Market	1979-1999	Percent
7a	Worldwide Average Selling Prices	1979-1983	Dollars
7b	Worldwide Average Selling Prices	1984-1989	Dollars
7c	Worldwide Average Selling Prices	1990-1994; 1999	Dollars
7d	Worldwide Average Selling Prices	1979-1983	Percent
7e	Worldwide Average Selling Prices	1984-1989	Percent
7f	Worldwide Average Selling Prices	1990-1994	Percent
7g	Worldwide Average Selling Prices	1979-1999	Percent
8a	Worldwide Market	1979-1983	Units
8b	Worldwide Market	1984-1989	Units
8c	Worldwide Market	1990-1994; 1999	Units
8d	Worldwide Market	1979-1983	Percent
8e	Worldwide Market	1984-1989	Percent
8f	Worldwide Market	1989-1994	Percent
8g	Worldwide Market	1979-1999	Percent

Each table gives estimates of semiconductor shipments listed by the major semiconductor device product categories. In these tables, semiconductor components are divided into three major product groups: integrated circuits, discrete devices, and optoelectronic devices. These groups are divided into a number of subgroups, some of which are segmented further.

DEFINITIONS AND CONVENTIONS

Dataquest uses a common manufacturer base for all data tables. This base includes all suppliers to the merchant semiconductor market. It includes aggregate revenue estimates for North American companies that manufacture devices solely for the benefit of the parent company, such as Burroughs, Delco, and IBM. Also included are companies that actively market semiconductor devices to the merchant market as well as to other divisions of their own companies. For such companies, both external and internal shipments are included. Devices that are used internally are valued at current market prices.

Shipment—Dataquest defines shipment as the purchase of a semiconductor device or devices. This definition must be differentiated from actual use of the device in a final product. A regional market size includes all devices sold to or shipped to that region, i.e., the total available market (TAM) in that region.

Hybrids—In earlier consumption data, hybrid devices were included as a separate segment of integrated circuits. Hybrid devices manufactured by semiconductor companies are now included in the most appropriate product segment, usually the analog segment.

The manufacturer base, product group definitions, and guidelines for including value of output that we have used in our tables may differ from those used in other studies of this type. Our base is nearly the same as that used by the World Semiconductor Trade Statistics program (WSTS), with the following exceptions:

- Dataquest includes all of AT&T's semiconductor revenue, both merchant and captive.
- Dataquest includes—and has included all along—nonrecurring engineering (NRE) charges associated with application-specific integrated circuit (ASIC) revenue. (This applies to both the bipolar digital and MOS digital logic categories.)
- Dataquest includes the revenue generated by sales of standalone circuit design software, sold by certain U.S. manufacturers of ASIC logic devices.
- Dataquest includes Signetics revenue with that of its parent company, Netherlands-based N.V. Philips.
- Dataquest includes revenue for Taiwanese semiconductor manufacturers.
- Dataquest includes revenue for three Japanese companies not estimated by WSTS: NBM Semiconductor, Seiko-Epson, and Yamaha.
- As noted herein, Dataquest includes hybrid revenue in the analog category.

Further information on the above points is available through Dataquest's Client Inquiry Center at (408) 437-8099.

Regions—North America is defined as including both the United States and Canada. Latin America, including Mexico, is considered part of the Rest of World (ROW) category. The ROW region also includes Asia/Pacific (including South Korea, Taiwan, Hong Kong, Singapore, and China). Western Europe includes Austria, Belgium, the Federal Republic of Germany, France, Italy, Luxembourg, the Scandinavian countries (Denmark, Finland, Norway, Sweden), Spain, and the United Kingdom and the rest of Europe. Japan, the fourth region, is the only single-country region.

DATA SOURCES

The information presented in the consumption data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- World Semiconductor Trade Statistics (WSTS) data, and Dataquest's estimates of regional company sales are used to determine shipments to North America.
- Japanese trade statistics compiled and published by the Ministry of Finance (MOF) and the Ministry of International Trade and Industry (MITI), WSTS data, and Dataquest's estimates of regional company sales are used to determine shipments to Japan.
- For Western European markets, marketing statistics from WSTS data and Dataquest's estimates of regional company sales are used to determine market size.
- In ROW, the major published sources used to estimate market size are WSTS data and Dataquest's estimates of company shipments into the region.

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data and the guidelines for the forecasts presented in the tables are as follows:

- Unit sales or revenue (or both) published by major industry participants, both in the United States and abroad
- Estimates presented by knowledgeable and reliable industry spokesmen
- Government data or trade association data such as those from the Electronics Industry Association (EIA), MITI, WSTS, and the U.S. Department of Commerce
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

ACCURACY

The tables presented here represent Dataquest estimates that we believe are reasonably accurate. Where we have no reasonable estimate, none is given. A zero in a table represents an estimate.

VALUATION OF SHIPMENTS

Regional market size is expressed in U.S. dollars (with the Japanese market also expressed in yen). To make the tables in this study useful in comparing different regions, it is necessary to express all values in a common currency, and we chose the U.S. dollar for convenience. However, the choice of the U.S. dollar (or any single currency, for that matter) as the currency basis for the tables brings with it some problems that require the readers' careful consideration in interpreting the data.

Inflation

All countries that participate significantly in international semiconductor markets suffered from an overall price inflation in the 1970s, continuing into the 1980s.

As a consequence, the dollar in a given year is not truly comparable with the dollar in any preceding year. Consumer and wholesale price indices and GNP deflators all measure price changes in various composite "market baskets" of goods. However, there is no price index that measures price changes of material, equipment, and labor inputs to the semiconductor industry. Indeed, the "mix" is changing so rapidly that what is used this year was sometimes unavailable last year, at any price. Nor is there a composite price index that measures price changes in aggregate semiconductor product. In an industry noted for its deflationary trends, this latter effect would tend to make the component purchaser's dollar worth more as time passed, in terms of purchasing ability.

We have made no adjustments in the historical data to account for these inflationary and deflationary effects. The data are expressed in current dollars (dollars that include the inflation rate and exchange rates of the given year) for all historical data; comparisons between different years must be interpreted accordingly.

Average Selling Prices

When considering the worldwide average selling prices (ASPs) for semiconductor components, one must look at the price per function of a circuit, the complexity of the circuit, and the product mix according to this increasing complexity. It is true that one characteristic of the semiconductor industry is that the price per function for integrated circuits has been dropping an average of 30 percent per year for the last 15 years. At the same time, circuits have become denser, resulting in an overall increase in the price of a device with a decreasing cost per function. Thus, Tables 7a through 7g show the worldwide ASPs increasing after many years of decreasing, due to the move toward higher-complexity devices. There are also regional differences in ASPs due to regional competition differences and the varying regional product consumption mix. The worldwide ASP is truly an aggregate measure and may differ significantly from ASPs in any specific market at any point in time.

Exchange Rates

Construction of the West European tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses Annual Foreign Exchange Rates for each year as published by The International Monetary Fund. As far as possible, we prepare our estimates in terms of local currencies before conversion to U.S. dollars. The exchange rates for major currencies can be found in Table 0 at the end of this introduction.

Japanese market size is originally expressed in yen. The Japanese data published in this study are expressed in both dollars (Tables 3a, 3b, and 3c) and in yen (Tables 4a, 4b, and 4c). The yen/dollar exchange rate used for each year can be found in Table 0. Because of the fluctuations in the exchange rate for the yen, the dollar values given tend to distort the growth rate of the Japanese market, but they do provide a useful basis for regional market size comparisons. However, the data in yen give a better picture of the real growth in the Japanese market.

FORECAST

As mentioned previously, historical data are expressed in current dollars or dollars that include the given year's inflation rate and exchange rates. However, the shipment forecasts use constant dollars and exchange rates, with no allowance for inflation or variations in the rates of exchange between countries. All estimates for 1989 and beyond are made as if 1989 monetary conditions will continue through 1999 and, therefore, show the absolute year-to-year growth during this period.

Table 0
Foreign Exchange Rates
(In U.S. Dollars)

Year	Yrly/ Qtrly	Japan (Yen per US$)	France (US$ per Franc)	West Germany (US$ per Deutsche Mark)	United Kingdom (US$ per Pound Sterling)	European Basket ECU (1980 = 100)
1970	YR	358	0.18	0.27	2.38	
1971	YR	343	0.18	0.29	2.44	
1972	YR	302	0.20	0.31	2.50	
1973	YR	269	0.22	0.37	2.44	
1974	YR	292	0.21	0.39	2.33	
1975	YR	297	0.23	0.41	2.22	
1976	YR	296	0.21	0.40	1.82	
1977	YR	269	0.20	0.43	1.75	
1978	YR	210	0.22	0.50	1.92	
1979	YR	219	0.24	0.55	2.13	
1980	YR	227	0.24	0.55	2.33	100
1981	YR	221	0.18	0.44	2.04	124
1982	YR	248	0.15	0.41	1.75	141
1983	YR	235	0.13	0.39	1.52	158
1984	YR	237	0.11	0.35	1.33	178
1985	YR	238	0.11	0.34	1.30	185
1986	YR	167	0.14	0.46	1.47	146
1987	YR	144	0.17	0.56	1.64	126
1988	YR	130	0.17	0.57	1.79	121

Source: The International Monetary Fund
Financial Times
Dataquest
February 1990

Table 1a

Worldwide Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	11,114	14,118	14,828	15,261	21,552
North American Captives	N/A	N/A	N/A	N/A	2,015
Total Semiconductor	11,114	14,118	14,828	15,261	19,537
Total IC	7,028	9,546	10,046	10,894	14,700
Bipolar Digital	1,674	2,374	2,337	2,412	3,015
Memory	324	572	558	511	603
Logic	1,350	1,802	1,779	1,901	2,412
MOS Digital	3,346	4,715	4,822	5,642	7,951
Memory	1,676	2,230	2,075	2,701	3,719
Micro	541	862	1,085	1,318	1,979
Logic	1,129	1,623	1,662	1,623	2,253
Analog	2,008	2,457	2,887	2,840	3,734
Total Discrete	3,522	3,883	3,985	3,547	3,865
Total Optoelectronic	564	689	797	820	972

N/A = Not Available

Source: Dataquest
February 1990

Table 1b

Worldwide Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	31,403	27,130	33,729	41,478	54,521	60,504
North American Captives	2,500	2,773	2,895	3,227	3,662	4,065
Total Semiconductor	28,903	24,357	30,834	38,251	50,859	56,439
Total IC	22,686	18,555	23,618	29,887	41,068	46,761
Bipolar Digital	4,771	3,672	4,325	4,760	5,200	4,409
Memory	774	589	606	621	689	543
Logic	3,997	3,083	3,719	4,139	4,511	3,866
MOS Digital	12,970	10,122	12,815	17,473	26,988	33,554
Memory	6,229	3,821	4,511	6,056	11,692	16,884
Micro	3,234	2,748	3,489	5,108	7,144	7,431
Logic	3,507	3,553	4,815	6,309	8,152	9,239
Analog	4,945	4,761	6,478	7,654	8,880	8,798
Total Discrete	4,987	4,576	5,730	6,655	7,612	7,622
Total Optoelectronic	1,230	1,226	1,486	1,709	2,179	2,056

Source: Dataquest
February 1990

Table 1c

Worldwide Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	61,460	70,678	85,130	111,830	121,386	254,535
North American Captives	4,165	4,767	5,723	7,518	8,107	20,740
Total Semiconductor	57,295	65,911	79,407	104,312	113,279	233,795
Total IC	47,537	55,111	67,301	90,264	97,765	210,688
Bipolar Digital	4,089	4,255	4,497	4,832	4,577	4,185
Memory	497	492	457	442	421	239
Logic	3,592	3,763	4,040	4,390	4,156	3,946
MOS Digital	34,474	40,385	50,312	69,981	75,630	174,069
Memory	17,078	19,415	24,143	35,417	38,300	91,985
Micro	7,781	9,412	11,666	15,914	17,486	39,410
Logic	9,615	11,558	14,503	18,650	19,844	42,674
Analog	8,974	10,471	12,492	15,451	17,558	32,434
Total Discrete	7,649	8,424	9,380	10,835	11,873	17,264
Total Optoelectronic	2,109	2,376	2,726	3,213	3,641	5,843

Source: Dataquest
February 1990

Table 1d

Worldwide Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	24.1%	27.0%	5.0%	2.9%	28.0%
Total IC	34.4%	35.8%	5.2%	8.4%	34.9%
Bipolar Digital	32.8%	41.8%	(1.6%)	3.2%	25.0%
Memory	N/A	76.5%	(2.4%)	(8.4%)	18.0%
Logic	N/A	33.5%	(1.3%)	6.9%	26.9%
MOS Digital	43.5%	40.9%	2.3%	17.0%	40.9%
Memory	N/A	33.1%	(7.0%)	30.2%	37.7%
Micro	N/A	59.3%	25.9%	21.5%	50.2%
Logic	N/A	43.8%	2.4%	(2.3%)	38.8%
Analog	22.7%	22.4%	17.5%	(1.6%	31.5%
Total Discrete	6.7%	10.2%	2.6%	(11.0%)	9.0%
Total Optoelectronic	33.6%	22.2%	15.7%	2.9%	18.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 1e

Worldwide Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	45.7%	(13.6%)	24.3%	23.0%	31.4%	11.0%
North American Captives	24.1%	10.9%	4.4%	11.5%	13.5%	11.0%
Total Semiconductor	47.9%	(15.7%)	26.6%	24.1%	33.0%	11.0%
Total IC	54.3%	(18.2%)	27.3%	26.5%	37.4%	13.9%
Bipolar Digital	58.2%	(23.0%)	17.8%	10.1%	9.2%	(15.2%)
Memory	28.4%	(23.9%)	2.9%	2.5%	11.0%	(21.2%)
Logic	65.7%	(22.9%)	20.6%	11.3%	9.0%	(14.3%)
MOS Digital	63.1%	(22.0%)	26.6%	36.3%	54.5%	24.3%
Memory	67.5%	(38.7%)	18.1%	34.2%	93.1%	44.4%
Micro	63.4%	(15.0%)	27.0%	46.4%	39.9%	4.0%
Logic	55.7%	1.3%	35.5%	31.0%	29.2%	13.3%
Analog	32.4%	(3.7%)	36.1%	18.2%	16.0%	(0.9%)
Total Discrete	29.0%	(8.2%)	25.2%	16.1%	14.4%	0.1%
Total Optoelectronic	26.5%	(0.3%)	21.2%	15.0%	27.5%	(5.6%)

Source: Dataquest
February 1990

Table 1f

Worldwide Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	1.6%	15.0%	20.4%	31.4%	8.5%
North American Captives	2.5%	14.5%	20.1%	31.4%	7.8%
Total Semiconductor	1.5%	15.0%	20.5%	31.4%	8.6%
Total IC	1.7%	15.9%	22.1%	34.1%	8.3%
Bipolar Digital	(7.3%)	4.1%	5.7%	7.4%	(5.3%)
Memory	(8.5%)	(1.0%)	(7.1%)	(3.3%)	(4.8%)
Logic	(7.1%)	4.8%	7.4%	8.7%	(5.3%)
MOS Digital	2.7%	17.1%	24.6%	39.1%	8.1%
Memory	1.1%	13.7%	24.4%	46.7%	8.1%
Micro	4.7%	21.0%	23.9%	36.4%	9.9%
Logic	4.1%	20.2%	25.5%	28.6%	6.4%
Analog	2.0%	16.7%	19.3%	23.7%	13.6%
Total Discrete	0.4%	10.1%	11.3%	15.5%	9.6%
Total Optoelectronic	2.6%	12.7%	14.7%	17.9%	13.3%

Source: Dataquest
February 1990

Table 1g

Worldwide Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	14.0%	14.9%	16.0%	N/A	15.5%
North American Captives	N/A	10.2%	14.8%	20.7%	N/A	17.7%
Total Semiconductor	21.1%	14.3%	15.0%	15.6%	17.6%	15.3%
Total IC	26.4%	15.6%	15.9%	16.6%	20.9%	16.2%
Bipolar Digital	23.3%	(1.6%)	0.8%	(1.8%)	10.2%	(0.5%)
Memory	19.0%	(6.8%)	(5.0%)	(10.7%)	5.3%	(7.9%)
Logic	24.2%	(0.7%)	1.5%	(1.0%)	11.1%	0.2%
MOS Digital	31.1%	20.9%	17.6%	18.1%	25.9%	17.9%
Memory	30.0%	22.1%	17.8%	19.2%	26.0%	18.5%
Micro	43.0%	18.1%	18.7%	17.6%	30.0%	18.2%
Logic	25.4%	21.4%	16.5%	16.5%	23.4%	16.5%
Analog	19.8%	12.2%	14.8%	13.1%	15.9%	13.9%
Total Discrete	7.2%	8.9%	9.3%	7.8%	8.0%	8.5%
Total Optoelectronic	16.9%	10.8%	12.1%	9.9%	13.8%	11.0%

N/A = Not Available

Source: Dataquest
February 1990

Table 2a

North American Semiconductor Market (Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	4,538	6,053	6,529	6,970	10,625
North American Captives	N/A	N/A	N/A	N/A	1,623
Total Semiconductor	4,538	6,053	6,529	6,970	9,002
Total IC	3,179	4,562	4,867	5,466	7,301
Bipolar Digital	901	1,411	1,339	1,367	1,664
Memory	185	396	375	320	373
Logic	716	1,015	964	1,047	1,291
MOS Digital	1,703	2,442	2,595	3,183	4,326
Memory	1,028	1,230	1,107	1,592	2,051
Micro	186	377	489	641	1,034
Logic	489	835	999	950	1,241
Analog	575	709	933	916	1,311
Total Discrete	1,161	1,269	1,378	1,201	1,353
Total Optoelectronic	198	222	284	303	348

N/A = Not Available

Source: Dataquest
February 1990

Table 2b

North American Semiconductor Market (Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	15,033	11,663	13,171	15,454	18,789	21,395
North American Captives	2,027	2,243	2,327	2,596	2,945	3,271
Total Semiconductor	13,006	9,420	10,844	12,858	15,844	18,124
Total IC	11,089	7,757	8,986	10,886	13,815	16,073
Bipolar Digital	2,818	1,926	2,030	2,099	2,012	1,732
Memory	441	288	267	271	235	215
Logic	2,377	1,638	1,763	1,828	1,777	1,517
MOS Digital	6,503	4,322	4,912	6,738	9,606	12,218
Memory	3,426	1,753	1,775	2,497	4,298	6,447
Micro	1,634	1,258	1,362	2,012	2,707	2,745
Logic	1,443	1,311	1,775	2,229	2,601	3,026
Analog	1,768	1,509	2,044	2,049	2,197	2,123
Total Discrete	1,503	1,295	1,542	1,642	1,676	1,691
Total Optoelectronic	414	368	316	330	353	360

Source: Dataquest
February 1990

Table 2c

North American Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	21,537	24,604	29,539	38,923	41,371	83,725
North American Captives	3,350	3,834	4,603	6,047	6,521	15,140
Total Semiconductor	18,187	20,770	24,936	32,876	34,850	68,585
Total IC	16,071	18,494	22,480	30,173	31,943	64,564
Bipolar Digital	1,548	1,614	1,662	1,747	1,580	923
Memory	184	183	166	161	153	80
Logic	1,364	1,431	1,496	1,586	1,427	843
MOS Digital	12,367	14,438	17,995	25,039	26,669	56,805
Memory	6,328	7,251	9,086	13,602	14,432	31,430
Micro	2,905	3,448	4,310	5,689	6,201	12,968
Logic	3,134	3,739	4,599	5,748	6,036	12,407
Analog	2,156	2,442	2,823	3,387	3,694	6,836
Total Discrete	1,742	1,863	2,001	2,179	2,325	3,126
Total Optoelectronic	374	413	455	524	582	895

Source: Dataquest
February 1990

Table 2d

North American Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	29.4%	33.4%	7.9%	6.8%	29.2%
Total IC	36.1%	43.5%	6.7%	12.3%	33.6%
Bipolar Digital	35.3%	56.6%	(5.1%)	2.1%	21.7%
Memory	N/A	114.1%	(5.3%)	(14.7%)	16.6%
Logic	N/A	41.8%	(5.0%)	8.6%	23.3%
MOS Digital	55.0%	43.4%	6.3%	22.7%	35.9%
Memory	N/A	19.6%	(10.0%)	43.8%	28.8%
Micro	N/A	102.7%	29.7%	31.1%	61.3%
Logic	N/A	70.8%	19.6%	(4.9%)	30.6%
Analog	0.9%	23.3%	31.6%	(1.8%)	43.1%
Total Discrete	15.5%	9.3%	8.6%	(12.8%)	12.7%
Total Optoelectronic	19.3%	12.1%	27.9%	6.7%	14.9%

N/A = Not Available

Source: Dataquest
February 1990

Table 2e

North American Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	41.5%	(22.4%)	12.9%	17.3%	21.6%	13.9%
North American Captives	24.9%	10.7%	3.7%	11.6%	13.4%	11.1%
Total Semiconductor	44.5%	(27.6%)	15.1%	18.6%	23.2%	14.4%
Total IC	51.9%	(30.0%)	15.8%	21.1%	26.9%	16.3%
Bipolar Digital	69.4%	(31.7%)	5.4%	3.4%	(4.1%)	(13.9%)
Memory	18.2%	(34.7%)	(7.3%)	1.5%	(13.3%)	(8.5%)
Logic	84.1%	(31.1%)	7.6%	3.7%	(2.8%)	(14.6%)
MOS Digital	50.3%	(33.5%)	13.7%	37.2%	42.6%	27.2%
Memory	67.0%	(48.8%)	1.3%	40.7%	72.1%	50.0%
Micro	58.0%	(23.0%)	8.3%	47.7%	34.5%	1.4%
Logic	16.3%	(9.1%)	35.4%	25.6%	16.7%	16.3%
Analog	34.9%	(14.6%)	35.5%	0.2%	7.2%	(3.4%)
Total Discrete	11.1%	(13.8%)	19.1%	6.5%	2.1%	0.9%
Total Optoelectronic	19.0%	(11.1%)	(14.1%)	4.4%	7.0%	2.0%

Source: Dataquest
February 1990

Table 2f

North American Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	0.7%	14.2%	20.1%	31.8%	6.3%
North American Captives	2.4%	14.4%	20.1%	31.4%	7.8%
Total Semiconductor	0.3%	14.2%	20.1%	31.8%	6.0%
Total IC	0	15.1%	21.6%	34.2%	5.9%
Bipolar Digital	(10.6%)	4.3%	3.0%	5.1%	(9.6%)
Memory	(14.4%)	(0.5%)	(9.3%)	(3.0%)	(5.0%)
Logic	(10.1%)	4.9%	4.5%	6.0%	(10.0%)
MOS Digital	1.2%	16.7%	24.6%	39.1%	6.5%
Memory	(1.8%)	14.6%	25.3%	49.7%	6.1%
Micro	5.8%	18.7%	25.0%	32.0%	9.0%
Logic	3.6%	19.3%	23.0%	25.0%	5.0%
Analog	1.6%	13.3%	15.6%	20.0%	9.1%
Total Discrete	3.0%	6.9%	7.4%	8.9%	6.7%
Total Optoelectronic	3.9%	10.4%	10.2%	15.2%	11.1%

Source: Dataquest
February 1990

Table 2g

North American Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	7.3%	14.1%	15.1%	N/A	14.6%
North American Captives	N/A	10.0%	14.8%	18.3%	N/A	16.6%
Total Semiconductor	23.4%	6.9%	14.0%	14.5%	14.9%	14.2%
Total IC	28.4%	7.7%	14.7%	15.1%	17.6%	14.9%
Bipolar Digital	25.6%	(9.3%)	(1.8%)	(10.2%)	6.8%	(6.1%)
Memory	19.0%	(13.4%)	(6.6%)	(12.2%)	1.5%	(9.4%)
Logic	27.1%	(8.6%)	(1.2%)	(10.0%)	7.8%	(5.7%)
MOS Digital	30.7%	13.4%	16.9%	16.3%	21.8%	16.6%
Memory	27.2%	13.5%	17.5%	16.8%	20.2%	17.2%
Micro	54.4%	10.9%	17.7%	15.9%	30.9%	16.8%
Logic	24.2%	16.0%	14.8%	15.5%	20.0%	15.2%
Analog	25.2%	3.7%	11.7%	13.1%	14.0%	12.4%
Total Discrete	5.3%	2.4%	6.6%	6.1%	3.8%	6.3%
Total Optoelectronic	15.9%	(2.8%)	10.1%	9.0%	6.2%	9.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 3a

Japanese Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	2,768	3,383	4,295	4,082	5,834
North American Captives	N/A	N/A	N/A	N/A	112
Total Semiconductor	2,768	3,383	4,295	4,082	5,722
Total IC	1,738	2,201	2,793	2,855	4,167
Bipolar Digital	304	345	438	498	706
Memory	52	57	77	87	109
Logic	252	288	361	411	597
MOS Digital	762	991	1,174	1,263	1,948
Memory	256	423	491	534	893
Micro	213	269	404	446	594
Logic	293	299	279	283	461
Analog	672	865	1,181	1,094	1,513
Total Discrete	889	986	1,237	970	1,217
Total Optoelectronic	141	196	265	257	338

N/A = Not Available

Source: Dataquest
February 1990

Table 3b

Japanese Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	8,909	8,300	12,018	15,107	20,977	22,308
North American Captives	135	151	163	180	205	226
Total Semiconductor	8,774	8,149	11,855	14,927	20,772	22,082
Total IC	6,517	5,985	8,802	11,263	16,127	17,653
Bipolar Digital	955	824	1,295	1,523	1,906	1,529
Memory	163	136	169	227	348	229
Logic	792	688	1,126	1,296	1,558	1,300
MOS Digital	3,621	3,232	4,762	6,424	10,501	12,498
Memory	1,579	1,185	1,738	2,268	4,424	6,233
Micro	979	884	1,368	1,902	2,573	2,588
Logic	1,063	1,163	1,656	2,254	3,504	3,677
Analog	1,941	1,929	2,745	3,316	3,720	3,626
Total Discrete	1,756	1,621	2,242	2,693	3,282	3,192
Total Optoelectronic	501	543	811	971	1,363	1,237

Source: Dataquest
February 1990

Table 3c

Japanese Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	22,231	25,381	30,381	39,062	42,564	85,060
North American Captives	233	267	320	420	453	1,782
Total Semiconductor	21,998	25,114	30,061	38,642	42,111	83,278
Total IC	17,674	20,255	24,535	32,223	34,937	73,045
Bipolar Digital	1,451	1,488	1,554	1,644	1,558	1,497
Memory	221	212	192	183	174	85
Logic	1,230	1,276	1,362	1,461	1,384	1,412
MOS Digital	12,591	14,516	17,885	24,389	26,261	60,445
Memory	6,125	6,773	8,270	11,817	12,834	30,945
Micro	2,681	3,193	3,927	5,263	5,789	13,527
Logic	3,785	4,550	5,688	7,309	7,638	15,973
Analog	3,632	4,251	5,096	6,190	7,118	11,103
Total Discrete	3,047	3,404	3,853	4,462	4,962	6,830
Total Optoelectronic	1,277	1,455	1,673	1,957	2,212	3,403

Source: Dataquest
February 1990

Table 3d

Japanese Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	13.1%	22.2%	27.0%	(5.0%)	40.2%
Total IC	24.2%	26.6%	26.9%	2.2%	46.0%
Bipolar Digital	17.4%	13.5%	27.0%	13.7%	41.8%
Memory	N/A	9.6%	35.1%	13.0%	25.3%
Logic	N/A	14.3%	25.3%	13.9%	45.3%
MOS Digital	29.6%	30.1%	18.5%	7.6%	54.2%
Memory	N/A	65.2%	16.1%	8.8%	67.2%
Micro	N/A	26.3%	50.2%	10.4%	33.2%
Logic	N/A	2.0%	(6.7%)	1.4%	62.9%
Analog	21.7%	28.7%	36.5%	(7.4%)	38.3%
Total Discrete	(6.0%)	10.9%	25.5%	(21.6%)	25.5%
Total Optoelectronic	36.9%	39.0%	35.2%	(3.0%)	31.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 3e

Japanese Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	52.7%	(6.8%)	44.8%	25.7%	38.9%	6.3%
North American Captives	20.5%	11.9%	7.9%	10.4%	13.9%	10.2%
Total Semiconductor	53.3%	(7.1%)	45.5%	25.9%	39.2%	6.3%
Total IC	56.4%	(8.2%)	47.1%	28.0%	43.2%	9.5%
Bipolar Digital	35.3%	(13.7%)	57.2%	17.6%	25.1%	(19.8%)
Memory	49.5%	(16.6%)	24.3%	34.3%	53.3%	(34.2%)
Logic	32.7%	(13.1%)	63.7%	15.1%	20.2%	(16.6%)
MOS Digital	85.9%	(10.7%)	47.3%	34.9%	63.5%	19.0%
Memory	76.8%	(25.0%)	46.7%	30.5%	95.1%	40.9%
Micro	64.8%	(9.7%)	54.8%	39.0%	35.3%	0.6%
Logic	130.6%	9.4%	42.4%	36.1%	55.5%	4.9%
Analog	28.3%	(0.6%)	42.3%	20.8%	12.2%	(2.5%)
Total Discrete	44.3%	(7.7%)	38.3%	20.1%	21.9%	(2.7%)
Total Optoelectronic	48.2%	8.4%	49.4%	19.7%	40.4%	(9.2%)

Source: Dataquest
February 1990

Table 3f

Japanese Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	(0.3%)	14.2%	19.7%	28.6%	9.0%
North American Captives	3.1%	14.6%	19.9%	31.3%	7.9%
Total Semiconductor	(0.4%)	14.2%	19.7%	28.5%	9.0%
Total IC	0.1%	14.6%	21.1%	31.3%	8.4%
Bipolar Digital	(5.1%)	2.5%	4.4%	5.8%	(5.2%)
Memory	(3.5%)	(4.1%)	(9.4%)	(4.7%)	(4.9%)
Logic	(5.4%)	3.7%	6.7%	7.3%	(5.3%)
MOS Digital	0.7%	15.3%	23.2%	36.4%	7.7%
Memory	(1.7%)	10.6%	22.1%	42.9%	8.6%
Micro	3.6%	19.1%	23.0%	34.0%	10.0%
Logic	2.9%	20.2%	25.0%	28.5%	4.5%
Analog	0.2%	17.0%	19.9%	21.5%	15.0%
Total Discrete	(4.5%)	11.7%	13.2%	15.8%	11.2%
Total Optoelectronic	3.2%	13.9%	15.0%	17.0%	13.0%

Source: Dataquest
February 1990

Table 3g

Japanese Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	20.2%	13.8%	14.9%	N/A	14.3%
North American Captives	N/A	10.9%	14.9%	31.5%	N/A	22.9%
Total Semiconductor	26.0%	20.3%	13.8%	14.6%	23.1%	14.2%
Total IC	30.3%	22.1%	14.6%	15.9%	26.1%	15.3%
Bipolar Digital	25.7%	9.9%	0.4%	(0.8%)	17.5%	(0.2%)
Memory	25.7%	7.0%	(5.3%)	(13.3%)	16.0%	(9.4%)
Logic	25.7%	10.4%	1.3%	0.4%	17.8%	0.8%
MOS Digital	36.6%	28.1%	16.0%	18.1%	32.3%	17.1%
Memory	43.9%	31.6%	15.5%	19.2%	37.6%	17.4%
Micro	35.7%	21.5%	17.5%	18.5%	28.4%	18.0%
Logic	29.4%	28.2%	15.7%	15.9%	28.8%	15.8%
Analog	23.6%	13.3%	14.4%	9.3%	18.4%	11.8%
Total Discrete	14.6%	12.7%	9.2%	6.6%	13.6%	7.9%
Total Optoelectronic	28.9%	19.8%	12.3%	9.0%	24.3%	10.6%

N/A = Not Available

Source: Dataquest
February 1990

Table 4a

Japanese Semiconductor Market (Billions of Yen)

	1979	1980	1981	1982	1983
Total Including Captives	606.3	768.0	949.3	1,012.3	1,371.0
North American Captives	N/A	N/A	N/A	N/A	26.3
Total Semiconductor	606.3	768.0	949.3	1,012.3	1,344.7
Total IC	380.7	499.7	617.3	708.0	979.3
Bipolar Digital	66.6	78.3	96.8	123.5	165.9
Memory	11.4	12.9	17.0	21.6	25.6
Logic	55.2	65.4	79.8	101.9	140.3
MOS Digital	166.9	225.0	259.5	313.2	457.8
Memory	56.1	96.0	108.5	132.4	209.9
Micro	46.6	61.1	89.3	110.6	139.6
Logic	64.2	67.9	61.7	70.2	108.3
Analog	147.2	196.4	261.0	271.3	355.6
Total Discrete	194.7	223.8	273.4	240.6	286.0
Total Optoelectronic	30.9	44.5	58.6	63.7	79.4
Exchange Rate (Yen per US$1)	219	227	221	248	235

N/A = Not Available

Source: Dataquest
February 1990

Table 4b

Japanese Semiconductor Market (Billions of Yen)

	1984	1985	1986	1987	1988	1989
Total Including Captives	2,111.3	1,975.3	2,006.9	2,175.4	2,727.0	3,084.5
North American Captives	32.0	35.9	27.2	25.9	26.7	31.2
Total Semiconductor	2,079.3	1,939.4	1,979.7	2,149.5	2,700.3	3,053.3
Total IC	1,544.4	1,424.4	1,469.9	1,621.9	2,096.4	2,440.9
Bipolar Digital	226.3	196.1	216.2	219.3	247.7	211.5
Memory	38.6	32.4	28.2	32.7	45.2	31.7
Logic	187.7	163.7	188.0	186.6	202.5	179.8
MOS Digital	858.1	769.2	795.3	925.1	1,365.1	1,728.0
Memory	374.2	282.0	290.2	326.6	575.1	861.8
Micro	232.0	210.4	228.5	273.9	334.5	357.8
Logic	251.9	276.8	276.6	324.6	455.5	508.4
Analog	460.0	459.1	458.4	477.5	483.6	501.4
Total Discrete	416.2	385.8	374.4	387.8	426.7	441.4
Total Optoelectronic	118.7	129.2	135.4	139.8	177.2	171.0
Exchange Rate (Yen per US$1)	237	238	167	144	130	138

Source: Dataquest
February 1990

Table 4c

Japanese Semiconductor Market (Billions of Yen)

	1990	1991	1992	1993	1994	1999
Total Including Captives	3,178.8	3,629.6	4,344.6	5,586.0	6,086.7	12,163.5
North American Captives	33.3	38.2	45.8	60.1	64.8	254.8
Total Semiconductor	3,145.5	3,591.4	4,298.8	5,525.9	6,021.9	11,908.7
Total IC	2,527.2	2,896.5	3,508.6	4,607.9	4,996.0	10,445.4
Bipolar Digital	207.5	212.8	222.3	235.1	222.8	214.1
Memory	31.6	30.3	27.5	26.2	24.9	12.2
Logic	175.9	182.5	194.8	208.9	197.9	201.9
MOS Digital	1,800.4	2,075.8	2,557.6	3,487.6	3,755.3	8,643.6
Memory	875.8	968.5	1,182.6	1,689.8	1,835.3	4,425.1
Micro	383.4	456.6	561.6	752.6	827.8	1,934.4
Logic	541.2	650.7	813.4	1,045.2	1,092.2	2,284.1
Analog	519.3	607.9	728.7	885.2	1,017.9	1,587.7
Total Discrete	435.7	486.8	551.0	638.1	709.6	976.7
Total Optoelectronic	182.6	208.1	239.2	279.9	316.3	486.6
Exchange Rate (Yen per US$1)	143	143	143	143	143	143

Source: Dataquest
February 1990

Table 4d

Japanese Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	17.9%	26.7%	23.6%	6.6%	32.8%
Total IC	29.6%	31.3%	23.5%	14.7%	38.3%
Bipolar Digital	22.4%	17.6%	23.6%	27.6%	34.3%
Memory	N/A	13.2%	31.8%	27.1%	18.5%
Logic	N/A	18.5%	22.0%	27.7%	37.7%
MOS Digital	35.2%	34.8%	15.3%	20.7%	46.2%
Memory	N/A	71.1%	13.0%	22.0%	58.5%
Micro	N/A	31.1%	46.2%	23.9%	26.2%
Logic	N/A	5.8%	(9.1%)	13.8%	54.3%
Analog	27.0%	33.4%	32.9%	3.9%	31.1%
Total Discrete	(2.0%)	14.9%	22.2%	(12.0%)	18.9%
Total Optoelectronic	42.9%	44.0%	31.7%	8.7%	24.6%

N/A = Not Available

Source: Dataquest
February 1990

Table 4e

Japanese Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	54.0%	(6.4%)	1.6%	8.4%	25.4%	13.1%
North American Captives	21.7%	12.2%	(24.2%)	(4.8%)	3.1%	16.9%
Total Semiconductor	54.6%	(6.7%)	2.1%	8.6%	25.6%	13.1%
Total IC	57.7%	(7.8%)	3.2%	10.3%	29.3%	16.4%
Bipolar Digital	36.4%	(13.3%)	10.2%	1.4%	13.0%	(14.6%)
Memory	50.8%	(16.1%)	(13.0%)	16.0%	38.2%	(29.9%)
Logic	33.8%	(12.8%)	14.8%	(0.7%)	8.5%	(11.2%)
MOS Digital	87.4%	(10.4%)	3.4%	16.3%	47.6%	26.6%
Memory	78.3%	(24.6%)	2.9%	12.5%	76.1%	49.9%
Micro	66.2%	(9.3%)	8.6%	19.9%	22.1%	7.0%
Logic	132.6%	9.9%	(0.1%)	17.4%	40.3%	11.6%
Analog	29.4%	(0.2%)	(0.2%)	4.2%	1.3%	3.7%
Total Discrete	45.5%	(7.3%)	(3.0%)	3.6%	10.0%	3.4%
Total Optoelectronic	49.5%	8.8%	4.8%	3.2%	26.8%	(3.5%)

Source: Dataquest
February 1990

Table 4f

Japanese Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	3.1%	14.2%	19.7%	28.6%	9.0%
North American Captives	6.7%	14.7%	19.9%	31.2%	7.8%
Total Semiconductor	3.0%	14.2%	19.7%	28.5%	9.0%
Total IC	3.5%	14.6%	21.1%	31.3%	8.4%
Bipolar Digital	(1.9%)	2.6%	4.5%	5.8%	(5.2%)
Memory	(0.3%)	(4.1%)	(9.2%)	(4.7%)	(5.0%)
Logic	(2.2%)	3.8%	6.7%	7.2%	(5.3%)
MOS Digital	4.2%	15.3%	23.2%	36.4%	7.7%
Memory	1.6%	10.6%	22.1%	42.9%	8.6%
Micro	7.2%	19.1%	23.0%	34.0%	10.0%
Logic	6.5%	20.2%	25.0%	28.5%	4.5%
Analog	3.6%	17.1%	19.9%	21.5%	15.0%
Total Discrete	(1.3%)	11.7%	13.2%	15.8%	11.2%
Total Optoelectronic	6.8%	14.0%	14.9%	17.0%	13.0%

Source: Dataquest
February 1990

Table 4g

Japanese Semiconductor Market (Compound Annual Growth Rates in Yen)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	7.9%	14.6%	14.9%	N/A	14.7%
North American Captives	N/A	(0.5%)	15.7%	31.5%	N/A	23.4%
Total Semiconductor	28.0%	8.0%	14.5%	14.6%	17.5%	14.6%
Total IC	32.3%	9.6%	15.4%	15.9%	20.4%	15.6%
Bipolar Digital	27.7%	(1.3%)	1.0%	(0.8%)	12.2%	0.1%
Memory	27.6%	(3.9%)	(4.7%)	(13.3%)	10.8%	(9.1%)
Logic	27.7%	(0.9%)	1.9%	0.4%	12.5%	1.2%
MOS Digital	38.7%	15.0%	16.8%	18.1%	26.3%	17.5%
Memory	46.2%	18.2%	16.3%	19.2%	31.4%	17.8%
Micro	37.9%	9.1%	18.3%	18.5%	22.6%	18.4%
Logic	31.4%	15.1%	16.5%	15.9%	23.0%	16.2%
Analog	25.6%	1.7%	15.2%	9.3%	13.0%	12.2%
Total Discrete	16.4%	1.2%	10.0%	6.6%	8.5%	8.3%
Total Optoelectronic	30.9%	7.6%	13.1%	9.0%	18.7%	11.0%

N/A = Not Available

Source: Dataquest
February 1990

Table 5a

Western European Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	3,018	3,686	3,041	3,167	3,650
North American Captives	N/A	N/A	N/A	N/A	280
Total Semiconductor	3,018	3,686	3,041	3,167	3,370
Total IC	1,747	2,333	1,892	1,988	2,323
Bipolar Digital	390	510	454	434	483
Memory	85	116	103	100	107
Logic	305	394	351	334	376
MOS Digital	781	1,139	882	948	1,227
Memory	367	543	426	469	581
Micro	125	189	149	168	239
Logic	289	407	307	311	407
Analog	576	684	556	606	613
Total Discrete	1,138	1,192	995	1,011	866
Total Optoelectronic	133	161	154	168	181

N/A = Not Available

Source: Dataquest
February 1990

Table 5b

Western European Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	5,245	5,218	5,992	6,949	9,003	10,168
North American Captives	338	379	405	451	512	568
Total Semiconductor	4,907	4,839	5,587	6,498	8,491	9,600
Total IC	3,752	3,634	4,116	4,840	6,669	7,719
Bipolar Digital	741	719	719	727	772	692
Memory	144	150	147	88	74	72
Logic	597	569	572	639	698	620
MOS Digital	2,146	1,952	2,270	2,761	4,364	5,476
Memory	990	749	813	854	1,797	2,558
Micro	476	489	574	805	1,212	1,290
Logic	680	714	883	1,102	1,355	1,628
Analog	865	963	1,127	1,352	1,533	1,551
Total Discrete	955	981	1,207	1,377	1,516	1,577
Total Optoelectronic	200	224	264	281	306	304

Source: Dataquest
February 1990

Table 5c

Western European Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	10,551	12,120	14,535	19,042	21,143	43,711
North American Captives	582	666	800	1,051	1,133	3,314
Total Semiconductor	9,969	11,454	13,735	17,991	20,010	40,397
Total IC	8,125	9,499	11,589	15,448	17,213	36,270
Bipolar Digital	669	692	768	853	905	1,099
Memory	65	70	73	71	67	49
Logic	604	622	695	782	838	1,050
MOS Digital	5,894	7,026	8,744	12,096	13,429	30,298
Memory	2,815	3,338	4,139	5,936	6,684	16,288
Micro	1,332	1,606	1,960	2,775	3,053	6,552
Logic	1,747	2,082	2,645	3,385	3,692	7,458
Analog	1,562	1,781	2,077	2,499	2,879	4,873
Total Discrete	1,548	1,640	1,781	2,100	2,277	3,239
Total Optoelectronic	296	315	365	443	520	888

Source: Dataquest
February 1990

Table 5d

Western European Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	29.0%	22.1%	(17.5%)	4.1%	6.4%
Total IC	41.1%	33.5%	(18.9%)	5.1%	16.9%
Bipolar Digital	34.0%	30.8%	(11.0%)	(4.4%)	11.3%
Memory	N/A	36.5%	(11.2%)	(2.9%)	7.0%
Logic	N/A	29.2%	(10.9%)	(4.8%)	12.6%
MOS Digital	46.0%	45.8%	(22.6%)	7.5%	29.4%
Memory	N/A	48.0%	(21.5%)	10.1%	23.9%
Micro	N/A	51.2%	(21.2%)	12.8%	42.3%
Logic	N/A	40.8%	(24.6%)	1.3%	30.9%
Analog	39.8%	18.8%	(18.7%)	9.0%	1.2%
Total Discrete	13.3%	4.7%	(16.5%)	1.6%	(14.3%)
Total Optoelectronic	37.1%	21.1%	(4.3%)	9.1%	7.7%

N/A = Not Available

Source: Dataquest
February 1990

Table 5e

Western European Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	43.7%	(0.5%)	14.8%	16.0%	29.6%	12.9%
North American Captives	20.7%	12.1%	6.9%	11.4%	13.5%	10.9%
Total Semiconductor	45.6%	(1.4%)	15.5%	16.3%	30.7%	13.1%
Total IC	61.5%	(3.1%)	13.3%	17.6%	37.8%	15.7%
Bipolar Digital	53.4%	(3.0%)	0	1.1%	6.2%	(10.4%)
Memory	34.6%	4.2%	(2.0%)	(40.1%)	(15.9%)	(2.7%)
Logic	58.8%	(4.7%)	0.5%	11.7%	9.2%	(11.2%)
MOS Digital	74.9%	(9.0%)	16.3%	21.6%	58.1%	25.5%
Memory	70.4%	(24.3%)	8.5%	5.0%	110.4%	42.3%
Micro	99.2%	2.7%	17.4%	40.2%	50.6%	6.4%
Logic	67.1%	5.0%	23.7%	24.8%	23.0%	20.1%
Analog	41.1%	11.3%	17.0%	20.0%	13.4%	1.2%
Total Discrete	10.3%	2.7%	23.0%	14.1%	10.1%	4.0%
Total Optoelectronic	10.5%	12.0%	17.9%	6.4%	8.9%	(0.7%)

Source: Dataquest
February 1990

Table 5f

Western European Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	3.8%	14.9%	19.9%	31.0%	11.0%
North American Captives	2.5%	14.4%	20.1%	31.4%	7.8%
Total Semiconductor	3.8%	14.9%	19.9%	31.0%	11.2%
Total IC	5.3%	16.9%	22.0%	33.3%	11.4%
Bipolar Digital	(3.3%)	3.4%	11.0%	11.1%	6.1%
Memory	(9.7%)	7.7%	4.3%	(2.7%)	(5.6%)
Logic	(2.6%)	3.0%	11.7%	12.5%	7.2%
MOS Digital	7.6%	19.2%	24.5%	38.3%	11.0%
Memory	10.0%	18.6%	24.0%	43.4%	12.6%
Micro	3.3%	20.6%	22.0%	41.6%	10.0%
Logic	7.3%	19.2%	27.0%	28.0%	9.1%
Analog	0.7%	14.0%	16.6%	20.3%	15.2%
Total Discrete	(1.8%)	5.9%	8.6%	17.9%	8.4%
Total Optoelectronic	(2.6%)	6.4%	15.9%	21.4%	17.4%

Source: Dataquest
February 1990

Table 5g

Western European Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	14.2%	15.8%	15.6%	N/A	15.7%
North American Captives	N/A	10.9%	14.8%	23.9%	N/A	19.3%
Total Semiconductor	10.2%	14.4%	15.8%	15.1%	12.3%	15.5%
Total IC	16.5%	15.5%	17.4%	16.1%	16.0%	16.7%
Bipolar Digital	13.7%	(1.4%)	5.5%	4.0%	5.9%	4.7%
Memory	11.1%	(12.9%)	(1.4%)	(6.1%)	(1.6%)	(3.8%)
Logic	14.4%	0.8%	6.2%	4.6%	7.4%	5.4%
MOS Digital	22.4%	20.6%	19.7%	17.7%	21.5%	18.7%
Memory	22.0%	20.9%	21.2%	19.5%	21.4%	20.3%
Micro	30.7%	22.1%	18.8%	16.5%	26.3%	17.6%
Logic	18.7%	19.1%	17.8%	15.1%	18.9%	16.4%
Analog	8.5%	12.4%	13.2%	11.1%	10.4%	12.1%
Total Discrete	(3.4%)	10.6%	7.6%	7.3%	3.3%	7.5%
Total Optoelectronic	8.5%	8.7%	11.3%	11.3%	8.6%	11.3%

N/A = Not Available

Source: Dataquest
February 1990

Table 6a

Rest of World Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	790	996	963	1,042	1,443
North American Captives	N/A	N/A	N/A	N/A	0
Total Semiconductor	790	996	963	1,042	1,443
Total IC	364	450	494	585	909
Bipolar Digital	79	108	106	113	162
Memory	2	3	3	4	14
Logic	77	105	103	109	148
MOS Digital	100	143	171	248	450
Memory	25	34	51	106	194
Micro	17	27	43	63	112
Logic	58	82	77	79	144
Analog	185	199	217	224	297
Total Discrete	334	436	375	365	429
Total Optoelectronic	92	110	94	92	105

N/A = Not Available

Source: Dataquest
February 1990

Table 6b

Rest of World Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	2,216	1,949	2,548	3,968	5,752	6,633
North American Captives	0	0	0	0	0	0
Total Semiconductor	2,216	1,949	2,548	3,968	5,752	6,633
Total IC	1,328	1,179	1,714	2,898	4,457	5,316
Bipolar Digital	257	203	281	411	510	456
Memory	26	15	23	35	32	27
Logic	231	188	258	376	478	429
MOS Digital	700	616	871	1,550	2,517	3,362
Memory	234	134	185	437	1173	1646
Micro	145	117	185	389	652	808
Logic	321	365	501	724	692	908
Analog	371	360	562	937	1430	1498
Total Discrete	773	679	739	943	1138	1162
Total Optoelectronic	115	91	95	127	157	155

Source: Dataquest
February 1990

Table 6c

Rest of World Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	7,141	8,573	10,675	14,803	16,308	42,039
North American Captives	0	0	0	0	0	504
Total Semiconductor	7,141	8,573	10,675	14,803	16,308	41,535
Total IC	5,667	6,863	8,697	12,420	13,672	36,809
Bipolar Digital	421	461	513	588	534	666
Memory	27	27	26	27	27	25
Logic	394	434	487	561	507	641
MOS Digital	3,622	4,405	5,688	8,457	9,271	26,521
Memory	1810	2053	2648	4062	4350	13322
Micro	863	1165	1469	2187	2443	6363
Logic	949	1187	1571	2208	2478	6836
Analog	1624	1997	2496	3375	3867	9622
Total Discrete	1312	1517	1745	2094	2309	4069
Total Optoelectronic	162	193	233	289	327	657

Source: Dataquest
February 1990

Table 6d

Rest of World Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	19.7%	26.1%	(3.3%)	8.2%	38.5%
Total IC	41.1%	23.6%	9.8%	18.4%	55.4%
Bipolar Digital	75.6%	36.7%	(1.9%)	6.6%	43.4%
Memory	N/A	50.0%	0	33.3%	250.0%
Logic	N/A	36.4%	(1.9%)	5.8%	35.8%
MOS Digital	(9.1%)	43.0%	19.6%	45.0%	81.5%
Memory	N/A	36.0%	50.0%	107.8%	83.0%
Micro	N/A	58.8%	59.3%	46.5%	77.8%
Logic	N/A	41.4%	(6.1%)	2.6%	82.3%
Analog	79.6%	7.6%	9.0%	3.2%	32.6%
Total Discrete	(3.5%)	30.5%	(14.0%)	(2.7%)	17.5%
Total Optoelectronic	64.3%	19.6%	(14.5%)	(2.1%)	14.1%

N/A = Not Available

Source: Dataquest
February 1990

Table 6e

Rest of World Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	N/M	N/M	N/M	N/M	N/M	N/M
North American Captives	N/M	N/M	N/M	N/M	N/M	N/M
Total Semiconductor	53.6%	(12.0%)	30.7%	55.7%	45.0%	15.3%
Total IC	46.1%	(11.2%)	45.4%	69.1%	53.8%	19.3%
Bipolar Digital	58.6%	(21.0%)	38.4%	46.3%	24.1%	(10.6%)
Memory	85.7%	(42.3%)	53.3%	52.2%	(8.6%)	(15.6%)
Logic	56.1%	(18.6%)	37.2%	45.7%	27.1%	(10.3%)
MOS Digital	55.6%	(12.0%)	41.4%	78.0%	62.4%	33.6%
Memory	20.6%	(42.7%)	38.1%	136.2%	168.4%	40.3%
Micro	29.5%	(19.3%)	58.1%	110.3%	67.6%	23.9%
Logic	122.9%	13.7%	37.3%	44.5%	(4.4%)	31.2%
Analog	24.9%	(3.0%)	56.1%	66.7%	52.6%	4.8%
Total Discrete	80.2%	(12.2%)	8.8%	27.6%	20.7%	2.1%
Total Optoelectronic	9.5%	(20.9%)	4.4%	33.7%	23.6%	(1.3%)

N/M = Not Meaningful

Source: Dataquest
February 1990

Table 6f

Rest of World Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	N/M	N/M	N/M	N/M	N/M
North American Captives	N/M	N/M	N/M	N/M	N/M
Total Semiconductor	7.7%	20.1%	24.5%	38.7%	10.2%
Total IC	6.6%	21.1%	26.7%	42.8%	10.1%
Bipolar Digital	(7.7%)	9.5%	11.3%	14.6%	(9.2%)
Memory	0	0	(3.7%)	3.8%	0
Logic	(8.2%)	10.2%	12.2%	15.2%	(9.6%)
MOS Digital	7.7%	21.6%	29.1%	48.7%	9.6%
Memory	10.0%	13.4%	29.0%	53.4%	7.1%
Micro	6.8%	35.0%	26.1%	48.9%	11.7%
Logic	4.5%	25.1%	32.4%	40.5%	12.2%
Analog	8.4%	23.0%	25.0%	35.2%	14.6%
Total Discrete	12.9%	15.6%	15.0%	20.0%	10.3%
Total Optoelectronic	4.5%	19.1%	20.7%	24.0%	13.1%

N/M = Not Meaningful

Source: Dataquest
February 1990

Table 6g

Rest of World Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	22.9%	24.5%	19.7%	20.6%	23.7%	20.1%
Total IC	29.5%	32.0%	20.8%	21.9%	30.8%	21.3%
Bipolar Digital	26.6%	12.2%	3.2%	4.5%	19.2%	3.9%
Memory	67.0%	0.8%	0	(1.5%)	29.7%	(0.8%)
Logic	24.6%	13.2%	3.4%	4.8%	18.7%	4.1%
MOS Digital	47.6%	36.9%	22.5%	23.4%	42.1%	22.9%
Memory	56.4%	47.7%	21.5%	25.1%	52.0%	23.3%
Micro	53.5%	41.0%	24.8%	21.1%	47.1%	22.9%
Logic	40.8%	23.1%	22.2%	22.5%	31.7%	22.4%
Analog	14.9%	32.2%	20.9%	20.0%	23.3%	20.4%
Total Discrete	18.3%	8.5%	14.7%	12.0%	13.3%	13.4%
Total Optoelectronic	4.6%	6.2%	16.1%	15.0%	5.4%	15.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 7a

Worldwide Average Selling Prices (Dollars)

	1979	1980	1981	1982	1983
Total Semiconductor	0.29	0.33	0.31	0.33	0.32
Total IC	0.97	1.07	1.02	0.99	1.03
Bipolar Digital	0.57	0.70	0.70	0.62	0.65
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.93	1.81	1.66	1.63	1.66
Memory	5.15	4.90	3.17	2.62	2.79
Micro	3.96	3.61	3.40	3.26	3.35
Logic	0.89	0.85	0.86	0.80	0.79
Analog	0.78	0.83	0.81	0.79	0.76
Total Discrete	0.12	0.12	0.11	0.11	0.09
Total Optoelectronic	0.51	0.44	0.39	0.29	0.28

N/A = Not Available

Source: Dataquest
February 1990

Table 7b

Worldwide Average Selling Prices (Dollars)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	0.36	0.30	0.34	0.33	0.42	0.42
Total IC	1.10	1.05	1.09	1.18	1.40	1.45
Bipolar Digital	0.65	0.71	0.71	0.69	0.70	0.69
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.95	1.64	1.63	1.94	2.36	2.35
Memory	3.90	2.59	2.41	3.09	4.70	6.62
Micro	3.53	3.14	3.13	3.56	4.15	3.67
Logic	0.85	0.93	0.99	1.12	1.13	0.95
Analog	0.75	0.76	0.84	0.82	0.84	0.76
Total Discrete	0.09	0.08	0.09	0.08	0.09	0.08
Total Optoelectronic	0.28	0.22	0.25	0.28	0.34	0.31

N/A = Not Available

Source: Dataquest
February 1990

Table 7c

Worldwide Average Selling Prices (Dollars)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	0.42	0.48	0.52	0.58	0.52	0.75
Total IC	1.44	1.53	1.61	1.84	1.68	2.06
Bipolar Digital	0.68	0.69	0.70	0.71	0.69	0.69
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	2.25	2.45	2.51	2.97	2.55	2.92
Memory	6.80	6.65	7.06	8.73	8.53	9.75
Micro	3.65	3.68	4.12	4.18	4.05	4.15
Logic	0.90	1.05	1.05	1.19	0.95	1.05
Analog	0.77	0.79	0.81	0.82	0.80	0.88
Total Discrete	0.08	0.09	0.09	0.09	0.08	0.09
Total Optoelectronic	0.31	0.34	0.35	0.36	0.35	0.38

N/A = Not Available

Source: Dataquest
February 1990

Table 7d

Worldwide Average Selling Prices (Percent Change in Dollars)

	1979	1980	1981	1982	1983
Total Semiconductor	3.6%	11.7%	(6.4%)	7.5%	(3.0%)
Total IC	(4.0%)	9.8%	(3.9%)	(2.8%)	3.1%
Bipolar Digital	(9.5%)	22.8%	0	(11.4%)	4.8%
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.2%	(6.3%)	(8.4%)	(1.8%)	2.2%
Memory	N/A	(4.9%)	(35.3%)	(17.4%)	6.5%
Micro	N/A	(8.8%)	(5.8%)	(4.1%)	2.8%
Logic	N/A	(4.5%)	1.2%	(7.0%)	(1.3%)
Analog	(7.1%)	6.4%	(2.4%)	(2.5%)	(3.8%)
Total Discrete	(7.7%)	0	(8.3%)	0	(18.2%)
Total Optoelectronic	8.0%	(12.8%)	(11.9%)	(25.6%)	(3.4%)

N/A = Not Available

Source: Dataquest
February 1990

Table 7e

Worldwide Average Selling Prices (Percent Change in Dollars)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	11.8%	(15.7%)	13.2%	(2.7%)	26.5%	(0.4%)
Total IC	7.5%	(4.4%)	3.5%	8.5%	18.0%	3.8%
Bipolar Digital	0	9.2%	0	(2.8%)	1.4%	(1.4%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	17.3%	(16.0%)	(0.5%)	18.6%	22.1%	(0.7%)
Memory	39.8%	(33.6%)	(6.9%)	28.2%	52.1%	40.9%
Micro	5.4%	(11.0%)	(0.3%)	13.7%	16.6%	(11.6%)
Logic	7.6%	9.4%	6.5%	13.1%	0.9%	(15.9%)
Analog	(1.3%)	1.3%	10.5%	(2.4%)	2.4%	(9.5%)
Total Discrete	0	(11.1%)	15.0%	(13.0%)	12.5%	(11.1%)
Total Optoelectronic	0	(21.4%)	13.6%	12.0%	21.4%	(8.8%)

N/A = Not Available

Source: Dataquest
February 1990

Table 7f

Worldwide Average Selling Prices (Percent Change in Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	0.6%	14.1%	6.8%	13.3%	(10.7%)
Total IC	(0.6%)	6.5%	4.6%	14.3%	(8.6%)
Bipolar Digital	(1.4%)	1.5%	1.4%	1.4%	(2.8%)
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	(4.1%)	8.9%	2.4%	18.6%	(14.3%)
Memory	2.7%	(2.2%)	6.2%	23.7%	(2.3%)
Micro	(0.5%)	0.8%	12.0%	1.5%	(3.1%)
Logic	(5.3%)	16.7%	0	13.3%	(20.2%)
Analog	1.3%	2.6%	2.5%	1.2%	(2.4%)
Total Discrete	0	12.5%	0	0	(11.1%)
Total Optoelectronic	0	9.7%	2.9%	2.9%	(2.8%)

N/A = Not Available

Source: Dataquest
February 1990

Table 7g

Worldwide Average Selling Prices
(Compound Annual Growth Rates in U.S. Dollars)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	4.1%	3.2%	4.4%	7.7%	3.6%	6.0%
Total IC	2.6%	5.6%	3.0%	4.1%	4.1%	3.6%
Bipolar Digital	2.7%	1.2%	0	0	1.9%	0
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	0.2%	3.7%	1.7%	2.8%	2.0%	2.2%
Memory	(5.4%)	11.2%	5.2%	2.7%	2.5%	3.9%
Micro	(2.3%)	0.8%	2.0%	0.5%	(0.8%)	1.2%
Logic	(0.9%)	2.2%	0	2.0%	0.7%	1.0%
Analog	(0.8%)	0.3%	1.0%	1.9%	(0.3%)	1.5%
Total Discrete	(5.6%)	(2.3%)	0	2.4%	(4.0%)	1.2%
Total Optoelectronic	(11.2%)	2.1%	2.5%	1.7%	(4.8%)	2.1%

N/A = Not Available

Source: Dataquest
February 1990

Table 8a

Worldwide Semiconductor Market (Millions of Units)

	1979	1980	1981	1982	1983
Total Semiconductor	37,703	42,870	48,081	46,022	60,743
Total IC	7,242	8,955	9,809	10,949	14,327
Bipolar Digital	2,937	3,391	3,339	3,890	4,638
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1,731	2,603	2,906	3,464	4,776
Memory	325	455	655	1,031	1,333
Micro	137	239	319	404	591
Logic	1,269	1,909	1,933	2,029	2,852
Analog	2,574	2,960	3,564	3,595	4,913
Total Discrete	29,350	32,358	36,227	32,245	42,944
Total Optoelectronic	1,111	1,557	2,045	2,828	3,471

N/A = Not Available

Source: Dataquest
February 1990

Table 8b

Worldwide Semiconductor Market (Millions of Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	80,377	80,380	89,881	114,551	120,410	134,174
Total IC	20,573	17,607	21,654	25,260	29,423	32,267
Bipolar Digital	7,340	5,172	6,092	6,899	7,429	6,390
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	6,639	6,171	7,850	9,028	11,423	14,301
Memory	1,597	1,475	1,872	1,960	2,488	2,550
Micro	916	875	1,115	1,435	1,721	2,025
Logic	4,126	3,820	4,864	5,633	7,214	9,725
Analog	6,593	6,264	7,712	9,334	10,571	11,576
Total Discrete	55,411	57,200	62,283	83,188	84,578	95,275
Total Optoelectronic	4,393	5,573	5,944	6,104	6,409	6,632

N/A = Not Available

Source: Dataquest
February 1990

Table 8c

Worldwide Semiconductor Market (Millions of Units)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	135,410	136,494	153,921	178,499	217,092	309,694
Total IC	32,994	35,906	41,910	49,185	58,277	102,495
Bipolar Digital	6,013	6,167	6,424	6,806	6,633	6,065
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	15,327	16,485	20,064	23,536	29,696	59,573
Memory	2,511	2,920	3,420	4,057	4,490	9,434
Micro	2,132	2,558	2,832	3,807	4,318	9,496
Logic	10,683	11,008	13,812	15,672	20,888	40,642
Analog	11,655	13,254	15,422	18,843	21,948	36,857
Total Discrete	95,613	93,600	104,222	120,389	148,413	191,822
Total Optoelectronic	6,803	6,988	7,789	8,925	10,403	15,376

N/A = Not Available

Source: Dataquest
February 1990

Table 8d

Worldwide Semiconductor Market (Percent Change in Units)

	1979	1980	1981	1982	1983
Total Semiconductor	20%	14%	12%	(4%)	32%
Total IC	40%	24%	10%	12%	31%
Bipolar Digital	47%	15%	(2%)	17%	19%
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	42%	50%	12%	19%	38%
Memory	N/A	40%	44%	57%	29%
Micro	N/A	75%	34%	27%	46%
Logic	N/A	51%	1%	5%	41%
Analog	32%	15%	20%	1%	37%
Total Discrete	16%	10%	12%	(11%)	33%
Total Optoelectronic	24%	40%	31%	38%	23%

N/A = Not Available

Source: Dataquest
February 1990

Table 8e

Worldwide Semiconductor Market
(Percent Change in Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	32%	0	12%	27%	5%	11%
Total IC	44%	(14%)	23%	17%	16%	10%
Bipolar Digital	58%	(30%)	18%	13%	8%	(14%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	39%	(7%)	27%	15%	27%	25%
Memory	20%	(8%)	27%	5%	27%	3%
Micro	55%	(4%)	27%	29%	20%	18%
Logic	45%	(7%)	27%	16%	28%	35%
Analog	34%	(5%)	23%	21%	13%	10%
Total Discrete	29%	3%	9%	34%	2%	13%
Total Optoelectronic	27%	27%	7%	3%	5%	3%

N/A = Not Available

Source: Dataquest
February 1990

Table 8f

Worldwide Semiconductor Market
(Percent Change in Units)

	1990	1991	1992	1993	1994
Total Semiconductor	1%	1%	13%	16%	22%
Total IC	2%	9%	17%	17%	18%
Bipolar Digital	(6%)	3%	4%	6%	(3%)
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	7%	8%	22%	17%	26%
Memory	(2%)	16%	17%	19%	11%
Micro	5%	20%	11%	34%	13%
Logic	10%	3%	25%	13%	33%
Analog	1%	14%	16%	22%	16%
Total Discrete	0%	(2%)	11%	16%	23%
Total Optoelectronic	3%	3%	11%	15%	17%

N/A = Not Available

Source: Dataquest
February 1990

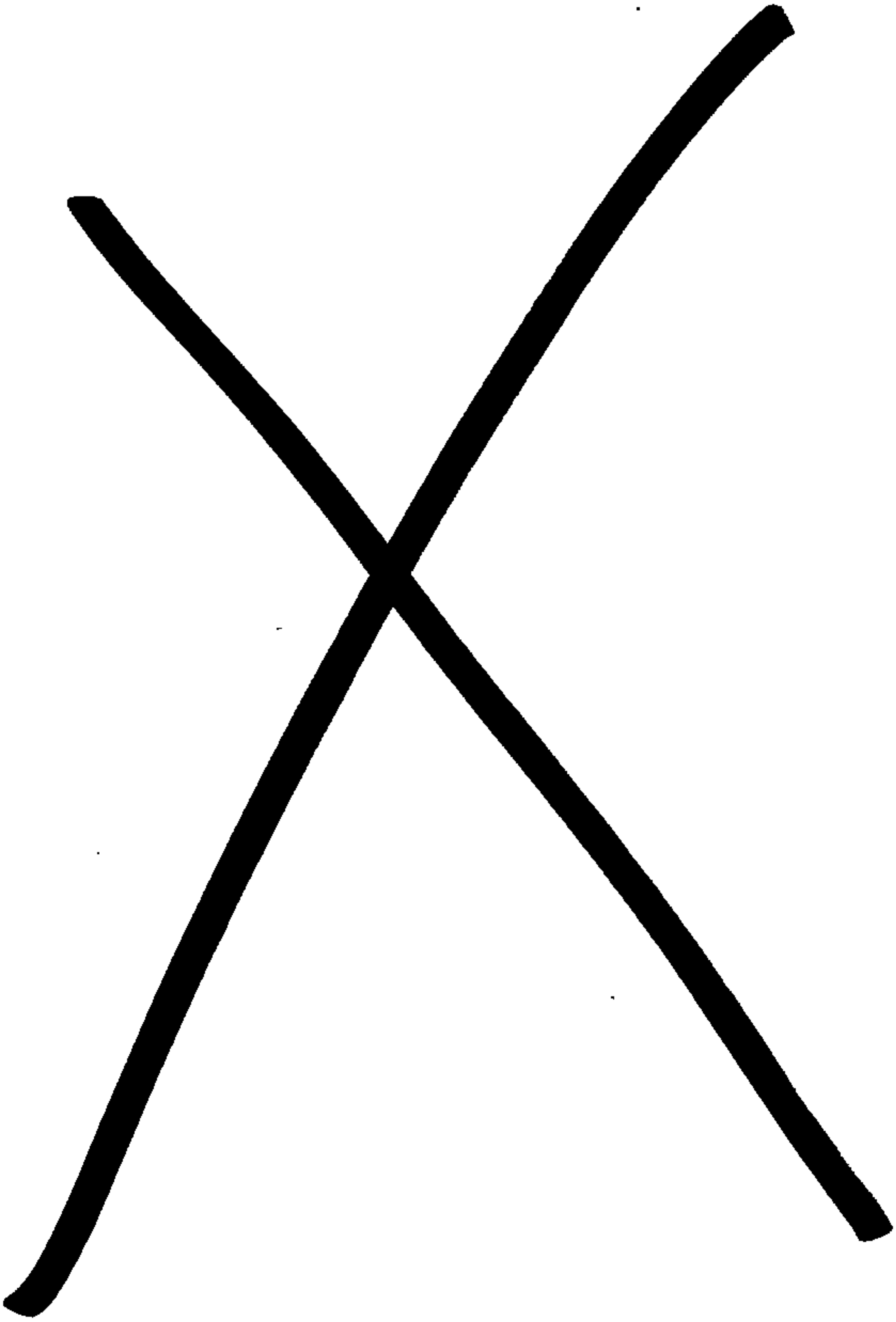
Table 8g

Worldwide Semiconductor Market
(Compound Annual Growth Rates in Millions of Units)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	16.3%	10.8%	10.1%	7.4%	13.5%	8.7%
Total IC	23.2%	9.4%	12.6%	12.0%	16.1%	12.3%
Bipolar Digital	20.1%	(2.7%)	0.8%	(1.8%)	8.1%	(0.5%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	30.9%	16.6%	15.7%	14.9%	23.5%	15.3%
Memory	37.5%	9.8%	12.0%	16.0%	22.9%	14.0%
Micro	46.3%	17.2%	16.4%	17.1%	30.9%	16.7%
Logic	26.6%	18.7%	16.5%	14.2%	22.6%	15.4%
Analog	20.7%	11.9%	13.6%	10.9%	16.2%	12.3%
Total Discrete	13.6%	11.4%	9.3%	5.3%	12.5%	7.2%
Total Optoelectronic	31.6%	8.6%	9.4%	8.1%	19.6%	8.8%

N/A = Not Available

Source: Dataquest
February 1990



Costs

The following is a list of material in this section:

- Semiconductor Cost Trends

Semiconductor Cost Trends

INTRODUCTION

Applications of Cost Model Analysis

Cost model use falls into two broad areas: near-term cost/price optimization planning and long-range system cost analysis. A usable model allows for both applications. The Dataquest semiconductor cost model uses 17 key variables of semiconductor manufacture after raw silicon wafers have been processed.

Semiconductor cost models are predominantly used to compile costs for use in near-term contract negotiations. By identifying areas where costs can be reduced, price negotiation results often benefit the buyer of parts. Applying experience-curve theory to cost model applications can give both short- and long-term cost price scenarios that can be a basis for strategic planning.

Strategic use of cost models in long-range planning has been under-utilized mainly because long-range variables are perceived as too erratic to model, let alone base plans on. By utilizing different learning curves to individual variables in the model and then modeling these derived inputs, one can better understand future trends and have alternative strategies at hand if any variable actually differs from its expected trend line. This method of cost model use can easily be made part, or the basis, of a proactive strategic plan.

The high rate of technological change in the semiconductor industry has caused the cost per function to decrease at an average rate of 35 percent per year for the last 20 years. This high rate of change is expected to continue for the foreseeable future.

COST ANALYSIS

Cost versus Price

In a competitive market, semiconductor manufacturers pass cost reductions on to their customers. Therefore, a knowledge of semiconductor costs and cost trends is useful for projecting long-term procurement costs and for selecting the most cost-effective semiconductor device for a particular application.

The cost/price relationship for semiconductor products varies from product to product, from company to company, and with time as a function of business conditions. A good way to perform cost/price analysis is to monitor prices and costs over a period of several years for selected product types and to identify the average gross margin for these types. By using this procedure, semiconductor users can develop a good feel for the cost/price relationship for the semiconductor products they buy. Buyers can use the cost/price data provided here to estimate the cost of purchased materials and determine target prices for future price negotiations.

Semiconductor Cost Trends

This section of the Semiconductor User Information Service notebooks provides users with the cost data necessary for cost/price analyses of specific semiconductor products.

Cost Factors

The cost of a semiconductor device is developed by adding the cost of each step in the manufacturing process. Figure 1 shows the manufacturing process flow for semiconductor devices and identifies the important cost steps in the process.

Our cost model categorizes costs into the following four areas:

- Wafer processing and die sort
- Assembly
- Final test
- Screening, qualification, mark, pack, and ship

Screening and qualification tests include burn-in and MIL-standard quality and reliability assurance processing requirements.

In our analyses, we have assumed that the product being modeled is being manufactured with technology that has passed the start-up phase. For example, shifts from 5-inch wafers will be indicated at a time when most manufacturers have made the change, rather than when the first manufacturer begins production.

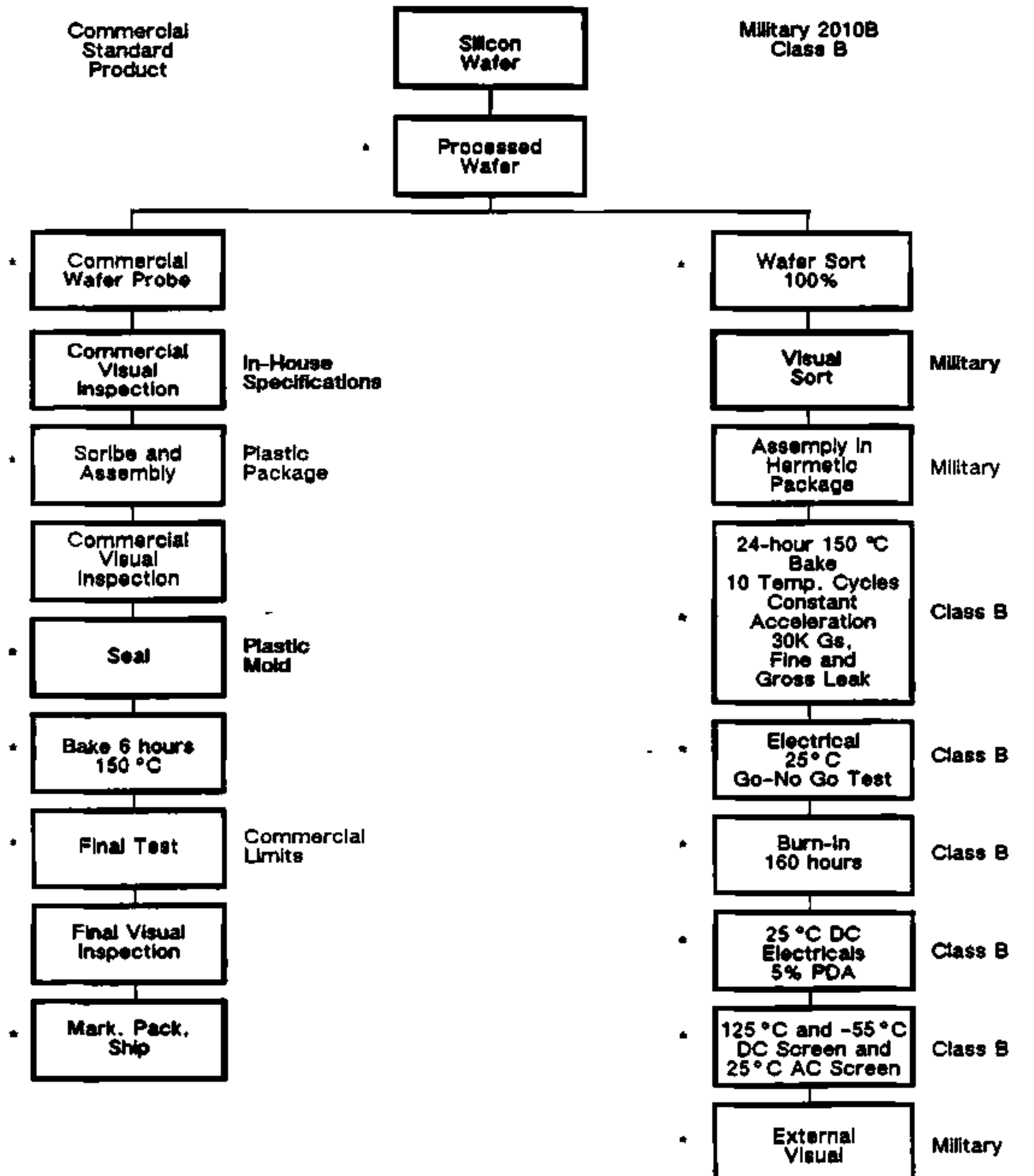
The manufacturing process starts with an unprocessed silicon wafer that costs from $15 to $25. After completing more than 100 processing steps, the cost of a processed wafer is 10 to 30 times the initial cost of the unprocessed wafer. The wafer cost is a function of the following:

- The number of mask layers required
- The photolithographic requirements
- The quality of chemicals and purchased wafers
- The clean room environment

There is a complex relationship among each of these elements, the processed wafer cost, and the end cost of the product.

Figure 1

Commercial and MIL-STD Manufacturing Flow



*Key Cost Points

0005851-1

Source: Dataquest February 1990

Number of Mask Layers

The cost of the wafer increases with each layer required. Additional mask layers could produce more defects and decrease yields. Generally speaking, more complex processes produce more expensive die. Table 1 lists the typical number of mask layers for most common integrated circuit processes.

Table 1

Integrated Circuit Process Mask Layers

	Typical Number of Layers	
Process	Single-Layer Metal	Multilayer Metal
Schottky TTL	7	9
ECL	8	10
NMOS	8	10
HMOS	9	11
CMOS	10	12-15
HCMOS	11	13-16
Bipolar Linear	7-9	9-11
BiMOS	14	16-18

Source: Dataquest
February 1990

Photolithographic Requirements

Wafer costs increase as device features become smaller. However, smaller features result in more die or more functions per wafer. While the wafer cost will be higher, the cost per function will often be lower.

Quality of Materials and Clean Room Environment

As device features become smaller, semiconductor circuits become more susceptible to defects in the semiconductor material. This results in lower yields. Defects occur in the purchased silicon wafers and masks; the defects are introduced during processing by chemicals and particles in the air.

Increasing the quality of materials and improving the clean room environment increases the cost of processed wafers. However, the resulting lower-defect material produces higher yields and lower unit costs. This is especially true for VLSI products.

Finished wafers are then tested and electrically sorted to separate the good die from the bad. The primary cost factors at wafer sort are the yield (percent) of good die on the wafer and the testing costs, which are a function of the cost per hour of using the test equipment and the time required to test each die. Increased wafer sort yield is the single most important factor in reducing the cost of VLSI products.

Package Costs

Electrically sorted die are then assembled into packages. Packaging costs vary from pennies to several dollars, depending on the type of packages needed. Table 2 provides cost estimates for representative packages used for integrated circuit products. As automation increases, labor content per device decreases. Total assembly costs are assumed to increase at a rate of 5 percent per year.

Assembled units then receive their final tests. The most important final test costs are the equipment operating cost, test time, and yield. The cost of performing tests over time is assumed to increase moderately, while yields increase as test methods and manufacturing methods are improved.

The final mark, pack, and ship step has only a minimal effect on the total product cost. Labor, shipping containers, and a 1 percent yield loss are the primary cost factors at this stage of manufacturing.

Table 2

1990 Packaging Cost Estimates Total Assembled Cost (Die–Free)

No. of Pins (Volume)	Plastic DIP (500K)	CERDIP/ CERQUAD (100K)	Ceramic* SideBraze (25K)	SOIC/ SOJ (500K)	PLCC (500K)	LDCC (25K)	CLCC (100K)	Ceramic PGA (25K)	Plastic PGA (25K)	QFP (EIAJ) (100K)	PQFP (JEDEC) (100K)
8	0.055	0.29	2.10	0.085	-	-	-	-	-	-	-
14	0.095	0.32	2.30	0.139	-	-	-	-	-	-	-
16	0.099	0.35	2.50	0.153	-	-	-	-	-	-	-
18	0.125	0.54	2.60	0.178	0.16	-	0.99	-	-	-	-
20	0.135	0.58	2.70	0.185	0.20	2.50	1.06	-	-	-	-
22	0.156	0.60	3.00	0.243	-	-	-	-	-	-	-
24	0.176	0.63	3.85	0.251	-	3.00	1.32	-	-	-	-
28	0.244	0.84	4.25	0.270	0.30	-	1.72	-	-	-	-
32	0.380	0.95	5.00	0.340	0.36	4.04	1.83	-	-	-	-
40	0.300	1.20	6.50	-	-	-	2.40	-	-	-	-
44	0.520	-	-	-	0.39	5.60	2.31	-	-	-	-
48	0.445	-	8.25	-	-	-	2.74	-	-	0.52	-
52	-	-	-	-	0.53	-	4.05	-	-	-	-
64	0.700	-	-	-	-	-	4.72	-	-	-	-
68	-	2.90	-	-	0.57	-	5.74	13.50	3.15	0.62	-
84	-	3.85	-	-	0.71	-	5.52	14.50	3.95	0.80(801d)	-
100	-	-	-	-	-	-	-	16.00	5.00	1.00	1.60
120	-	-	-	-	-	-	-	20.50	6.05	1.50	2.20(1321d)
140	-	-	-	-	-	-	-	28.50	7.15	1.70(1441d)	-
160	-	-	-	-	-	-	-	37.50	8.30	2.10	2.80(1641d)
180	-	-	-	-	-	-	-	-	-	-	-
208	-	-	-	-	-	-	-	55.20	10.56	5.50*	-
256	-	-	-	-	-	-	-	-	12.95	8.40*	-
308	-	-	-	-	-	-	-	-	15.40	-	-

*<5K Volume

Material Consideration:											
Ld Frame Mat'l	C194	A42	A42	C194	C151	A42	None	A42	Cu	A42	C194
Ld Form	TH	TH	TH	Gull	J	Gull	None	TH	TH	Gull	Gull
Wire	Au	Al	Al	Au	Au	Al	Al	Al	Au	Au	Au
Lid	Epoxy	Ceramic	Au/Kovar	Epoxy	Epoxy	Au/Kovar	Au/Kovar	Au/Kovar	Au/Epoxy	Epoxy	Epoxy
Preform	N/A	Glass	Au/Sn	N/A	N/A	Au/Sn	Au/Sn	Au/Sn	Epoxy	N/A	N/A

N/A = Not Available
*Without Gold Adder

Source: Dataquest
February 1990

Semiconductor Cost Trends

COST MODEL

This cost model determines the variable cost for the device modeled. The variable cost includes the cost of direct labor and materials for each product modeled.

Processed wafer cost, number of die per wafer, test cost per hour, and assembly cost are all empirical data; so are the yield percentages used in each step. The following outline shows how each line of the cost model is developed.

Wafer Sort	
Wafer size (diameter in inches)	= A
Capacity utilization (%)	= B
Geometry (microns)	= C
Processed wafer cost ($)	= D
Die area (square mils)	= E
Active area factor	= F
Number of masks	= G
Defect density per square inch per mask	= H
Gross die per wafer	= $I = (0.9 * \pi *(A/2) x 10^6/E$
Processed wafer cost per gross die ($)	= D/I = J
Test cost per hour ($)	= K
Wafers tested per hour	= L
Wafer sort cost per gross die ($) (K/L)/I	= M
Cost per gross die at wafer sort ($) J + M	= N
Wafer sort yield (%)=$(((E/F/10^6)*GxH)*100)$	= O
Cost per sorted die ($)=Nx100/0	= P
Assembly	
Material cost/sorted die-SOJ pkg. ($)	= Q
Number of Pins	= R
Assembly yield (%)	= S
Cost per assembled die ($)=(P + Q)/S*100	= T
Final Test	
Test time per die (sec.)	= U
Cost per hour of testing ($)	= V
Test cost per die ($) U * V/3600	= W
Final test yield (%)	= X
Cost per final tested unit ($)	= Y = (T + W)/X*100
Mark, Pack, and Ship	
Cost at 99% yield (%) = 0.01*Y	= Z
Total fabrication cost per unit ($)	= AA = Y+Z
Foreign Market Value (FMV) Formula Adders	
R&D expense (15%) = 0.15*AA	= AB
SG&A expense (10%) = (AA + AB)*0.10	= AC
Profit (8%) (AA + AB + AC)*0.08	= AD
Constructed FMV = AA + AB + AC + AD	

UNDERSTANDING YIELDS

Only a portion of die on a given wafer will meet the electrical test specifications to which the die was designed. The percentage of good die per wafer is known as yield. As a silicon wafer is processed, each step decreases the final yield of good parts that meet specification and are shippable.

Calculating Yield

There are several methods to calculate electrical test yields of semiconductor wafers. Dataquest uses an exponential equation called Murphy's formula to approximate yield:

$$\text{Yield} = e^{-DA};$$

where e is the constant 2.72, D is the defect density in defects per square inch, and A is the area of the chip in square inches. This mathematical formula is useful for analyzing the key factors that affect semiconductor yields: the number of defects on the wafer and the number of chips on the wafer. The number of chips per wafer is determined by the area of each chip. Defects on a wafer are caused by particles in the air falling on the wafer during semiconductor manufacture. The number of defects on a wafer is determined by the number of particles in the air and the number of mask steps required in the processing of the wafer. An increase in mask levels requires more time in the fab area, thus increasing the chances of particles falling on the wafer and causing a reduction in yield.

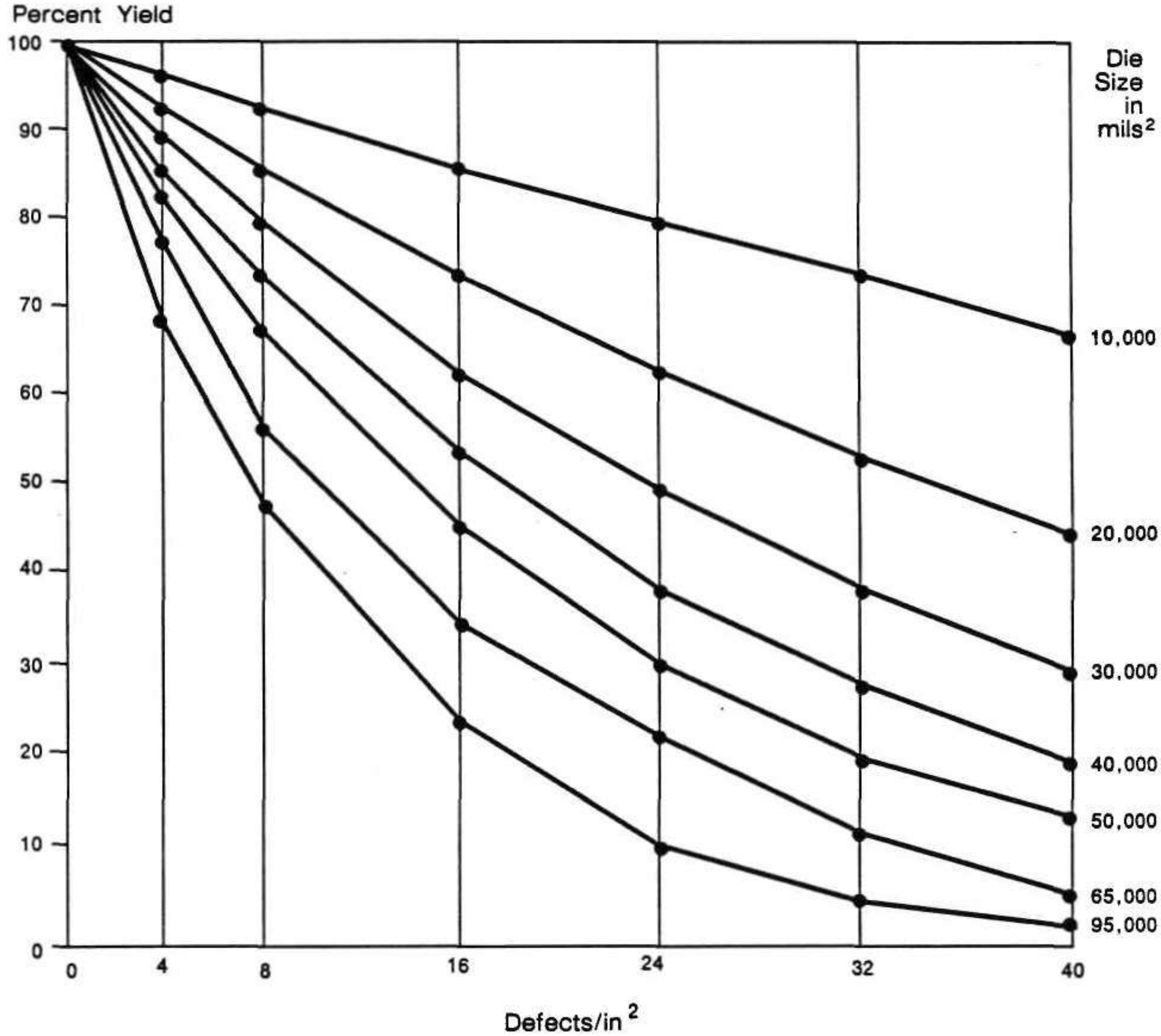
Yield Trade-Offs

Figure 2 describes graphically the effect of defects on wafer electrical test yield. Each line represents the yield curve size for a given defect density. Many facilities presently in production produce 8 to 20 defects per square inch, while state-of-the-art VLSI facilities will produce only from 1 to 5 defects per square inch. As the size of a die continues to increase, the effects of defects per square inch become increasingly detrimental to yield. In response to this necessity, Class 10 and lower clean rooms are becoming the norm for competitive semiconductor manufacturers. (Class refers to the amount of particulates of a certain size per square foot that exist in a clean room. For example, a Class 10 clean room has no more than 10 particulates per square foot.)

By taking a typical 1Mb DRAM with two different die sizes (approximately 75K square mils and 85K square mils) in two different manufacturing areas, one with 8 defects per square inch and the other with 4 defects per square inch, one can easily see in Table 3 the advantages of utilizing a clean room with less particulates. This points out why it is more economical to ship larger die if the fabrication area is cleaner, because more die per wafer are shippable.

Figure 2

Semiconductor Yield
Defect-Density Effect



0005851-2

Source: Dataquest February 1990

Table 3

1Mb DRAM Yield Loss to Defects
(Percent Good Die/Number Good Chips Per Wafer)

Chip Size (Mils^2)	Fab Area	
	8 Defects/In.^{2}	4 Defects/In.^{2}
75,000	54%--186 die	74%--251 die
85,000	51%--150 die	71%--213 die

Note: A cleaner fabrication area allows for more shippable product even if the die size is larger than in a "dirtier" area.

Source: Dataquest
February 1990

Yield and Related Costs

Semiconductor chips are electrically tested several times to separate die that meet specifications from those that do not. Wafer sort, assembly, and final test are the three areas in semiconductor manufacturing where related testing occurs.

Electrical Wafer Sort

The first test, electrical wafer sort, is done on processed wafers by a computer-based tester at a test station specifically designed for that device. The tester automatically tests each die on the wafer by contracting each pad on each chip and marking with a dot of ink those die that do not pass the test. Test costs consist of equipment operating costs, direct operator costs, and the amount of time required to test each wafer.

Equipment operating costs are dominated by the depreciation of the test equipment. Semiconductor test equipment is generally depreciated over five years and can range in price from $250,000 to $1,000,000, depending on test requirements. Dataquest uses estimates of test costs per hour ranging from $25 to $100 per hour. The most complex integrated circuit test costs range from $50 to $100 per hour.

Dataquest assumes that a test operator supports each piece of test equipment and estimates the labor cost per hour to be $17. The total test cost, including labor, then ranges from $40 to $115 per hour.

The time to test a wafer is determined by the circuit complexity, the number of chips per wafer, and the yield. Good die take about 10 times as long to test as bad die. Test programs are formulated and used to minimize test time by testing functions of the device statistically proven to most likely fail first. Test times for good die are kept to a minimum by performing only those tests that assure 85 to 90 percent test yield when packaged. Wafer sort test times for full-production VLSI chips takes no longer than 5 seconds for each chip.

Applying the above to a 1Mb DRAM example results in the following: there are 321 gross die per six-inch wafer, and 202 (63 percent) are good. The test time for each wafer is about 51 minutes. For this example, we use a test cost per hour of $58 ($41 for equipment, $17 for the operator). Total test cost per wafer is $49.30, with the test cost per die totaling $0.239.

Assembly and Packaging

Semiconductor chips in the form of processed and tested wafers are electrically functional and could be used as they are. Functional die in wafer form, although theoretically functional, are too fragile in that state for commercial or other use. In order to have a protective container for a device, various packages have been created to provide different devices with different degrees of ruggedness. Ranging from ceramic packages with gold contacts to blobs of plastic covering chips on PC boards, the encapsulation method for electrically good die is determined by the end use of the system that the device is part of.

Packaging technology has continuously improved, but the basic assembly steps have not changed significantly during the past 20 years. The three main areas of assembly are as follows:

- Die separation
- Die attach and lead bond
- Encapsulation

Die Separation. This step refers to the method of separating the individual die on a wafer. One technique is very similar to the method of cutting and breaking glass. A diamond stylus automatically scratches the wafer in the areas between the die, called scribe lines. Once the total wafer has been scribed, the wafer is placed on a machine that fractures the wafer along the scribe lines. Some manufacturers use laser scribe machines to etch a line along the scribe line. Thick wafers require diamond sawing along the scribe lines.

After the wafer is completely broken into individual die, each chip is visually inspected under a microscope to remove any that have been physically damaged during manufacturing. Chips are also eliminated at this point if they do not conform to dimensional design rules. Good chips are separated and moved to the next step of manufacture, die attach and lead bond.

Die Attach and Lead Bond. Assuming use of a standard plastic dual-in-line package (DIP), good die are attached to metal lead frames with a small amount of molten gold or low-cost epoxy. It is imperative that a die be securely attached to the lead frame in order for it to withstand later testing requirements made of the finished device. The next step is bonding the pads of the chip to individual leads of the package with either gold or aluminum wire that is between 1.0 and 1.5 thousandths of an inch in diameter. Thermocompression bonding involves heating the lead frame and attached die to about 340° centigrade. The bonding wire is automatically pressed against the bonding pad on the heated die, fusing the wire to the die. The wire is then drawn to its respective bonding pad on the lead frame, which is also fused. Automated bonding machines are capable of bonding more than 1,000 packages per hour. Once the die is attached with bonded leads, another visual inspection is performed to eliminate devices that were damaged or bonded incorrectly.

Encapsulation. Assembled lead frames for plastic DIPs are placed in molds into which molten plastic is injected, thus forming the body of the semiconductor device. Between 20 and 50 packages are encapsulated at once, resulting in low production costs. The molded packages are cured in a 200° centigrade oven for 40 hours. Excess metal is then removed from the devices and the leads are formed to the finished product configuration. The parts are tested for open or shorted circuits that might have resulted during encapsulation. The packaged parts are now ready for final test.

Final Test

After the die have been packaged, they undergo one final test. Packaged parts are transferred from assembly to the final test area in static-free plastic tubes that are inserted into automated package handlers. The handler releases one package at a time into a test socket or head that is wired to an automated test computer. Many manufacturers are using multiple-head test systems to increase the throughput of a test system.

Each unit is stringently tested at this step, across "worst case" conditions. The circuits are tested for maximum and minimum speeds, for power dissipation, and for many combinations of inputs and outputs—i.e., they are tested to ensure that they will meet all of the manufacturer's specifications and guarantees. The automatic test equipment performs thousands of separate tests in seconds. A typical final test by the manufacturer runs from less than one second on a TTL logic device to up to 35 seconds or more on some 4Mb DRAMs.

The final test must be stringent enough to ensure that the device performs over its guaranteed temperature range. The environmental conditions are usually assured in one of the following two ways:

- All devices are tested at the high-temperature end of the specifications.
- The devices are tested at room temperature over sufficiently wide tolerances (guard bands) so that operation at the temperature extremes is assured.

The first approach is obviously the safer method, but it is also much more expensive. As a result, many semiconductor manufacturers will correlate the room temperature characteristics with the characteristics at temperature extremes, add a safety guard band to the room temperature test parameters, and then test at room temperature. Samples are regularly taken from the production lots and tested across the full range of environmental conditions to ensure that the correlation parameters are accurate.

The functions of wafer sort and final test correlate very closely. Often both tests are performed in the same room and/or on the same test machine; the chief difference is the test program. One of the main functions of the wafer sort program is to minimize the amount of additional labor and materials that would be assigned in producing bad circuits. This is especially important to devices with low die costs and higher assembly costs. However, wafer sort cannot eliminate all potentially defective die for the following reasons:

- Most sophisticated circuits (i.e., 1Mb DRAMs) cannot completely be tested in wafer form due to parasitic effects resulting from the probes and wiring, incident room light, and other factors involved with physically sorting the die.

- Some of the die may be damaged during the assembly process.

- The die cannot be tested across the temperature range in wafer form because the wafer and probes cannot be easily maintained at temperatures below the ambient.

The objective of wafer sort is to ensure that enough of the potentially rejectable circuits have been discarded so that final test yields will be high enough to support a desired level of profitability. Excessively high final test yields are not necessarily acceptable. This may mean that potentially good devices are being thrown away at wafer sort. As a result, many manufacturers will adjust the tightness of their internal wafer-sort test to allow the final test yields to fall in the range of 80 to 90 percent good units.

COST MODEL USAGE

As shown in Tables 4 and 5, we expect improvements in yield to be made over time as specific product processes become better understood. Yield improvements result directly in lower costs. The more existing capacity (plant, machinery, etc.) utilized, the lower the per-unit cost, since fixed costs are spread over more units. High capacity utilization combined with higher yields results in lower costs per unit that are directly reflected in lower prices under normal circumstances. This characteristic of the semiconductor industry can be used to knowledgeably estimate current and future price trends for product planning or price negotiation decisions.

1Mb DRAM and Gate Array Examples

The 1Mb DRAM and gate array cost models shown in Tables 4 and 5 reflect both yield improvement trends (1988, 1989, and 1990) and capacity use effects (1989; 100 percent to 25 percent utilization). Capacity utilization greatly affects unit cost even as yields improve. At a certain point, low utilization of capacity results in lower yields as process control procedures become difficult to monitor because of the lower volumes manufactured. This compound effect (higher fixed costs plus lower yields) in down markets is often cited in antidumping rhetoric as market prices temporarily dip below costs. The opposite occurs in growing markets under normal situations as shown in the 1988 and 1989 cost-price trends.

Table 4

Dataquest
Semiconductor Cost Model
1Mb DRAM

	1988	1989	1989	1989	1989	1990
Wafer Sort						
Wafer size (inches diameter)	6	6	6	6	6	6
Capacity Utilization (%)	100.00	100.00	75.00	50.00	25.00	100.00
Geometry (microns)	1.20	1.05	1.05	1.05	1.05	0.90
Processed wafer cost ($)	373	429	466	583	729	455
Die area (square mils)	83,000	79,210	79,210	79,210	79,210	73,000
Active area factor	1.00	1.00	1.00	1.00	1.00	1.00
Number of masks	11	12	12	12	12	12
Defect density per square inch per mask	0.625	0.625	0.625	0.625	0.625	0.625
Gross die per wafer	307	321	321	321	321	349
Processed wafer cost per gross die ($)	1.2166	1.3352	1.4513	1.8142	2.2677	1.3053
Test cost per hour ($)	47.00	58.00	110.78	138.48	195.25	60.00
Wafers tested per hour	0.81	0.85	0.85	0.85	0.85	0.87
Wafer sort cost per gross die ($)	0.1893	0.2124	0.4057	0.5071	0.7150	0.1978
Cost per gross die at wafer sort ($)	1.4059	1.5476	1.8570	2.3213	2.9827	1.5031
Wafer sort yield (%)	57	63	41	28	14	80
Cost per sorted die ($)	2.4875	2.4529	4.4849	8.4092	21.6110	1.8802

(Continued)

Table 4 (Continued)

Dataquest
Semiconductor Cost Model
1Mb DRAM

	1988	1989	1989	1989	1989	1990
Assembly						
Material cost/sorted die--SOJ pkg. ($)	0.1900	0.2000	0.2020	0.2040	0.2061	0.1900
Number of pins	20	20	20	20	20	20
Assembly yield (%)	90	92	92	92	92	93
Cost per assembled die ($)	2.9750	2.8836	5.0945	9.3622	23.7142	2.2260
Final Test						
Test time per die (sec.)	35.00	8.95	8.95	8.95	8.95	8.00
Cost per hour of testing ($)	47.00	58.00	110.78	138.48	195.25	60.00
Test cost per die ($)	0.4934	0.1442	0.2754	0.3443	0.4854	0.1333
Final test yield (%)	90	92	88	86	82	93
Cost per final tested unit ($)	3.8538	3.2910	6.0883	11.2297	29.4706	2.5369
Mark, Pack, and Ship Cost at 99% yield (%)	0.0385	0.0329	0.0609	0.1123	0.2947	0.0254
Total fabricated cost per net unit ($)	3.8924	3.3239	6.1492	11.3420	29.7653	2.5623
Foreign Market Value (FMV) Formula Adders						
R&D expense (15%)	0.58	0.50	0.92	1.70	4.46	0.38
SG&A expense (10%)	0.45	0.38	0.71	1.30	3.42	0.29
Profit (8%)	0.39	0.34	0.62	1.15	3.01	0.26
Constructed FMV	5.32	4.54	8.40	15.50	40.67	3.50

Source: Dataquest
February 1990

Table 5

Dataquest
Semiconductor Cost Model
6,000-Gate Array

	1988	1989	1989	1989	1989	1990
Wafer Sort						
Wafer size (inches diameter)	6	6	6	6	6	6
Capacity utilization (%)	100.00	100.00	75.00	50.00	25.00	100.00
Processed wafer cost 1.2 micron ($)	375	387	484	605	756	395
Die area (square mils)	115,494	103,945	103,945	103,945	103,945	98,747
Active area factor	0.60	0.60	0.60	0.60	0.60	0.60
Number of masks	12	15	15	15	15	15
Defect density per square inch	0.63	0.63	0.63	0.63	0.63	0.63
Gross die per wafer	220	245	245	245	245	258
Processed wafer cost per gross die ($)	1.7020	1.5808	1.9760	2.4700	3.0875	1.5328
Test cost per hour ($)	74.29	76.00	169.54	218.50	319.12	80.26
Wafers tested per hour	5.45	4.90	4.90	4.90	4.90	4.66
Wafer sort cost per gross die ($)	0.0619	0.0633	0.1413	0.1821	0.2659	0.0669
Cost per gross die at wafer sort ($)	1.7639	1.6441	2.1173	2.6521	3.3535	1.5997
Wafer sort yield (%)	77	74	74	74	74	76
Cost per sorted die ($)	2.2873	2.2076	2.8429	3.5610	4.5027	2.1165
Assembly						
Material cost/sorted die-plastic PGA ($)	7.1715	7.5301	7.5301	7.5301	7.5301	7.6807
Number of pins	172	172	172	172	172	172
Assembly yield (%)	90	90	90	90	90	91
Cost per assembled die ($)	10.5098	10.7658	11.5255	12.3234	13.3032	10.7777
Final Test						
Test time per die (sec.)	10.00	10.00	10.00	10.00	10.00	10.00
Cost per hour of testing ($)	74.29	76.00	169.54	218.50	319.12	80.26
Test cost per die ($)	0.2064	0.2476	0.4709	0.6069	0.8864	0.2229
Final test yield (%)	90	91	89	87	83	92
Cost per final tested unit ($)	11.9069	12.1160	13.4668	14.8113	17.1093	11.9572
Mark, Pack, and Ship Cost at 99% yield (%)	0.1191	0.1212	0.1347	0.1481	0.1711	0.1196
Total fabricated cost per net unit ($)	12.0259	12.2371	13.6014	14.9594	17.2804	12.0768
Foreign Market Value (FMV) Formula Adders						
R&D expense (15%)	1.80	1.84	2.04	2.24	2.59	1.81
SG&A expense (10%)	1.38	1.41	1.56	1.72	1.99	1.39
Profit (8%)	1.22	1.24	1.38	1.51	1.75	1.22
Constructed FMV	16.43	16.72	18.58	20.44	23.61	16.50

Source: Dataquest
February 1990

Semiconductor Cost Trends

SUMMARY

Individual unit costs of semiconductors form the most tangible variable in the total cost of a semiconductor device. The understanding of cost modeling and the variables that go into that model allows for more efficient allocation of resources both in planning and in the execution of those plans. By applying different assumptions to different variables in the model, one can uncover areas of cost not previously considered important. Many different "what if" scenarios are often required to utilize cost modeling fully in long-range system analysis.

Modeling is inherently flexible and can be updated if proven historical data basically differ from calculated model results. Checking and updating a model against known data insures that the model is correct and current. Revisions to existing algorithms to better match reality are made when basic changes occur, not for perturbations that deviate from the norm.

Those in procurement can use cost modeling and experience curve analysis for both short- and long-term contract negotiations. Periodic "reality checks" of the model insure that, when cost and price trends track in the same or different directions, plans can be made with confidence that the best information was available at that time. Cost modeling can also be used as an internal audit to note where actual costs compare with model costs. Traditional use of cost models in price negotiations combined with experience curve trends can fine-tune the final outcome of these important agreements.

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Products

The following is a list of the material in this section:

- Product Overview
- DRAM Product Trends
- SRAM Product Trends
- EPROM Product Trends
- Application Specific Integrated Circuit (ASIC) Product Trends
- Standard Logic Product Trends
- MOS Microcomponent Product Trends
- Analog Product Trends

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Product Overview

INTRODUCTION

This section discusses each major semiconductor product family. The section examines life-cycle trends, potential replacements, and developments within the product family. In terms of supply-base management, this section aims to enable design engineers, purchasing managers, and strategic planners to choose the *right* semiconductor product for new systems as well as system redesigns.

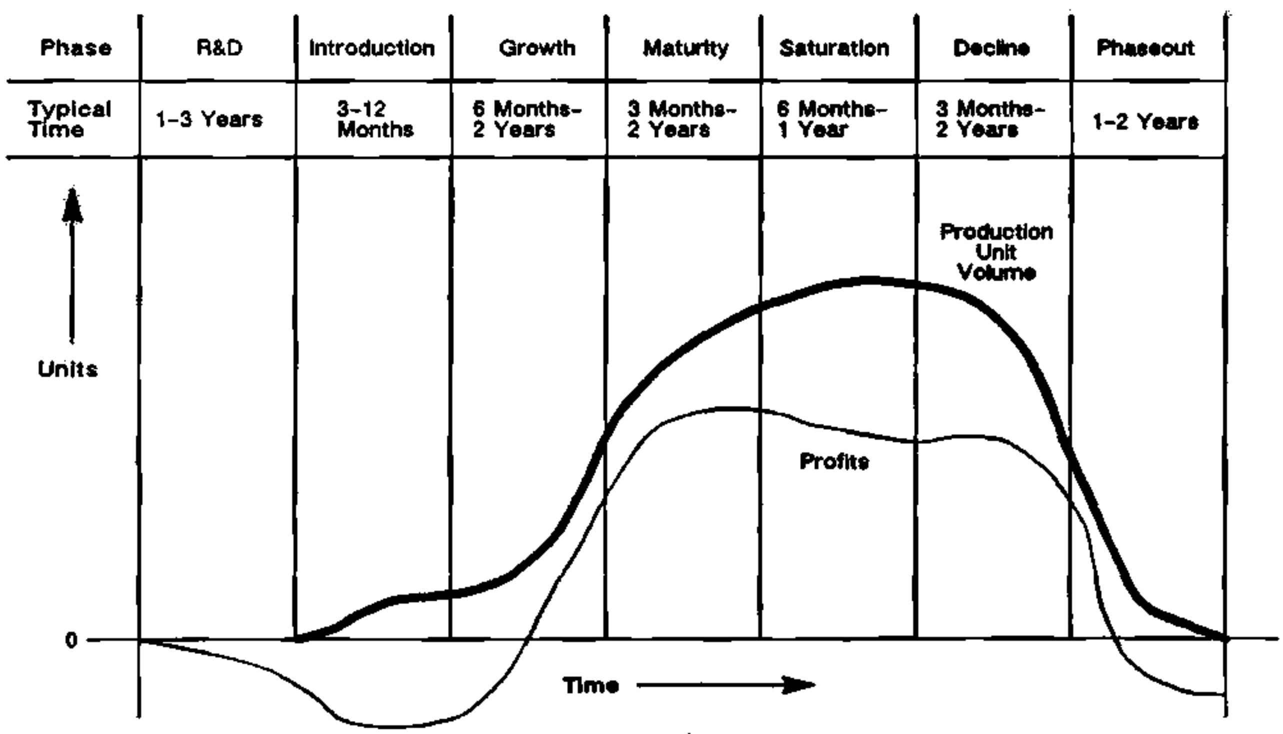
SEMICONDUCTOR PRODUCT LIFE CYCLE

Semiconductors follow the traditional life cycle of a manufactured product: development, introduction, growth, maturity, market saturation, decline, and phaseout.

Figure 1 illustrates a typical IC life cycle. Due to the high cost of development, the manufacturer does not begin to realize profits from the device until well into the growth phase of the product's life. Manufacturers of leading-edge electronic equipment usually adopt the product in this phase of its life cycle. The pattern of low profitability during the early stages of the IC life cycle (Figure 1) is known as "life cycle pricing" or "forward pricing."

Figure 1

Typical Integrated Circuit Life Cycle



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Source: Dataquest
April 1990

The life cycle of a device and of the equipment into which it is being designed should always be compared. Selecting a device in its decline phase may force the equipment manufacturer to pay a premium price for an obsolescent product or to make a lifetime buy of that part. At the other end of the life cycle, the risk of designing in an untried product must be weighed against the technical advantages offered by the new device. The information in this section is intended to assist in these decisions.

Some of the major factors that affect semiconductor life-cycle length and timing are as follows:

- Technology changes
  - Device and circuit innovations, e.g., chip sets, EEPROM, RISC, intelligent power
  - Process evolution, e.g., bipolar ECL, silicon gate CMOS
  - Innovative processes, e.g., gallium arsenide (GaAs), BiCMOS, bipolar dielectric isolation
- Economic factors
  - Extreme pricing pressure on suppliers, e.g., 1Mb DRAM in 1989
  - Limited number of competitors relative to total volume demand, e.g., 256K DRAM
  - Exchange rates, volatility of dollar against yen/deutsche mark
- Political and legal factors
  - U.S.-Japan Semiconductor Trade Arrangement renewal or termination during 1991
  - Deregulation in Europe moving toward 1992
  - Legal action surrounding 68030 and 80386 microprocessors
- Manufacturing constraints
  - Phase-over to new production equipment, e.g., from 5- or 6-inch wafers to 8-inch wafers
  - Delays in availability of new test or production methods, e.g., inadequate surface-mount test capability

Some IC products become obsolete in just several years, especially such products as semiconductor memory. This accelerated life cycle can adversely affect the market position of the semiconductor user's end product. The best protection against this occurrence is for the user to work with the supplier base to anticipate the next one or two generations of product evolution. This procedure allows the next generation of semiconductor devices to be incorporated into the final product by means of minimal engineering changes.

Succinctly, system life cycles—which can range from as short as one-half year in the case of consumer electronics to as long as 50 years for certain industrial equipment—*must* be coordinated as closely as possible with semiconductor product life cycles. Toward that goal, this Product Overview section strives to provide as much detailed information as possible on the expected length of *each phase* of the life cycle for any given semiconductor family.

PRODUCT TECHNOLOGY TRENDS

Projecting semiconductor product life cycle *by technology* provides a key mechanism by which supply-base managers can coordinate system and semiconductor life cycles. Figure 2 provides information on semiconductor technology life cycles. Analysis focuses on the opposite extremes of the curve—the introduction/growth stages and the decline/phaseout stages—because these stages typically generate greatest concern for supply-base managers.

Figure 2 shows that the BiCMOS process technology approaches the growth stage of the life cycle. Dataquest views the BiCMOS process as an essentially safe and "evolutionary" technology that evolves from the familiar bipolar and CMOS vendor camps. Users can design BiCMOS SRAM, ASICs, and intelligent power ICs into systems with firm expectation of solid support over the long term from a widening supplier base.

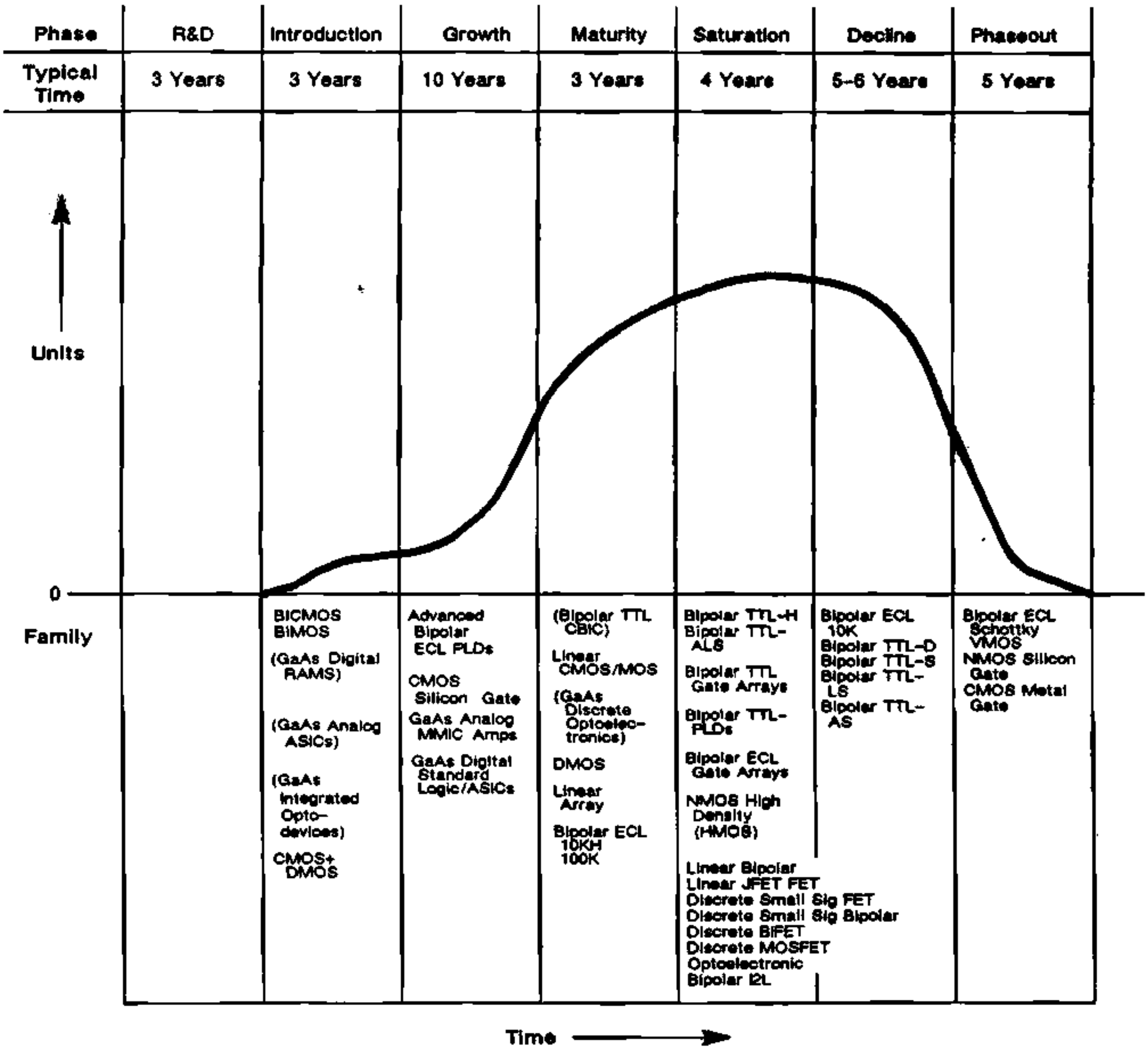
Figure 2 positions the GaAs technology at either the introduction or growth stages of the life cycle, depending on the specific product. GaAs marks a fundamental shift from the use of silicon as the basis of semiconductor technology and remains relatively unproven. Users must carefully explore their systems' needs and the strength of the supplier base in weighing whether or not to design GaAs products into systems.

Dataquest fully expects long life cycles for two technologies—CMOS silicon gate and bipolar ECL—that now are moving through the growth stage of the cycle.

At the other end of the spectrum, Figure 2 reveals that a host of product technologies—for example, MOS metal gate, PMOS/NMOS silicon gate, bipolar TTL—have hit the decline or phaseout stage. Users whose systems incorporate these semiconductor technologies *must* develop contingency plans to safeguard against the twin problems of phaseout (of these product technologies) and premature system obsolescence.

Figure 2

Technology Life Cycle as of April 1990



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Source: Dataquest
April 1990

Source: Dataquest
April 1990

Standard Logic

New system designs continue to move toward a higher mix of microprocessor interface logic. Figure 3 depicts the relative position of the standard logic families on the life curve.

TTL

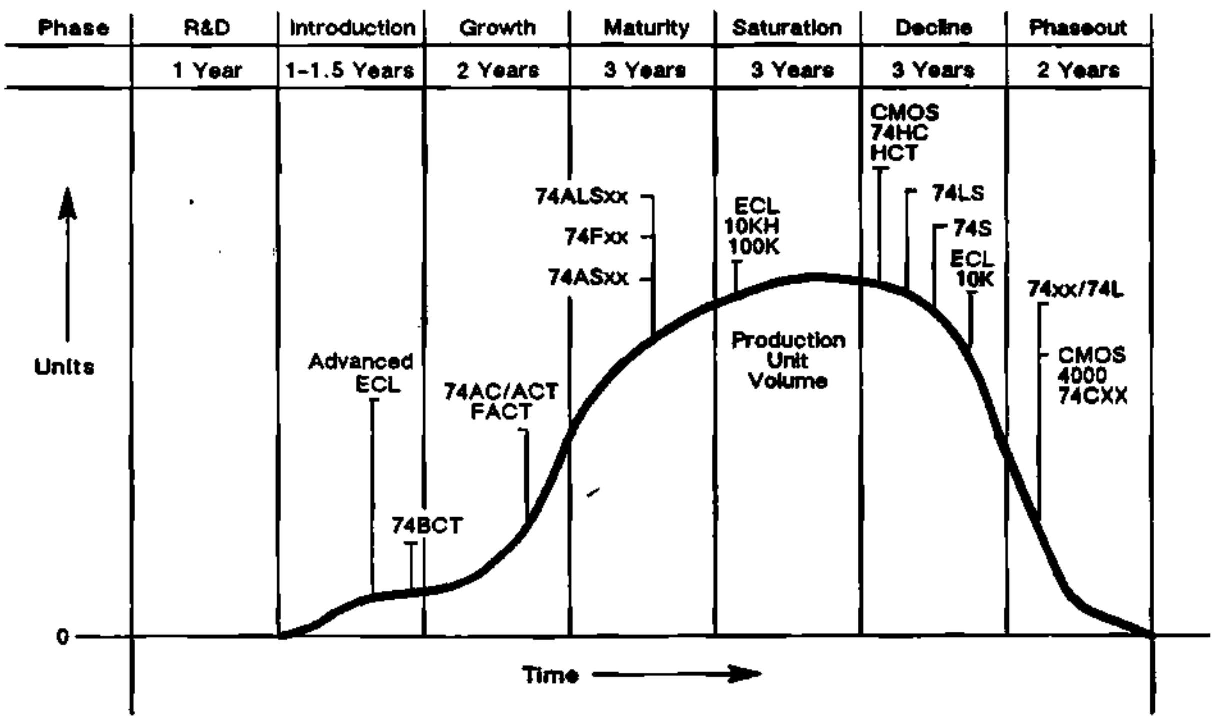
The early 74 series logic families are either being phased out (74/74L) or else are approaching the decline stage (74LS/74S). New system designs and redesigns displace 74/74S with 74AS, 74F (FAST), or ASICs. Similarly, 74ALS or ASICs displace 74L/74LS in newer applications.

CMOS

The original 4000/74C parts are being phased out. More mature CMOS logic (HC, HCT) saturated the marketplace and is being replaced by low-cost CMOS gate arrays. The newer CMOS logic families (74AC/ACT, FACT) serve as replacement alternatives. As shown in Figure 3, Dataquest foresees continued growth for 74AC, ACT, and FACT.

Figure 3

Standard Logic Life Cycle as of April 1990



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Source: Dataquest
April 1990

ECL

The standard high-ECL families are mature in technology. High-performance ECL gate arrays are a natural replacement for those products, not only because of the increased performance in gate speed but also because of the reduction of package interconnect delays associated with discrete logic devices. Figure 3 shows that the advanced ECL family of standard logic stands at the introduction stage of the cycle.

BiCMOS

Figure 3 also reveals that users can expect a family of BiCMOS standard logic (74BCT) in the market over time. The BiCMOS family will be used for interface functions in high-drive applications.

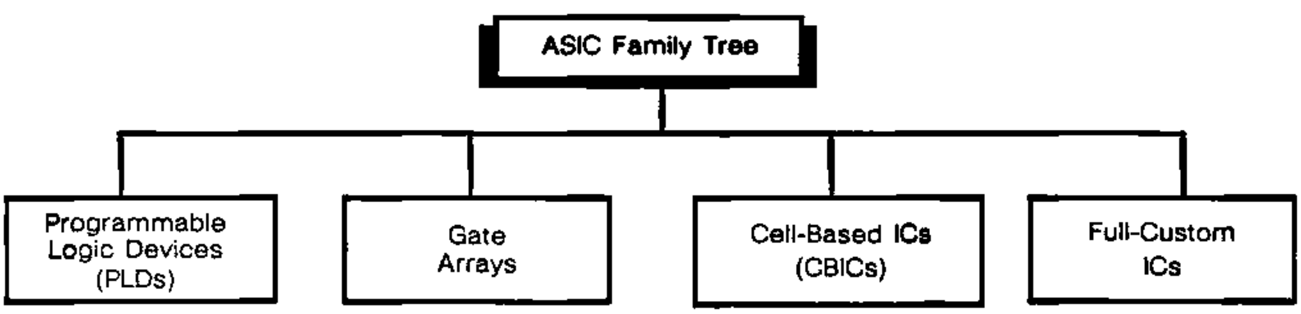
Application-Specific Integrated Circuits (ASICs)

An ASIC is a logic product customized for a single user. Evolutions of the various ASIC technologies have resulted in a significant increase in circuit density and a dramatically increased cost-effectiveness. The continued acceptance of ASICs in almost all end-product designs results in the declining shipment of standard logic.

The ASIC product category is composed of several device types or design approaches. Figure 4 shows the ASIC family tree. Figure 5 displays Dataquest's definition of the ASIC design approaches on the life-cycle curve relative to specific technologies. Figure 5 reveals the accelerated life cycle of ASICs vis a vis other semiconductor products.

Figure 4

ASIC Family Tree



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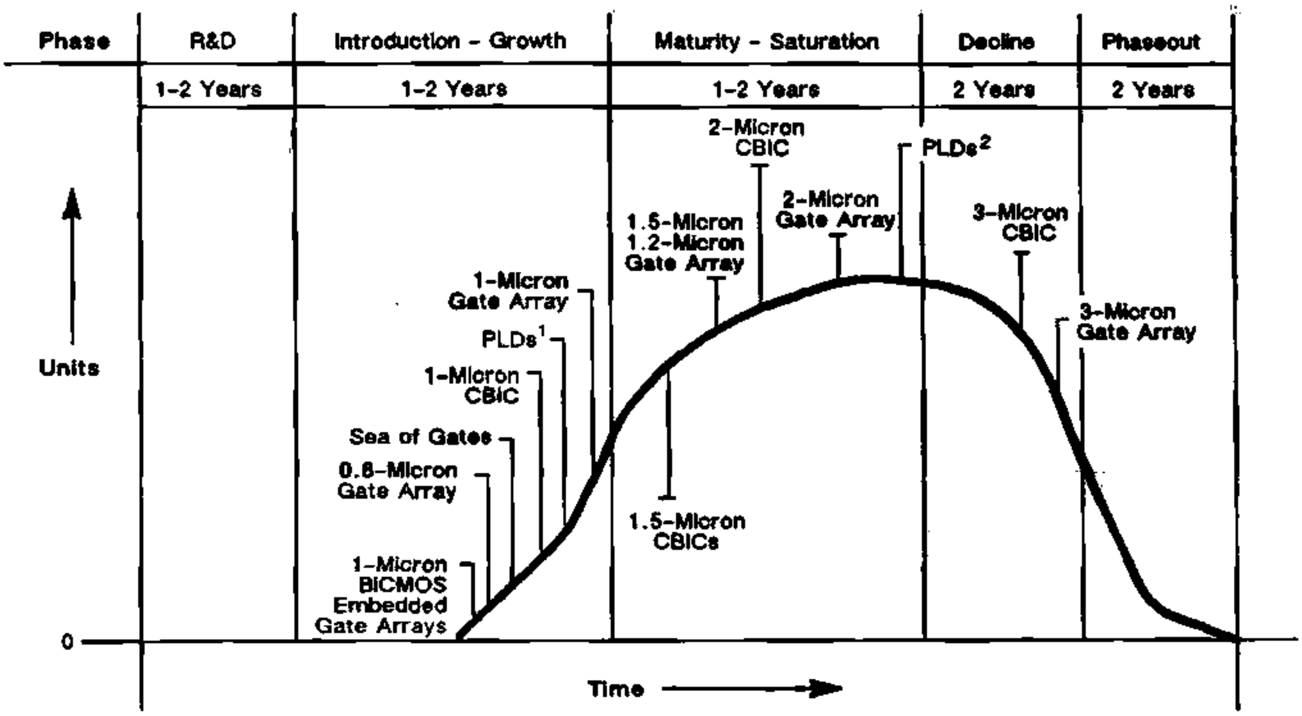
Source: Dataquest
April 1990

Figure 5

ASIC Life Cycle as of April 1990
(Production Unit Volume)



[1] <15ns
[2] >15ns

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Source: Dataquest April 1990

Gate Arrays

Gate arrays are defined as semicustom digital or linear/digital ICs containing a configuration of uncommitted logic elements, which are customized by interconnecting the logic elements with one or more routing layers. While gate arrays themselves are not at a specific point on the life-cycle curve, the various process and technology levels tend to follow the movement of the curve. As shown in Figure 5, gate arrays in line geometries between 1.0 and 1.5 microns represent the predominant technology for 1990 through 1992. "Sea of gate" devices are being designed into systems during 1990.

The average NRE-per-gate is decreasing because of better design efficiencies and experience-curve cost reductions. By technology, BiCMOS gate arrays will take share from both CMOS and ECL gate arrays.

Emerging gate array products for which we see strong demand in the 1990s include high-density CMOS channelless arrays, high-density ECL arrays, BiCMOS arrays, and embedded gate arrays (e.g., megacells such as RAM embedded in the gate array base wafer).

Cell-Based ICs (CBICs)

CBICs are digital or mixed linear/digital ICs that are customized using a full set of masks. CBICs consist of precharacterized cells or macros including standard cells, megacells, and compilable cells. CMOS is the predominant process technology in cell-based designs. The geometry design trend is from 2.0 microns down to 1.0 micron or 0.8 micron at the high-performance end.

The key to the long-term acceptance of these products is the design tools and development software that are emerging. Electronic design automation tools play a critical role in making the cell library functionality readily usable.

Programmable Logic Devices (PLDs)

PLDs are user-programmed ICs and include programmable logic arrays (PLAs), field programmable logic arrays (FPLAs), and field programmable logic cell arrays (LCAs). Recent innovations in PLDs have resulted in erasable PLDs (EPLDs) that use EPROM or EEPROM technology to store the logic configuration. Memory devices such as PROMs and ROMs are not included in this market segment.

As an alternative design solution, programmable logic has already replaced standard logic in many applications. There is also some displacement by PLDs of very low gate count gate arrays.

Density, flexibility, and pure speed are key issues with PLDs. Some of the newer products offer tremendous functionality but may not have quite the speed required for throughput-intensive applications. Other PLDs are very fast due to their ECL technology. Dataquest expects to see the newer CMOS PLD designs reach typical bipolar propagation delays. GaAs technology also wins a slice in this marketplace.

Microcomputing Devices

Included in the microcomputing devices category here are MOS microprocessors, microcontrollers, and microperipherals. The trend toward the use of CMOS devices in all microprocessor areas is important to consider in new design decisions.

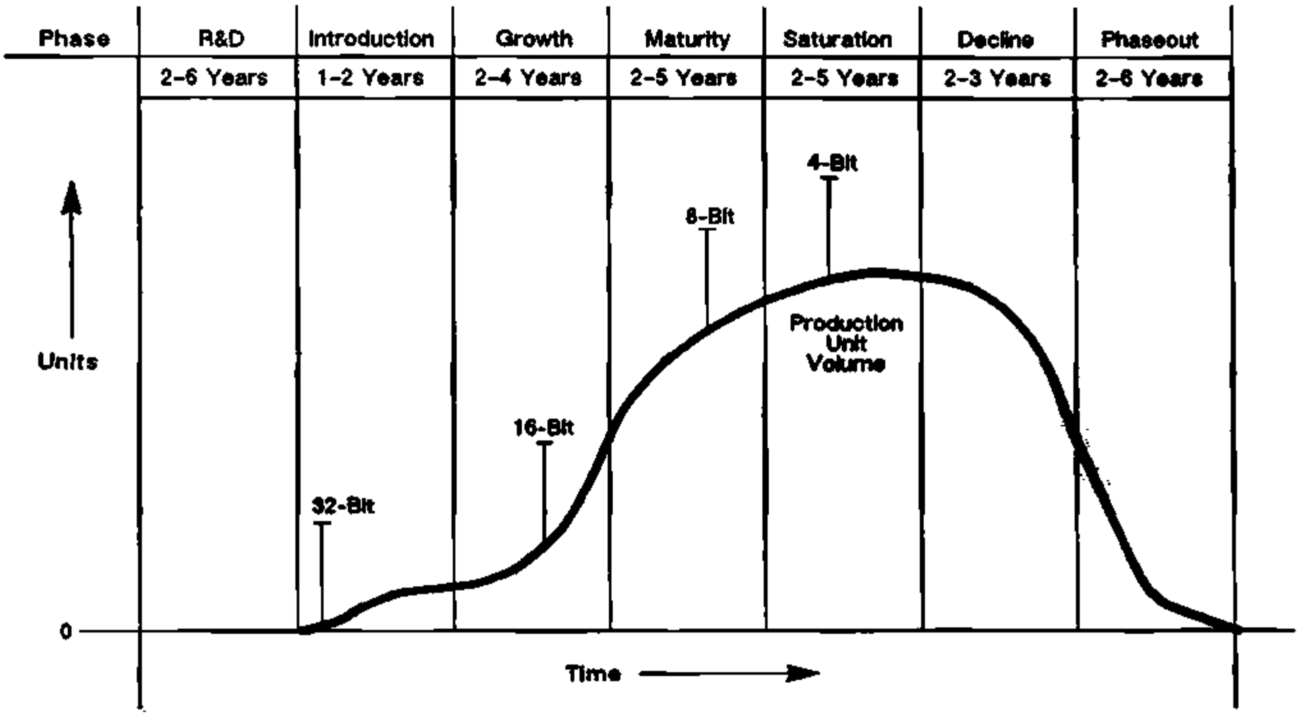
MOS Microcontrollers

Dataquest defines a microcontroller as a single-chip component that contains on-board program memory in the form of ROM, EPROM, or EEPROM; some input/output capability; a general-purpose read/write memory; the CPU function; and possibly other functions such as timers or digital/analog conversion. Microcontrollers (MCUs) usually have much longer life cycles than other integrated circuits. Figure 6 shows the product life cycles of typical microcontrollers.

MCUs are widely used in products that also have long life cycles. Such products frequently require 6 to 18 months from product concept to initial production, so there is a long gestation period between early samples and volume purchases. The gestation period may be further extended if the product is an intermediate piece of equipment that will be incorporated into another product.

Figure 6

Microcontroller Product Life Cycle as of April 1990



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Source: Dataquest
April 1990

As shown in Figure 6, microcontroller products have lengthy product life cycles (13 to 31 years). The 4-bit MCU devices stand at the saturation (or peak) stage of their life cycle and should remain in that stage for the next three to five years. The addition of new features to these mature devices in effect extends the life cycle.

Designs are making use of the more advanced technologies and architectures available at the 8-bit level. On-chip EPROM has been a successful feature for prototype or small-volume applications. Along these same lines, EEPROM offers yet another level of flexibility in designs where alterable parameters must be stored and perhaps changed as a result of a recalibration. Another important trend is the increased integration of application-specific features. Items such as analog/digital conversion, high-resolution timers, and serial communication channels enhance system performance and create a more cost-effective solution. The advantages of low power consumption in battery backup situations and noise immunity in harsh environments are becoming important to users, but price also will be a definite consideration in the changeover.

The clear trend is a move away from general-purpose parts to devices differentiated on the basis of application. The 16-bit MCUs are still emerging and will not supplant most existing 8-bit designs for a few years. Instruction-set compatibility is an issue here as any major rewrite of MCU code tends to be costly. In addition, microcontroller users tend to match the MCU to the needs of the application, advancing to a more costly MCU only when absolutely necessary. Another factor is that the addition of new features such as analog/digital conversion or EPROMs onto 8-bit MCUs cuts into potential demand for 16-bit devices.

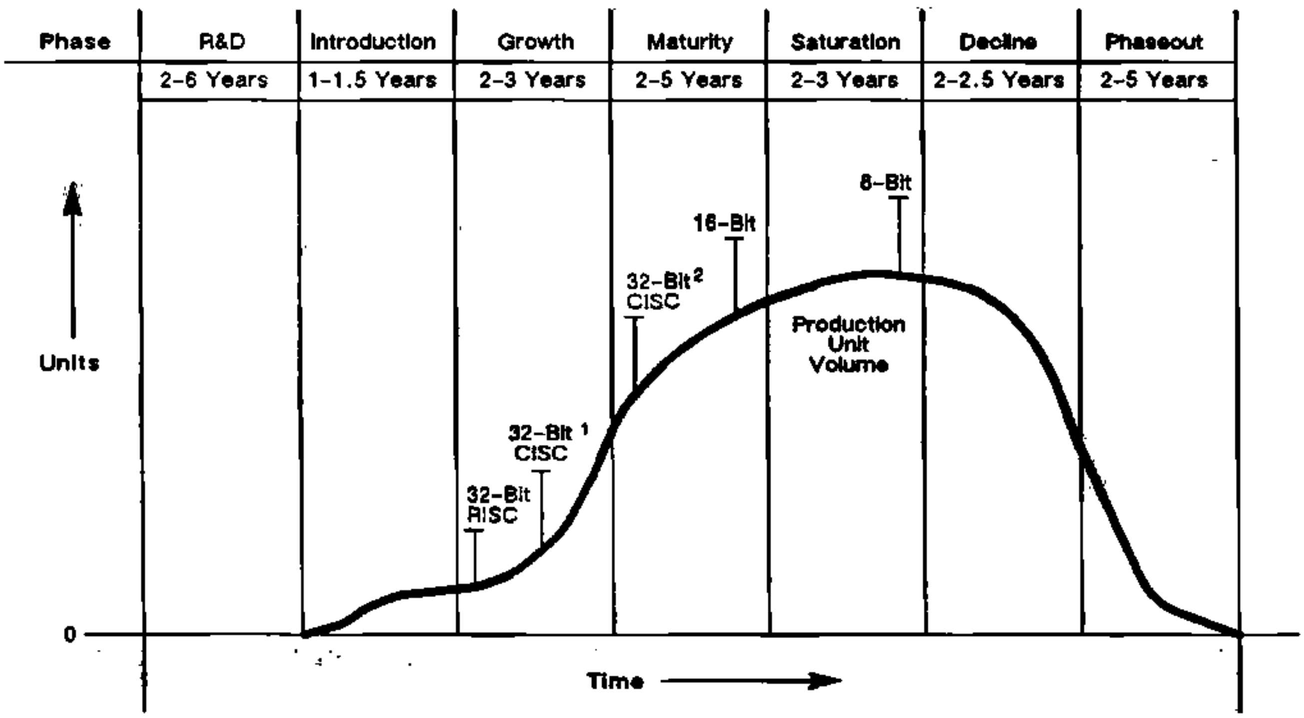
MOS Microprocessors and Microperipherals

The trend toward CMOS products in the microprocessor (MPU) and microperipheral area is on a par with microcontrollers. Figure 7 shows the life-cycle positions of MPU products.

Two significant trends in the area of MOS microprocessors and microperipherals are the development of increasingly sophisticated peripheral devices and the use of increasing numbers of peripheral devices with each microprocessor. Continued MPU technology refinements allow for better use of silicon. This in turn enables suppliers to achieve higher levels of integration. An emerging trend during the 1990s in the complex instruction set computing (CISC) 32-bit marketplace will be on-chip availability of microperipheral functions (e.g., math coprocessor, floating point).

Figure 7

Microprocessor Product Life Cycle as of April 1990



1 > or = 20 MHz
2 16 MHz

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Source: Dataquest
April 1990

As shown on Figure 7, 16-bit MPUs such as the 80286 device now are in the late maturity/saturation stage of their life cycles. However, the 16-bit product is just now entering the growth stage in new regional markets such as the USSR and Eastern Europe. The 32-bit MPUs, which operate at speeds of 20 MHz, 25 MHz, or 33 MHz, now stand at the growth stage of their life cycle. Of these devices, the 25-MHz 32-bit MPU version appears to be in the lead during the first half of 1990. Users can expect the introduction of faster versions (e.g., 33 MHz) during 1990 and 1991. By contrast, 16-MHz 32-bit MPUs are becoming mature products.

RISC Versus CISC

As shown in Figure 7, the reduced-instruction-set computing (RISC) architecture moves into the growth stage of the life cycle. This newly evolving product technology—which reduces the complexity of not only the instruction set but also the control logic and other internal operations—is establishing itself as a viable microprocessor alternative.

RISC products are targeted at high-end workstations, graphics systems, imaging systems, accelerator applications, and high-performance embedded control.

The BiCMOS technology represents an emerging market for applications such as RISC processors, which require greater performance than the CMOS process but do not warrant the cost of high-performance bipolar.

Memory Devices

Developments in the memory segment of the semiconductor industry continue to reverberate throughout the entire worldwide electronics industry. DRAM continues to serve as a technology process driver for many semiconductor suppliers.

The U.S.-Japan Semiconductor Trade Arrangement generated the DRAM sourcing headaches of 1987 and 1988 for users of 64K, 256K, and 1Mb devices. The supply crunch spilled over to other memory markets (EPROM, SRAM) and ultimately raised the cost of systems production. Significant developments in memory products include the following:

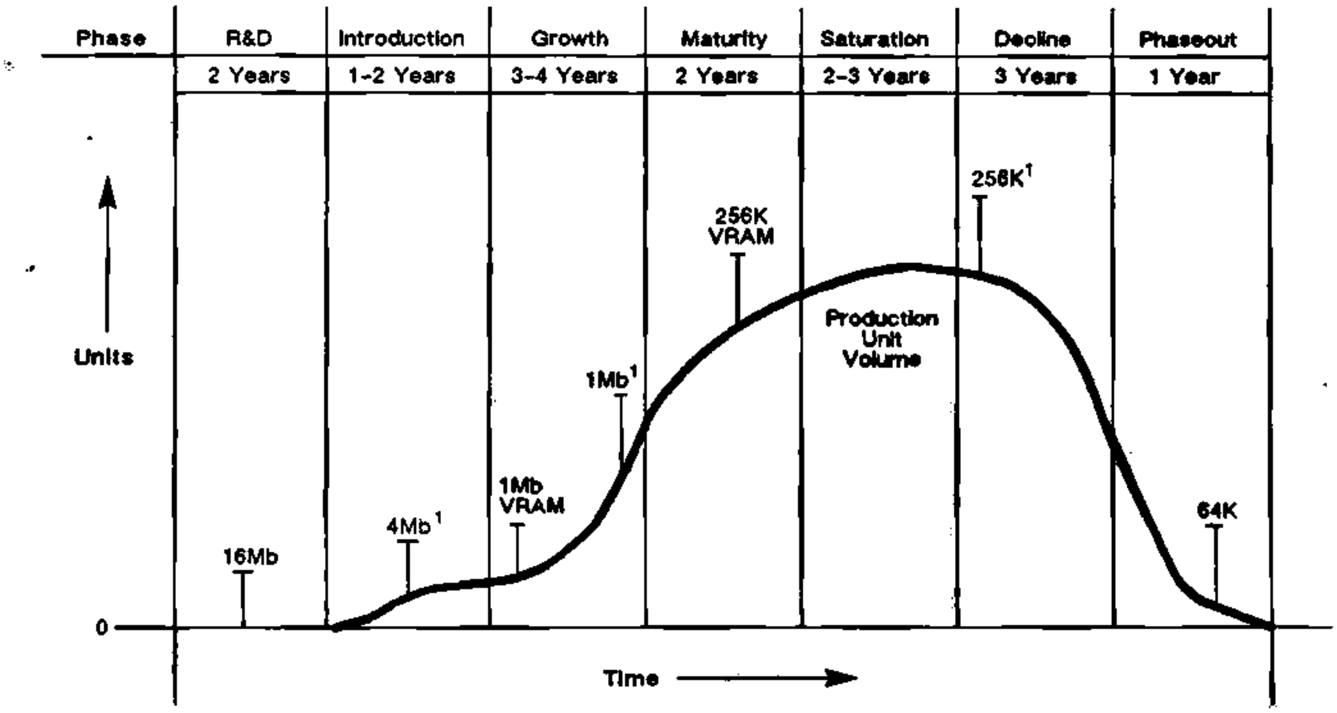
- Sustained long-term growth but an uncertain outlook for 1990
- Growth of fast SRAMs, megabit DRAMs, and slow SRAMs
- Emergence of DRAM products such as SIMMs and video RAMs (VRAMs)
- Emergence of BiCMOS for high-speed memory
- Innovative packaging techniques including modules, ZIP, and surface mount

MOS DRAMs

Despite market volatility, the DRAM market continues its orderly product progression, as shown in Figure 8. The mainstream 1Mbx1 100ns DRAM device now is approaching the maturity stage of the life cycle. Unit production should not decline until the mid-1990s. By contrast, the 64K DRAM is being phased out. The 256K DRAM device should move through its decline phase from 1990 to 1993.

Figure 8

DRAM Product Life Cycle as of April 1990



[1] Also: SIMMs

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Source: Dataquest
April 1990

Several suppliers introduced 4Mb DRAMs during the second half of 1989, and many others are likely to do so during 1990 and 1991. Several suppliers already have announced the development on die of 16Mb DRAMs, although first shipments are not expected until 1992 or 1993.

New products and packaging innovations reflect the dynamics of the worldwide DRAM business. Figure 8 shows many of the newer or less familiar DRAM devices, including 256K VRAMs and 1Mb VRAMs. The VRAM has dual ports, in contrast to the single-port DRAM. The second (or serial) port of the VRAM is dedicated to sending a continual series of information to the computer's screen.

Single in-line memory modules (SIMMs) also are growing in market popularity. SIMMs can be useful for system memory upgrades, system prototypes, and hedging new designs during the period of an impending DRAM crossover (e.g., the 1991 crossover to 4Mb DRAM from 1Mb DRAM).

MOS SRAMs

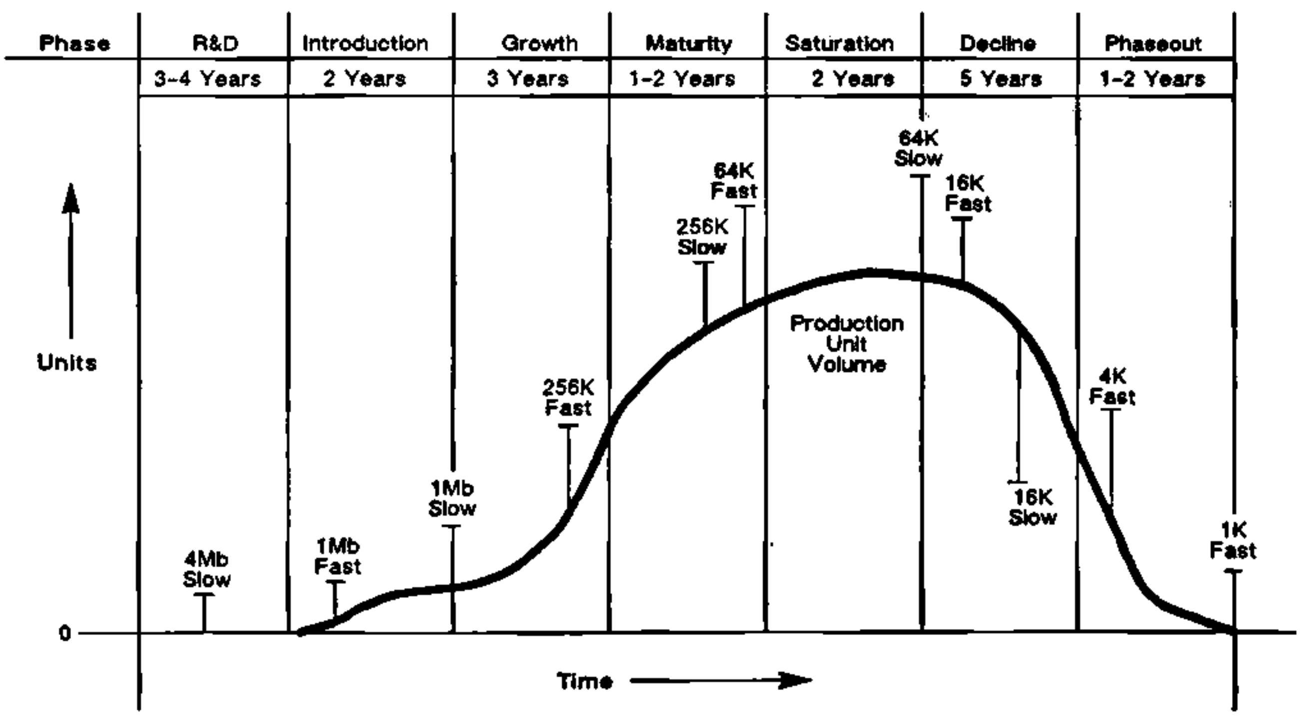
The MOS SRAM product segment is divided into slow and fast speed categories. Slow static RAMs are considered to be 70ns or greater; fast static RAMs are in the speed range of 70ns or less. Most slow SRAMs are organized in the x8 configuration. Fast SRAMs are organized in x1, x4, x8, and x16 configurations. Small-geometry CMOS procedures are now implemented in low-density SRAMs to arrive at higher speeds. Figure 9 shows the position of both slow and fast SRAMs on the life-cycle curve.

As shown in Figure 9, the SRAM product life cycle is marked by somewhat quick introduction and growth stages eventually followed by a long decline period. For example, CMOS fast 16K SRAMs (16Kx1, 4Kx4 and 2Kx8) and CMOS slow 16K SRAMs (2Kx8) now are moving through the five-year decline stage of their life cycles. The output of 4K fast SRAMs also is slowly declining. Other low-density SRAMs (e.g., 4K or below) either have been phased out or are being phased from production except for specialized applications (e.g., military systems).

At densities of 64K and above, CMOS is the predominant technology. However, BiCMOS technology should make a sharp inroad for high-speed cache memory and other applications that require access times of 20ns or faster. Figure 9 reveals that CMOS fast 64K SRAMs have matured as a product but do not face the phaseout stage until the late 1990s. The CMOS fast 256K SRAM—which will move through the growth stage for the next several years—should battle 64K fast device for position as the mainstream unit during 1990 and 1991.

Figure 9

SRAM Product Life Cycle as of April 1990



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Source: Dataquest
April 1990

CMOS is expected to remain the leading technology for slow SRAM products. The CMOS slow 64K SRAM (8Kx8) stands at the peak (or saturation) stage. The 256K slow SRAM (32Kx8)—which now is approaching the maturity stage—is replacing the 64K device as the mainstream production unit.

MOS ROMs

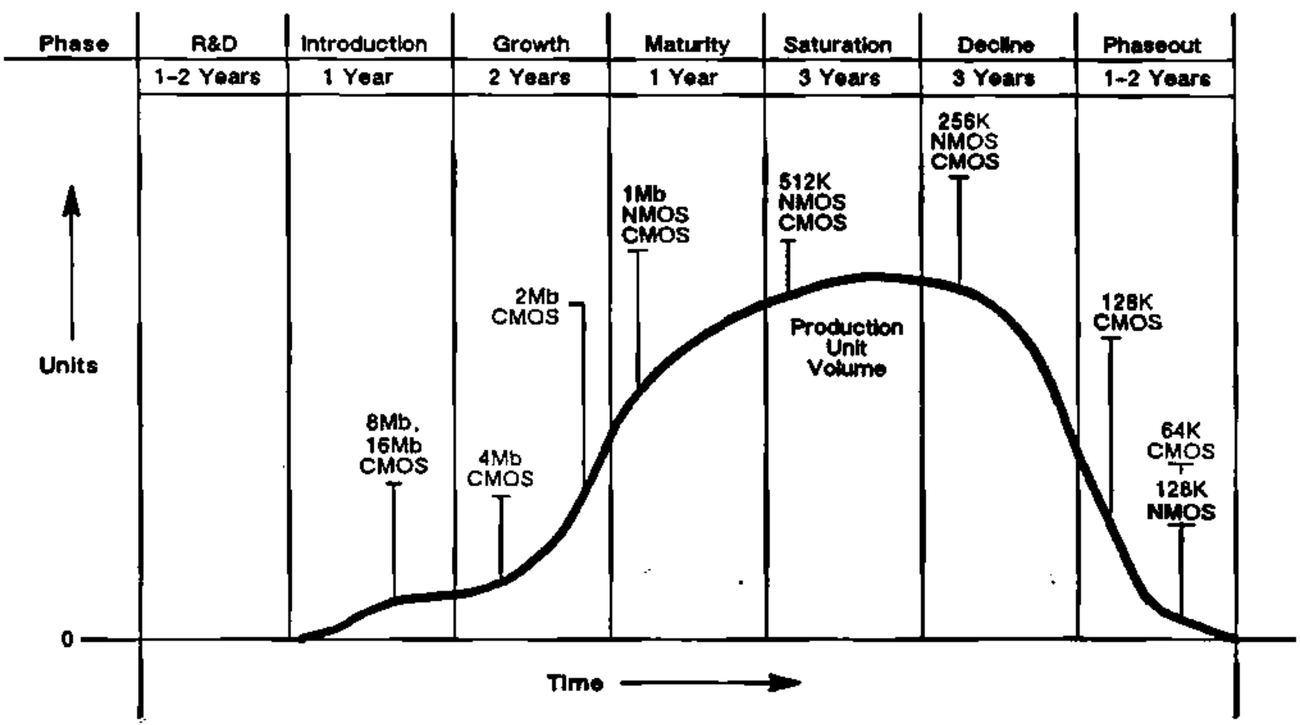
Figure 10 shows the life-cycle trend for MOS ROMs. This market is fairly stable and the life cycles are consistent.

High-volume/slower-speed applications such as disk drives, electronic typewriters, laptop computers, and video games typically drive ROM product supply and technology trends. These slower-speed applications mean a large supply of ROMs that operate at speeds of 200ns or slower but a more limited supply of devices that offer a speed of less than 150ns. At megabit-density levels, the predominant speeds for ROM should range from 150ns to 250ns.

As shown in Figure 10, 1Mb ROMs are approaching the peak stage of their life cycle. Dataquest expects 4Mb ROMs—which now are moving through their growth stage—to follow the path of the 1Mb product. The outlook is less certain for the intermediate 2Mb product because of fewer design wins and lower demand. The 8Mb and 16Mb ROMs have been or will be introduced by an increasing number of suppliers during 1990 and 1991.

Figure 10

MOS ROM Product Life Cycle as of April 1990



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Source: Dataquest April 1990

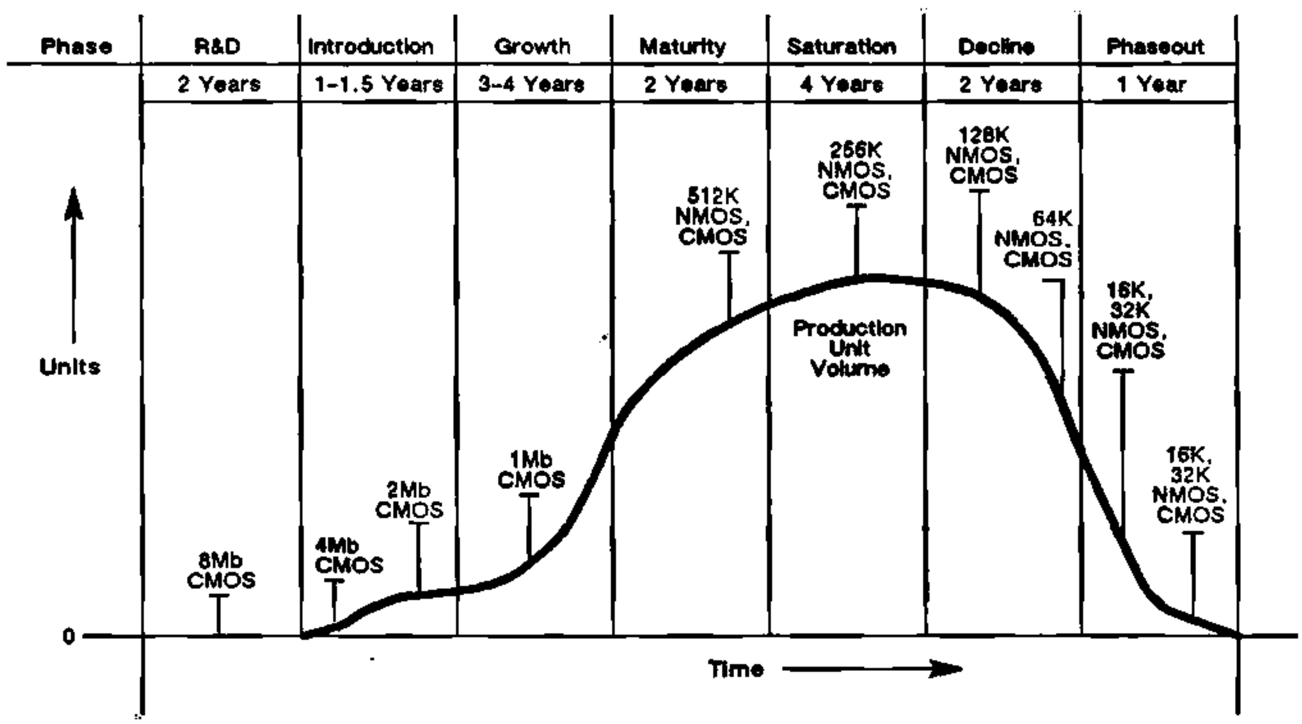
EPROMs

MOS EPROMs serve as the industry workhorse for nonvolatile storage (e.g., 32-bit systems). CMOS is the major technology at the higher-density levels. BiCMOS is not expected to penetrate this market.

As shown in Figure 11, lower-density EPROMs (128K and below) either are being phased out or are moving down the decline stage of the life cycle. The 512K devices and the 256K parts represent the mainstream product of 1990; however, the CMOS 1Mb EPROM now is moving through the growth stage of its life cycle. At densities of 1Mb and above, Dataquest foresees no role for NMOS technology and, as noted, little use for the BiCMOS process.

Figure 11

MOS EPROM Product Life Cycle as of April 1990



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Source: Dataquest
April 1990

EEPROMs

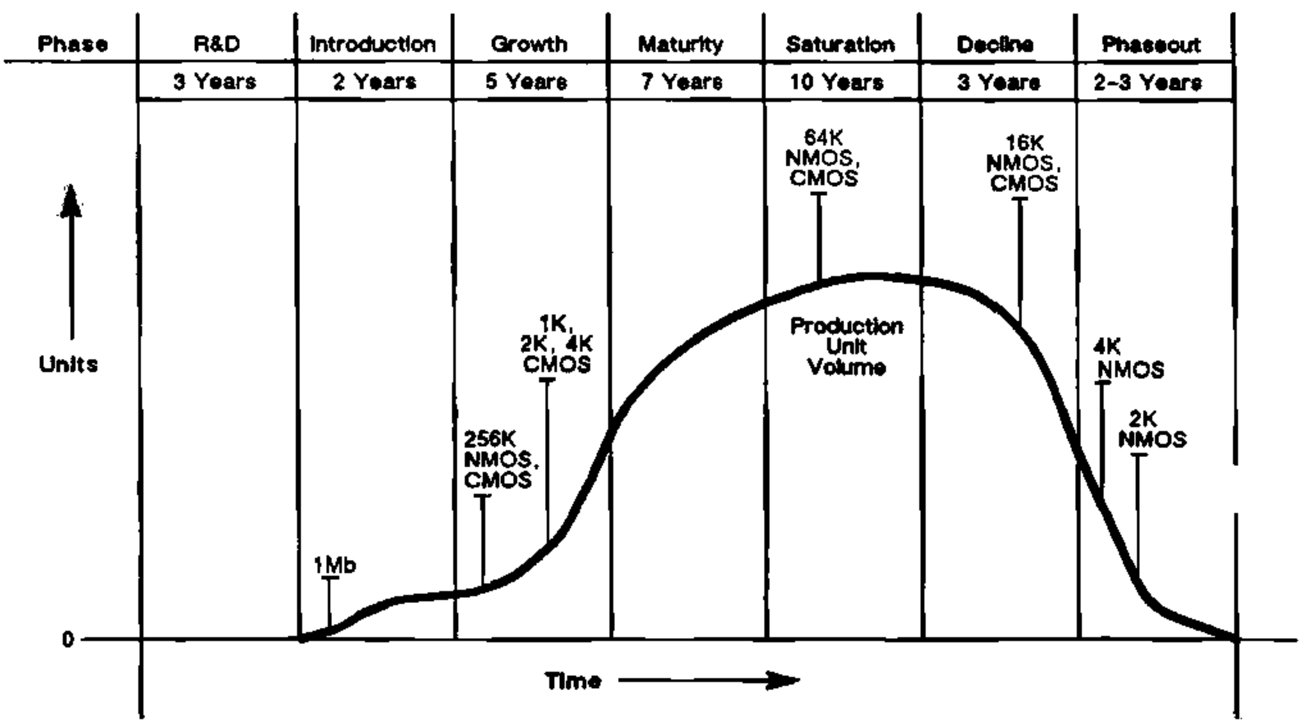
EEPROMs offer the advantages of in-circuit and remote reprogramming. Figure 12 shows the life-cycle positioning for these devices. As noted, life cycles (e.g., military devices) can extend for 30 to 35 years.

The 16K EEPROM now moves through the decline stage. The 64K part is in the long mature stage. The 256K E^2 is now moving through the growth stage. The 1Mb EEPROM is now being introduced.

Two newer EEPROM device technologies for consideration are flash EEPROMs and fast EEPROMs ($\leq$70ns).

Figure 12

EEPROM Product Life Cycle as of April 1990



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Source: Dataquest April 1990

Analog ICs

Contrary to the digital world, where the life cycle of a new part might be less than 10 years, analog circuits have very long life cycles. Many of the early product standards introduced in the late 1960s still are major sellers. Although improvements in performance continue to take place, these early parts became standards because they satisfied a basic need, and some of these requirements have not changed over the years. Hence, unlike other product technologies, many analog circuits are complete in their present form. Pressures for change in the analog IC world come from the desire to operate at 5V and to integrate analog circuits into ASIC technology.

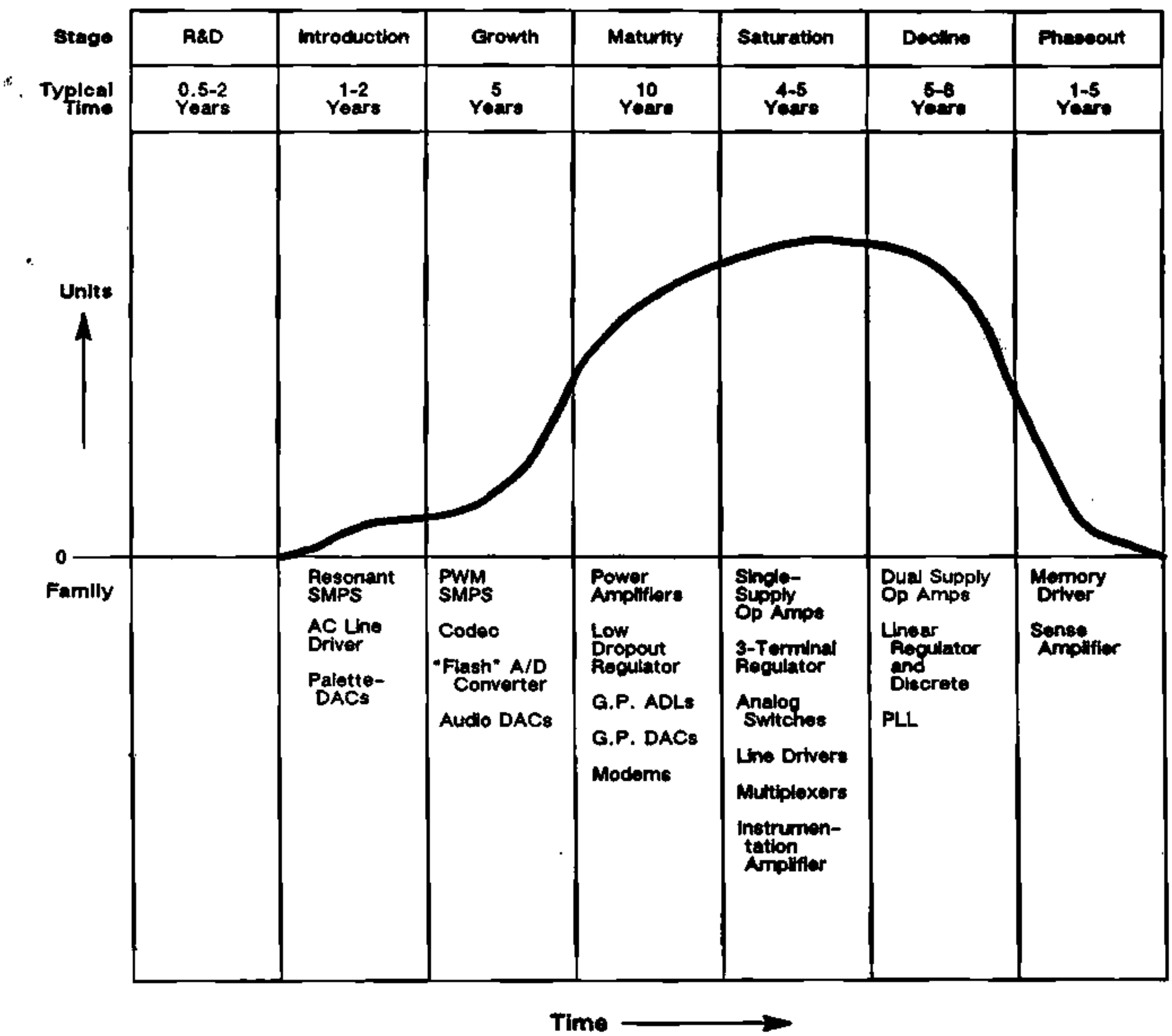
Semicustom analog or mixed analog digital circuits can be expected to have shorter life cycles than standard analog products. ASIC life cycles are tied to specific customers and end products, as is typical with custom circuits. Custom and semicustom ICs are not included in this discussion of analog IC life cycles.

When talking about analog product families, such as amplifiers, the concept of a complete life cycle (birth to death) may not be completely applicable. Families of products have widely different aging profiles that may or may not include a stage of decline. Dataquest foresees no period of decline for many of the analog product families in the future. Individual product types do have positions on the standard life-cycle curve, as illustrated in Figure 13.

The more that a cell in an ASIC or in a more integrated function can perform the analog function, the faster the market for simple functions will decline. The most common mixed-mode cell-based designs integrate simple analog functions (comparators, amplifiers, and drivers) with complex digital circuitry to eliminate the presence of a few outside ICs.

Figure 13

Analog IC Life Cycle as of April 1990



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Source: Dataquest
April 1990

DRAM Product Trends

The *Products* section of the Semiconductor User Information Service (SUIS) binders provides semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendors, and at what price.

This section on DRAMs contains three parts, the first of which examines the supply base in this market by using DRAM product life cycle analysis. The second part analyzes the product strategies and market shares of some leading suppliers of DRAMs, and the third combines the analyses of the DRAM supplier base and product life cycles to give users a practical way of assessing their ability to obtain a supply of the different densities of DRAMs during the 1990 through 1995 period.

Cumulatively, the information in this section enables DRAM users to develop sound strategies for satisfying demand on a consistent, cost-conscious basis over the long term despite sharp shifts in market conditions and the supplier base.

DRAM PRODUCT LIFE CYCLES

This part presents information on DRAM product life cycles as a guide to assist DRAM users in anticipating and adjusting to market forces. In general, product life cycle analysis is most useful in comparing component product life cycles with manufacturers' systems life cycles. This comparison aids in projecting component costs and planning for component changeovers in those cases where life cycles do not match.

In addition, this part also lays the base for other analyses based on DRAM life cycles. DRAM product life cycles are examined in more detail in the subsection entitled "Supply Base Analysis."

Typical DRAM Life Cycles

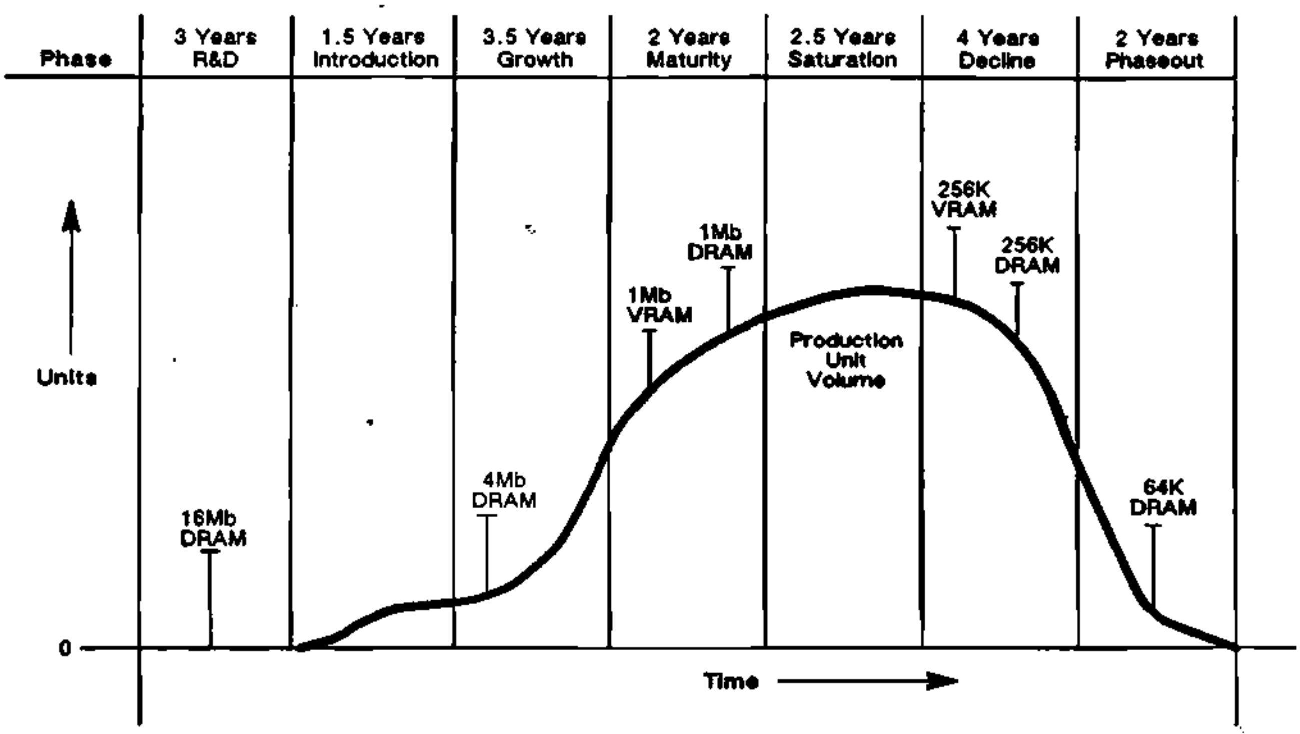
Figure 1 presents the product life cycles over time (as of August 1990) for DRAM devices in densities of 64K, 256K, 1Mb, 4Mb, and 16Mb during the 1990 through 2005 period. The figure also provides life cycle information on single in-line memory modules (SIMMs) and video RAMs (VRAMs).

As shown in Figure 1, the DRAM product has a short introductory stage followed by growth-to-saturation stages that extend for eight years combined. A shorter decline/phaseout phase of five or six years follows. As will be discussed, the DRAM research and development (R&D) stage has been extending and now lasts three years. The decline stage also has extended somewhat.

SIMM life cycles are virtually the same as those of the underlying DRAM devices. By contrast, VRAM life-cycle stages lag behind the stages of the equivalent-density DRAM (e.g., 256 VRAM versus 256 DRAM) by nearly one year (see Figure 1). In turn, the VRAM life cycle should exceed the life of the equivalent-density DRAM by one year.

Figure 1

DRAM Product Life Cycles as of August 1990



Source: Dataquest (August 1990)

Factors that Affect DRAM Life Cycle Behavior

DRAM product evolution during the 1990s hinges on manufacturers' ability to push submicron process geometries to greater levels of miniaturization. Challenges associated with implementing three-dimensional cell structures at the submicron level *could* cause delays in the development of future high-density DRAM products. One effect would be an extension of the R&D and early introduction stages of future DRAM product life cycles such as the 16Mb devices. A concomitant effect would be an extension of the maturity phase of current-generation DRAM devices (e.g., 4Mb DRAMs during mid-1990s). DRAM process advances are likely to necessitate substantial fab retooling, which also could retard the growth of new DRAM product technologies.

For example, as of mid-1990 most suppliers of next-generation 4Mb DRAMs are just achieving acceptable yield rates. Factors such as high initial manufacturing costs and users' tight system-production schedules—which can stand no delays—require suppliers to be conservative in terms of bringing 4Mb DRAMs to market. During the second half of 1989 and the first half of 1990, several leading-edge suppliers dedicated the limited output of 4Mb DRAMs toward strategic sampling or first-volume shipments at key accounts. In addition, relatively few users to date have been motivated or prepared to do design work with the complex 4Mb part.

4Mb DRAMs: 300-mil or 350-mil Standard?

Setting industry standards on DRAMs also can affect life-cycle behavior. For example, a short-term production discontinuity could be brought on by the existence of dual standards in the 4Mb DRAM marketplace, e.g., 300-mil wide or 350-mil wide packages. System designers and buyers reject component uncertainty associated with dual product standards such as the 300- or 350-mil DRAM choice. During 1990, the design of 4Mb DRAMs into systems slowed, partly because of this dual standard. At the time this article was written, the 300-mil device had begun to emerge as the prevailing 4Mb DRAM standard, partly because of its suitability for use in memory boards.

SUPPLIER ANALYSIS

This subsection analyzes the product and market strategies of leading DRAM suppliers. This analysis covers each company's DRAM product positioning, market ranking, and strategy.

Users should note that the highly competitive early stages of the DRAM product life cycles—an intense R&D period followed by a short introductory phase—continue to create significant competitive advantages for early entrants, which are able to enjoy premium pricing through the introduction and growth phases. An extended maturity phase eventually tips the competitive balance to low-cost producers, which can turn a profit throughout the maturity phase. Anticipating possible delays in the development of 16Mb and 64Mb devices, DRAM suppliers are likely to focus even more intently on minimizing their eventual manufacturing costs for the 4Mb and 16Mb devices in order to remain competitive throughout the maturity phase.

Table 1 shows the 1989 ranking of the top 15 DRAM suppliers in terms of dollarized units. The table also presents each company's ranking in the 64K-through-4Mb densities.

Early leadership for the next-generation product often signals future DRAM market leadership. Users should note the correlation in Table 1 between 1Mb DRAM ranking and total DRAM revenue ranking. Dataquest expects the 1992 to 1993 total ranking to be strongly influenced by 4Mb ranking.

Table 1

Top 15 DRAM Suppliers
(Based on Dollarized Units)

Supplier	1989 Total Revenue Ranking	Rank by Density 64K	256K	1Mb	4Mb
Toshiba	1		9	1*	1
NEC	2		1*	2*	3
Samsung	3	1	8	3	
Hitachi	4		3*	5*	2
Fujitsu	5		4*	4*	4
Texas Instruments	6	2	2*	7*	8
Mitsubishi	7		7*	6	9
Oki	8	5	6	8	5
Motorola	9		16	9	7
Siemens	10		12	10	10
Matsushita	11	4	14*	11*	6
Micron	12	3	5*	13	
NMB	13		10	12	
Sharp	14		11	15	
Intel	15		18	14	

*Includes VRAMs
Note: Hyundai ranks thirteenth in 256K DRAM products. Vitelic ranks fifteenth in 256K DRAM products, which include VRAMs.
Source: Dataquest (August 1990)

Toshiba

As shown in Table 1, Toshiba continues to hold the number one ranking in 1Mb DRAMs, 4Mb devices, and the total DRAM market. The foreign market value (FMV) pricing system, among other factors, enabled Toshiba, as the leader in 1Mb DRAM cost reduction, to race ahead of the other 1Mb DRAM competitors to become the world's leading merchant producer of 1Mb devices.

During the second half of 1989, Toshiba forged ahead in the 4Mb segment, reducing its commitment to 1Mb business somewhat during the first half of 1990. As of mid-1990, Toshiba is working hard to maintain the number one spot in the 4Mb product area. Toshiba must adjust to the apparent market move by users and suppliers of 4Mb DRAMs to an industry standard 300-mil-wide 4Mb device. Toshiba and some other suppliers started with a 350-mil device.

Regardless of short-term challenges, Toshiba has dedicated enormous fab capacity and other resources to megabit-density DRAM production. Toshiba will be a major DRAM player for the foreseeable future. Users can also look to Toshiba for 1Mb VRAMs (e.g., 256Kx4 and 128Kx4) and SIMMs. Toshiba is now sampling high-speed 4Mb DRAMs that operate at 60ns. The company has 16Mb DRAMs under development.

NEC

Table 1 shows second-ranked NEC's recent performance in the DRAM business: it is first in the 256K density, second at the 1Mb level, and third in the emerging 4Mb arena.

NEC is unusual in that it has developed a history of successfully playing catch-up in a learning-curve-dominated industry. This catching up has been accomplished through superior manufacturing planning and a long-term "deep-pockets" mentality. As a full-range supplier of electronic products and the world's top ranked supplier of semiconductors, NEC has the financial resources necessary to remain a top DRAM player.

The challenge of producing 4Mb DRAMs profitably has, to some extent, reinforced the company's medium-term commitment to the 256K and 1Mb DRAM business, although market success with the higher-density device remains the key strategic goal. Users also can look to this company for 256K VRAMs (NMOS 64Kx4 devices), 1Mb VRAMs (CMOS 256Kx4), and SIMMs. During the summer of 1990, NEC started to sample high-speed 4Mb DRAMs that operate at 60ns (300-mil package).

An early leader in the 4Mb market, NEC's technology and volume production experience should enable it to remain a top player well into the product's life cycle. Like most other early suppliers of 4Mb DRAMs, the company confronts a stiff challenge in terms of perfecting the complex manufacturing process and sustaining profitable yield rates.

NEC currently supplies 256K DRAMs from its Roseville, California, fab and 1Mb DRAMs from its Scotland, United Kingdom, fab in addition to its Japanese fabs. During 1991, users can expect shipments of 4Mb DRAMs from both the California and Scotland fabs.

NEC has scheduled the opening of a 16Mb DRAM fab in Japan during the 1992 to 1993 time frame. The California fab is designed for eventual production of 16Mb DRAMs. NEC also is developing a 0.4-micron, 64Mb DRAM product in the Tsukuba, Japan, R&D center.

Samsung

Third-ranked Samsung of South Korea surprised the world with its impressive advance in the DRAM marketplace during the late 1980s. As Table 1 reveals, the company is the world leader in the 64K density, ranks eighth at the 256K level, and holds third ranking in the critical 1Mb segment.

The company's vertically integrated structure puts it in a position to emerge as a low-cost DRAM producer; however, Samsung has been strictly a technology follower. Nevertheless, during 1989, Samsung emerged as a force in the worldwide DRAM business. Samsung's greatest challenges are to maintain product quality and avoid trade friction.

Users can expect strong commitment by Samsung in the 1Mb DRAM business during 1990 and 1991. Special long-term supply arrangements could be forged for users of 64K devices and 256K parts. Users also can look to this company for SIMMs.

Samsung has been conservative in terms of bringing the complex 4Mb DRAM device to market. This careful approach has sound merit because slippage in critical product delivery dates and/or quality standards could undercut Samsung's (or any supplier's) long-term role in the high-density DRAM business.

In July 1990, Samsung announced the first volume shipments of 4Mb DRAMs. At the time this article was written, Samsung also announced samples of a 16Mb DRAM.

Hitachi

Hitachi, the fourth-ranked DRAM supplier, has battled ferociously to overcome FMV-related setbacks of recent years. As Table 1 shows, Hitachi ranks third in the 256K density, fifth in the 1Mb segment, and second in the emerging 4Mb segment. Hitachi has been the most aggressive supplier in terms of targeting the 4Mb arena, reducing commitment to lower-density products in the process. Dataquest places Hitachi among the earliest and strongest entrants into the 4Mb market.

Hitachi now draws upon the manufacturing and marketing expertise that made it the number one DRAM supplier for several years. In addition to its manufacturing and design expertise, users can expect Hitachi to continue to display the device speed and packaging technology expertise that has allowed it to achieve effective DRAM product differentiation in the past.

For example, during the second half of 1989 and the first half of 1990, Hitachi steadily won new design-ins for its 4Mb DRAMs (300-mil package). More than any other player in the 4Mb DRAM market today, Hitachi has the motivation to expand share through early volume shipments, design expertise, and aggressive pricing. As of mid-1990, Hitachi is sampling high-speed 4Mb DRAMs that operate at 60ns.

In addition, Hitachi will utilize technology agreements and other alliances as needed to protect its position in the 256K and 1Mb segments (e.g., Hitachi-Goldstar alliance) as well as in the 4Mb and 16Mb arenas. Hitachi's product portfolio includes SIMMs as well as 256K VRAMs (CMOS 64Kx4 devices) and 1Mb VRAMs (CMOS 256Kx4). Hitachi has developed a 16Mb DRAM prototype product.

Fujitsu

As shown in Table 1, fifth-ranked Fujitsu ranks fourth in the 256K, the 1Mb, and the 4Mb DRAM segments. Fujitsu remains somewhat buffered—although not immune—from DRAM merchant market turbulence by an unusually high percentage of captive demand.

Users can look to this company as a dependable and competitive supplier of 1Mb DRAMs during 1990 and 1991. Lower-density devices will be de-emphasized; however, currently Fujitsu remains active in the 256K segment. Users can also look to Fujitsu for 256K VRAMs (CMOS 64Kx4 parts), 1Mb VRAMs (CMOS 256Kx4), and SIMMs.

Fujitsu may be forced to play catch-up in the 4Mb segment. The supplier has been an early proponent of the now-emerging 300-mil 4Mb device. Fujitsu is stressing the thin small-outline package (TSOP) for the 4Mb and 16Mb devices because of multiplexing issues and the increased acceptance of higher pin-count packages.

Texas Instruments

Sixth-ranked Texas Instruments (TI), which benefited from the US-Japan Trade Arrangement, remains committed to success in the DRAM business. Table 1 reveals that this company ranks second in the 64K and 256K densities, seventh in the 1Mb segment, and eighth in the new 4Mb arena.

Users can look to this company as a dependable and competitive supplier of 1Mb DRAMs during 1990 and 1991. The 256K device will be de-emphasized somewhat, although TI will remain responsive to market demand. The product portfolio includes SIMMs, 256K VRAMs (NMOS 64Kx4 devices), and 1Mb VRAMs (CMOS 256Kx4).

Like other suppliers, TI initially moved aggressively into the 4Mb market but was quieter than originally expected in this segment during the first half of 1990. Like other suppliers, TI confronts the full range of challenges associated with the move to 4Mb DRAMs: device complexity, yield rates, fab expense, design wins, delivery dates, and product quality.

In order to ensure its long-term role in the megabit-density DRAM marketplace, TI has been among the most resourceful of suppliers in terms of forging strategic alliances and other arrangements of sharing the risks and benefits of participation in this worldwide market.

Mitsubishi

Table 1 shows that seventh-ranked Mitsubishi ranks seventh in the 256K segment, sixth at the 1Mb density, and ninth in the emerging 4Mb arena. Mitsubishi's 1Mb devices are manufactured at its Kochi, Japan, plant and at the Durham, North Carolina (USA), fab.

Mitsubishi's rankings have slipped somewhat in recent years—the company ranked third in both the 256K and 1Mb segments during 1988. Nevertheless, the huge Mitsubishi organization has identified the areas of computers, telecommunications equipment, and semiconductors as central to its plans to evolve toward a more technology-oriented product mix and has targeted these segments for aggressive long-term market growth. Mitsubishi uses DRAM production as a technology driver to generate shared learning across a wide variety of component types. In addition to 256K DRAMs and 1Mb products, users can obtain SIMMs and 256K VRAMs (NMOS 64Kx4 devices) from Mitsubishi.

Although not an early leader, Mitsubishi ranks within the first tier of suppliers in the 4Mb arena. For example, the company was one of the first suppliers to market the high-speed 4Mb DRAMs that operate at 60ns. The competitive advantage of Mitsubishi's process and packaging technology expertise is likely to grow more significant as the industry moves to the 16Mb and 64Mb densities. Mitsubishi is developing 16Mb devices at its central research facility in Saijo, Japan.

Oki

Table 1 reveals that eighth-ranked Oki ranks fifth in the 64K segment, sixth in the 256K market, eighth at the 1Mb density, and fifth in the emerging 4Mb arena. Despite trade frictions, the company has been resilient in response to market pressures and, in fact, advanced one position overall among worldwide suppliers during 1989. Users can expect Oki to de-emphasize the older 64K DRAM product and, to a lesser extent, 256K devices. In addition to 1Mb DRAMs, Oki's emphasis will be on 4Mb DRAMs and modules that incorporate megabit-density DRAMs. Oki has been a leader among SIMM suppliers; in fact, Oki was one of the first companies to introduce 4Mb SIMMs to the marketplace.

More so than other Japan-based DRAM suppliers, Oki manufactures its products in Japan rather than in local offshore markets. Oki plans to assemble its memory modules in the United States but will produce its 4Mb DRAMs at its Miyagi facility in Japan.

Motorola

Ninth-ranked Motorola has advanced during the past several years through its DRAM technology alliance with Toshiba. The first phase of this agreement pertained to product densities of 4Mb and below. At the time this article was written, Motorola had just signed a memorandum of understanding with Toshiba that extended their agreement to DRAM product densities of 16Mb and above. Motorola also has been discussing an alliance with IBM regarding Motorola's use of IBM'S 16Mb device technology.

Table 1 shows that Motorola ranks sixteenth in the 256K density segment, ninth at the 1Mb level, and seventh in the emerging 4Mb segment. Having departed the DRAM business in the 1980s, 1989 marked Motorola's return to a top ten ranking among DRAM suppliers.

As a large, full-line semiconductor manufacturer, Motorola is well situated to shift additional fab capacity to DRAM manufacture should market conditions dictate. The company will emphasize 1Mb and 4Mb devices but remain responsive to market demand for 256K products. Motorola also will be active in the SIMM marketplace.

Siemens

Siemens' recent surge in the worldwide DRAM marketplace is evidenced by the company's tenth-place ranking among global suppliers. Table 1 reveals that Siemens ranks twelfth in both the 256K segment and tenth in the 1Mb and 4Mb arenas. Users should view Siemens as a prospective entrant to the SIMM business.

As Europe moves toward 1992 consolidation, Siemens' competitive position in that region of the world should strengthen as non-European DRAM suppliers struggle to comply with the complexities of local content regulations. At the time this article was written, Siemens was negotiating with SGS-Thomson regarding joint production of 4Mb and 16Mb DRAMs. North American users should note that Siemens views North American sales as a key element of its long-term strategy.

Matsushita

Table 1 reflects eleventh-ranked Matsushita's recent performance in the DRAM business. The company is fourteenth at the 256K density, eleventh at the 1Mb level, and sixth in the emerging 4Mb arena. This company also supplies 256K VRAMs (NMOS 64Kx4) and 1Mb VRAMs (CMOS, 256Kx4, and 128Kx8).

In recent years, this huge, vertically integrated supplier has battled for a leadership position among suppliers of megabit-density DRAMs. The results in the 1Mb segment to date are not entirely positive. Matsushita's performance in the 4Mb DRAM business could prove crucial to the long-term role in the DRAM marketplace. Matushita has a 16Mb DRAM prototype under development.

Micron

As shown in Table 1, twelfth-ranked Micron ranks third in the 64K DRAM segment, fifth in the 256K density, and thirteenth in the 1Mb market.

Although this relatively small memory supplier (vis-à-vis giants such as NEC or Motorola) is diversifying into a wider array of memory devices, Micron remains first and foremost a DRAM supplier. Micron is shifting from 256K to 1Mb products, which is concurrent with other cost-oriented competitors such as Samsung. Users of 64K and 256K DRAMs should be able to forge special long-term supply arrangements with this supplier. Micron's product portfolio also includes SIMMs.

NMB

NMB—a recent entrant to the DRAM business—has carefully positioned itself as a supplier of high-speed DRAM devices that operate at speeds of 60ns *and* faster. NMB holds a 90 percent share of the high-speed 256K and 1Mb DRAM markets.

The result is shown in Table 1: the small company rapidly emerged as the world's thirteenth-ranked DRAM producer. In terms of total DRAM sales, NMB ranks tenth at the 256K DRAM level and twelfth at the 1Mb density.

To compete with the giants in the DRAM world, NMB has relied on strategic alliances for design technology and foundry service. For example, NMB has acquired DRAM designs from Alliance Semiconductor, Inmos (now owned by SGS-Thomson), Ramtron, and Vitelic.

Through the Ramtron alliance, NMB now supplies 4Mb DRAMs that operate at 50ns. This 350-mil-wide device will be available next in a 300-mil version. A even faster 4Mb part might become available. NMB and Ramtron also are developing a high-speed 16Mb DRAM product.

NMB operates two state-of-the-art automated DRAM fabs in Tateyama, Japan. A third fab in Japan should open during the third quarter of 1990. Foundry arrangements add to NMB's production capacity.

Earlier in 1990, Intel signed an agreement that makes NMB a major supplier of DRAMs to Intel. In exchange for the right to market NMB's high-speed products, Intel will buy a large share of NMB'S output. The impact and direction of this alliance were not clear at the time this article was written.

SUPPLY BASE ANALYSIS

This part of the section uses information on DRAM product life cycles and suppliers to present a density-by-density evaluation of the supply base for these devices over the medium to long term. The figures herein show the 1989 total market size (in units) and the shares of the leading suppliers of each density.

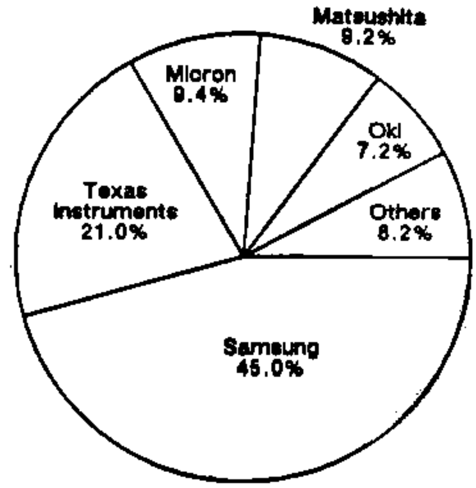
Supply Base for 64K DRAMs

The 64K DRAM device is being phased out (see Figure 1). The phaseout stage represents a difficult phase of the product life cycle for procurement managers. Buyers of 64K DRAMs face the loss of multiple sources by 1992.

Figure 2 shows that production of 64K DRAMs during 1989 totaled 67 million units, and the figure reveals that the leading suppliers are Samsung, Texas Instruments, and Micron. Unit production of 64K DRAMs dropped by 30 percent during 1989.

Figure 2

64K DRAM Supplier Base



Total Units = 67 Million

Source: Dataquest (August 1990)

Dataquest recommends that users migrate from this device in system designs lacking a long-term procurement arrangement. Users that will need this device should target Micron and Samsung for special long-term supply contracts.

Supply Base for 256K DRAMs

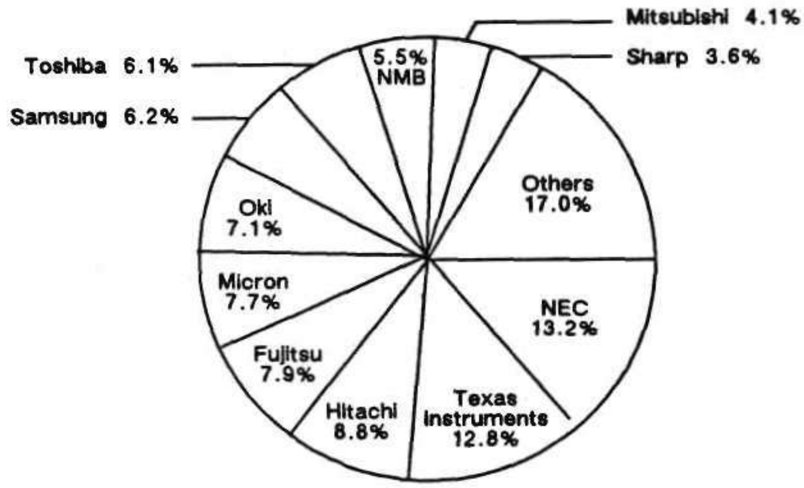
Figure 3 lists the top-ranked 256K DRAM suppliers by 1989 unit share. It presents the leading suppliers (in order) in terms of unit shipments; the suppliers are NEC, Texas Instruments, Hitachi, Fujitsu, Micron, Oki, Samsung, Toshiba, NMB, Mitsubishi, and Sharp. Table 1 provides the full spectrum of suppliers.

As shown in Figure 1, the 256K DRAM product is moving through the decline stage of the life cycle. During 1989, production of 256K DRAMs dropped by 10 percent to a total of 854 million units. Nevertheless, users can expect worldwide output to exceed 100 million units each year through 1993. Users also can expect a dependable supply of 256K devices during this period. A number of suppliers from around the world are likely to support demand for 256K DRAM devices during the next several years.

During 1989, the following companies maintained their share of the declining 256K marketplace: NEC, Hitachi, Micron, Oki, Toshiba, and NMB. Even so, users can expect leading-edge 4Mb DRAM suppliers such as Hitachi and Toshiba to be least supportive of 256K DRAM demand during the 1990 through 1992 period. Newer suppliers such as Goldstar, Hyundai, and Motorola will support 256K demand in order to win accounts for their higher-density DRAM products.

Figure 3

256K DRAM Supplier Base



Source: Dataquest (August 1990)

Supply Base for 1Mb DRAMs

As shown in Figure 1, the 1Mb DRAM stands at the maturity stage of the life cycle with market saturation (or peak production) expected during 1992 and 1993. With the supplier base of 4Mb DRAMs still limited as of mid-1990, the mainstream 1Mb DRAM market segment should remain highly competitive during the 1990 through 1993 time frame. Users should note that as this product moves through the saturation stage (in 1992 and 1993), 1Mb DRAM price competition could intensify—*especially* if the US-Japan Semiconductor Trade Arrangement expires during the second half of 1991.

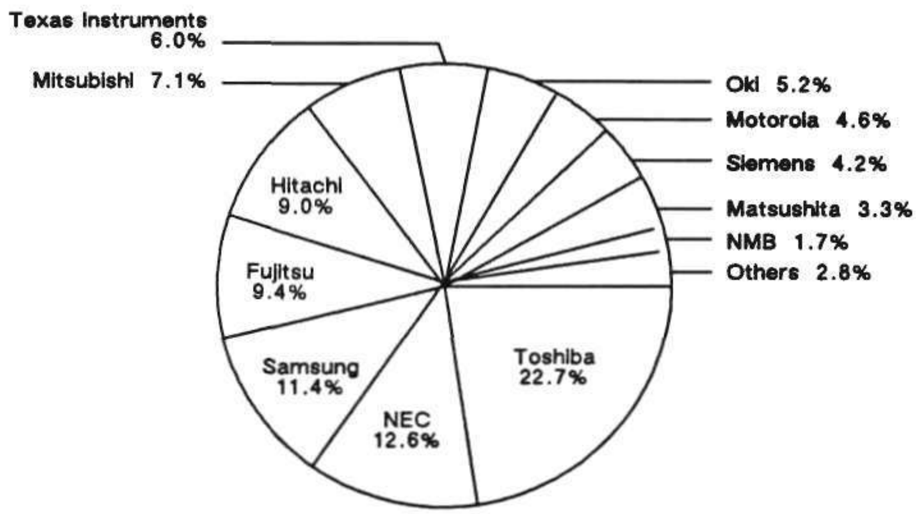
During 1990, most suppliers have been conservative in terms of bringing the complex 4Mb product to market, leaving the 1Mb segment crowded with a global network of competitive suppliers. As suppliers shift capacity to 4Mb DRAMs during 1990 and 1991, the competitors that remain in the 1Mb market are likely to be companies with process technology, die size, and basic cost structures that allow for profitable production at lower price levels.

Figure 4 presents the top-ranked 1Mb DRAM suppliers by 1989 unit share. The figure shows that the top-ranked suppliers (in order) in terms *unit* shipments are Toshiba, NEC, Samsung, Fujitsu, Hitachi, Mitsubishi, Texas Instruments, Oki, Motorola, Siemens, Matsushita and NMB. Table 1 provides the full range of suppliers.

During 1989, production of 1Mb DRAMs more than doubled to a total output of 503 million units (versus 1988 production of 212 million units). Users can expect worldwide output to exceed 700 million units during 1990 and to peak at a level of 1 billion units for 1992 and 1993. Users can expect an ample supply of 1Mb products during the early 1990s.

Figure 4

1Mb DRAM Supplier Base



Total Units = 503 Million

Source: Dataquest (August 1990)

Source: Dataquest (August 1990)

Some suppliers from around the world still are either entering or increasing production, while other suppliers (first-tier 4Mb DRAM suppliers) are shifting their efforts to higher-density DRAMs. During 1989, two suppliers—Samsung and Motorola—sharply increased their share of the growing 1Mb DRAM market. Siemens and NMB also made impressive gains. The following suppliers essentially held their share of the 1Mb marketplace during this period: NEC, Fujitsu, Oki, and Matsushita. However, Toshiba, Fujitsu, Hitachi, Mitsubishi, and Texas Instruments lost share during 1989.

Users of mainstream 1Mbx1 DRAMs (80ns to 100ns) should target Motorola, NEC, Samsung, Siemens, and Texas Instruments for supply during the 1990 through 1991 period. Micron also should advance its market share during this period. Users should expect leading-edge 4Mb DRAM suppliers such as Hitachi and Toshiba to move quickly away from the 1Mb segment; however, a slower-than-expected ramp in 4Mb DRAM production would undercut this scenario.

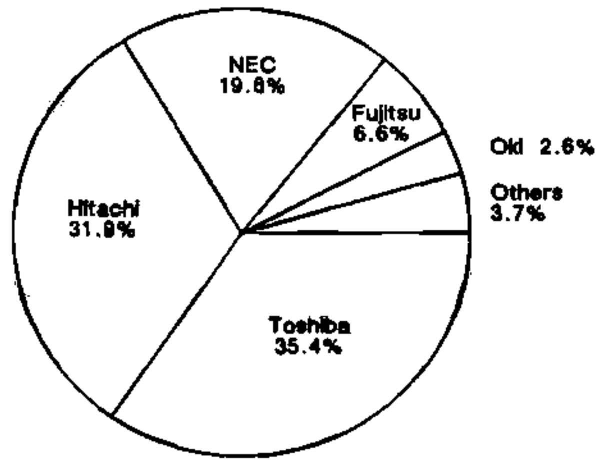
Supply Base for 4Mb DRAMs

Figure 1 shows that the 4Mb DRAM device stands at the early growth stage of the life cycle. First volume shipments of the 4Mb DRAMs began during 1989, but the product complexity to both to users *and* suppliers thwarted rapid growth during 1990. Worldwide output should total 21 million units during 1990.

Figure 5 lists the top-ranked 4Mb suppliers by 1989 unit market share. The leading suppliers (in order) in terms of unit shipments are Toshiba, Hitachi, NEC, Fujitsu, and Oki. Table 1 shows the full range of suppliers.

Figure 5

4Mb DRAM Supplier Base



Total Units = 1.9 Million

Source: Dataquest (August 1990)

Source: Dataquest (August 1990)

Some suppliers expected a quicker market move to 4Mb DRAMs. Current and prospective suppliers of 4Mb DRAMs have encountered stiff challenges in achieving acceptable yields. For example, the issue of a dual standard on wafer size (300 or 350 mil) has complicated users' design efforts (e.g., memory board upgrades).

During late 1990 and 1991, users can expect 4Mb DRAM yields to increase. As manufacturing costs decrease, more suppliers will begin to ramp up production. As shown in Figure 1, impressive growth in output should occur during the 1991 through 1993 time frame, a period that should be marked by rapid capacity expansion and new entrants. Dataquest expects worldwide production to grow to 120 million units in 1991, 420 million units in 1992, and 865 million units in 1993. The product life cycle should extend beyond the year 2000.

Supply Base for 16Mb DRAMs

Figure 1 shows that the 16Mb DRAM product is at the R&D stage of the life cycle. Several companies such as Hitachi and Texas Instruments have produced a prototype. Most suppliers of 4Mb DRAMs have a 16Mb DRAM product under development. During the next two to four years, the 16Mb DRAM prototype will go through a series of process adjustments and redefinitions in order to ensure that acceptable manufacturing yields can be achieved. The R&D phase ends with final product definition and release to production.

Dataquest believes that the very first 16Mb DRAMs will appear on the market by late 1992, although the genuine introduction stage should run during 1993 and into 1994. As shown in Figure 1, the product life cycle of this part should extend beyond the year 2005.

SRAM Product Trends

The section entitled "Products" in the Semiconductor User Information Service (SUIS) binders provides semiconductor users with practical, strategic information for choosing which semiconductor devices to use, from which vendors, and at what price. In terms of supply base management, this section focuses primarily on the choice of the right SRAM for a given system and from which vendor.

Fast MOS SRAMs (hereafter, fast SRAMs) are defined as those static RAMs that operate at access times of 70 nanoseconds (ns) or less. Slow MOS SRAMs (hereafter, slow SRAMs) are defined as those static RAMs that operate at access times of greater than 70ns (typically, in the x8 configuration).

This section contains four parts, the first of which examines the supply base in this market by using SRAM product life cycle analysis. The second part analyzes the product strategies and market shares of some leading suppliers of SRAMs; the third combines the analyses of the SRAM supplier base and product life cycles to give users a practical way of assessing their ability to obtain a supply of the different densities of SRAMs during the 1990 through 1995 period. The fourth part looks at the key industry issues affecting users of SRAMs now and in the future.

Cumulatively, the information in this section enables design engineers, purchasing managers, strategic planners, and other supply base managers to develop a sound strategy for satisfying system demand for SRAMs.

SRAM PRODUCT LIFE CYCLES

This section uses information on SRAM product life cycles as a guide to help users adjust to the continuing flow of new products over the short and long terms. This section also forms the basis for other analyses based on SRAM life cycles.

Typical Life Cycles for MOS SRAMs

Figure 1 presents the product life cycles as of July 1990 for SRAM devices (1K, 4K, 16K, 64K, 256K, and 1Mb densities) during the 1990 through 2005 period.

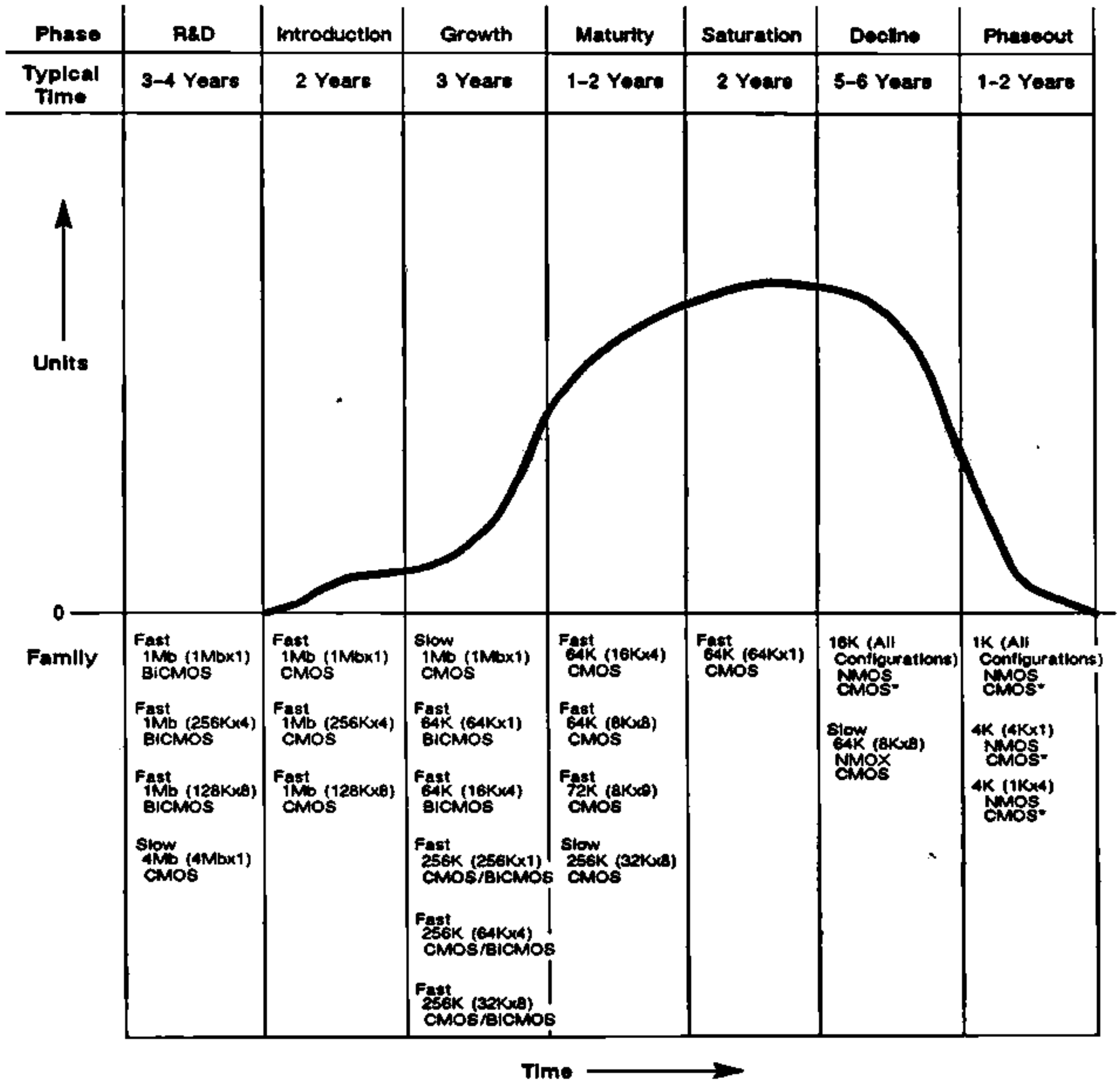
As shown Figure 1, the SRAM product enjoys a relatively long life cycle, with the decline/phaseout stages of the cycle stretching nearly ten years. For example, fast SRAM suppliers typically stretch life cycles over time by designing faster versions of older-density parts.

Figure 1 reveals that during 1990 and 1991 users of fast SRAMs and slow SRAMs can expect a large supply of 64K parts and a growing supply of 256K devices. Nineteen ninety marks the introduction of 1Mb fast SRAMs and the early ramp stage of 1Mb slow SRAMs. At the other end of the spectrum, lower-density SRAMs (e.g., 16K and below) move through the decline or phaseout stages.

SRAM product life cycles are examined by technology and configuration in the subsection entitled "Supply Base Analysis."

Figure 1

SRAM Life Cycle as of July 1990



*Fast and slow

Source: Dataquest (August 1990)

Source: Dataquest (August 1990)

SUPPLIER ANALYSIS

This section analyzes the product and market strategies of some leading suppliers of fast SRAMs and slow SRAMs. Table 1 shows worldwide ranking for the top suppliers of SRAMs at the 4K, 16K, 64K, 256K, and 1Mb density levels. The SRAM ranking is based on 1989 unit shipments.

Please note that *slow* SRAMs do not serve primarily as a technology-process driver for most manufacturers of these devices; DRAMs or fast SRAMs fulfill that strategic objective. Rather, slow SRAMs serve as "fab-fillers" that help suppliers (typically vertically integrated manufacturers) meet internal captive demand and simultaneously keep fabs operating at higher capacity levels. The slow SRAM supplier base is limited vis-à-vis other semiconductor products because of the captive demand element.

By contrast, fast SRAMs can serve as technology-process drivers, especially for suppliers that do not make DRAMs. In addition, product differentiation is driving the fast SRAM market and

Table 1

1989 Ranking of Top SRAM Suppliers by Density (Based on Unit Shipments)

	4K		16K		64K		256K		1Mb	
Company	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow
AMD	1		11							
Cypress	2		1		6		9		X	
Fujitsu			12		2	8	1	4	X	6
Hitachi			3	4	1	3	2	1	X	2
IDT			4		8		4		X	
Micron			20		14		5		X	
Mitsubishi			15		9	10	3	2	X	7
MOSel			14		12		7			
Motorola			5		4		11		X	
National Semiconductor							8			
NEC				10	10	2		3	X	5
Sanyo				2		4				
Seiko				6				7		
SGS-Thomson	3		2		3		19			
Sharp				5	11	5	10	8		
Sony			18	3	7	6	6	6	X	1
Toshiba			8		5	1	12	5	X	3
UMC	5		7	1						
VLSI			10						X	

X = 1990 introduction/early volume production
Source: Dataquest (August 1990)

creating supplier opportunities in profitable, speed-based niche markets. Consequently, the fast SRAM supplier base is wider vis-à-vis most other semiconductor memory products such as slow SRAMs.

Cypress Semiconductor

Cypress' strength as a supplier of fast SRAMs derives from its ability to push product technology and drive access times to ever-faster thresholds.

Table 1 shows Cypress' ranking by density during 1989. Cypress ranks second among suppliers of fast 4K SRAMs, first in the fast 16K arena, sixth in the fast 64K segment, and ninth in the expanding fast 256K marketplace.

This supplier's strategy remains consistent over time: it must dependably supply new SRAM products that offer state-of-the-art speeds in lower-density devices (e.g., 16K or below) and gradually extend that strategy to higher-density segments.

Fujitsu

Fujitsu ranks as a leading supplier of 16K fast SRAMs, 64K fast SRAMs, and high-density slow SRAMs (e.g., 256K and above). The company's reputation as a reliable supplier of leading-edge, higher-density SRAMs stems partly from its vertically integrated organization.

Fujitsu's market ranking as shown in Table 1 reflects its product positioning: it is second at the 64K density of fast SRAMs, first in the 256K fast SRAM segment, fourth in the 256K slow SRAM arena, and sixth in the nascent 1Mb slow SRAM market. Users can expect Fujitsu to be a long-term force in the SRAM business, especially the BiCMOS fast SRAM segment.

Hitachi

Table 1 shows Hitachi's leadership position in high-density slow SRAMs. The company has battled to maintain its competitive position in the fast SRAM business and uses its expertise in the BiCMOS process as a key element to its long-term strategy.

Table 1 shows that Hitachi ranked third among suppliers of fast 16K SRAMs and first in the 64K fast segment. It also ranked first among suppliers of slow 256K SRAMs and second in the 1Mb slow SRAM segment. The company furthermore holds the third-place position in the 64K slow SRAM marketplace.

Users can expect Hitachi to keep at the forefront of SRAM product technology in terms of product speed and density. One goal is to lower 1Mb SRAM speeds to 25ns or below; another goal is to maintain a leadership role among suppliers of high-density slow SRAMs.

IDT

IDT has forged a reputation as a dependable supplier of high-performance fast SRAMs. Table 1 shows that the company ranks fourth among suppliers of fast 16K SRAMs, eighth in the fast 64K segment, and fourth in the fast 256K business.

In terms of future product direction, IDT remains committed to expanding sales of application-specific memories in commercial markets, especially because of contraction of the military market.

Mitsubishi

Mitsubishi, a vertically integrated manufacturer, has been a rising star in the SRAM marketplace. North American and European users can expect a long-term commitment by Mitsubishi to serving SRAM demand.

As shown in Table 1, Mitsubishi ranks second among suppliers of slow 256K SRAMs and third in the fast 256K segment. In terms of 64K SRAMs, the company ranks ninth in the fast 64K marketplace and tenth in the slow 64K arena. Mitsubishi holds a seventh-place ranking among suppliers of slow 256K SRAMs.

Motorola

Motorola continues to advance in the worldwide semiconductor memory marketplace. Table 1 reveals that Motorola ranks fifth among suppliers of fast 16K SRAMs, fourth in the fast 64K segment, and eleventh in the young 256K fast SRAM marketplace.

The company's future product direction in SRAMs links to its position as a major supplier of application-specific memories. North American and European users of SRAM should expect continued advance by Motorola in this market.

NEC

NEC is a vertically integrated supplier of SRAMs; its position in the marketplace has been strengthened by captive demand for slow SRAMs.

Table 1 reveals NEC's strength in the slow SRAM market. As shown in Table 1, NEC ranks second at the 64K density of slow SRAMs, third in the 256K segment, and fifth in the newly emerging 1Mb arena. North American and European users of slow SRAMs can expect a strong commitment by NEC to serving demand in SRAM segment of the semiconductor memory business.

Toshiba

Toshiba ranks as a leading player in the slow SRAM marketplace and as a major force in the fast SRAM segment. Users should expect Toshiba to remain a leading full-line supplier of SRAMs.

Table 1 reveals that the company ranked first during 1989 in the 64K slow SRAM business, fifth in 256K slow SRAM market, and third in the emerging 1Mb slow SRAM arena. Toshiba ranks eighth in the 16K fast SRAM segment, fifth in 64K fast SRAM marketplace, and twelfth in the growing 256K fast SRAM segment.

Toshiba maintains a strong strategic commitment to high-density DRAMs as technology-process driver, which *can* periodically cut into capacity for slow SRAM production. The company remains attuned to new market applications for high-density fast SRAMs through its vertically integrated organization.

SGS-Thomson

SGS-Thomson advanced its stake in the SRAM business through the acquisition of Inmos. SGS-Thomson faces a challenge in the higher-density segments of the fast SRAM marketplace.

Table 1 shows that SGS-Thomson holds a solid position among suppliers of fast SRAMs at densities of 64K or below. The company ranks third among suppliers of fast 4K SRAMs, second in the fast 16K segment, and third in the fast 64K SRAM market. As shown by its ranking in the fast 256K marketplace, SGS-Thomson faces a battle in the higher-density segments of the fast 256K SRAM business.

SUPPLY BASE ANALYSIS

This section uses information on SRAM product life cycles and SRAM suppliers to present an evaluation of the supply base for these devices in the 4K, 16K, 64K, 256K, and 1Mb densities over the medium and long terms. It provides users with a practical way of analyzing the long-term supply base and offers guidance for choosing suppliers. Table 1 serves as the basis for supplier analysis.

Product life cycle analysis serves as the basis for a succinct assessment from the user's viewpoint of the anticipated supply base for each SRAM density. Figure 1 presents SRAM life-cycle information for select product technology and configurations over time. The in-text summary includes a short statement as to whether the user faces a favorable or critical supply base for each density of SRAM.

Supply Base for 4K SRAMs

North American, European, and other users of fast 4K SRAMs face a tightening situation in terms of supply. As of 1990, the 4K SRAM is in the middle of the lengthy decline/phaseout stages of its product life cycle. Looking forward, users can expect a phaseout during the 1993 to 1995 period.

AMD, Cypress, and SGS-Thomson remain leading suppliers of fast 4K SRAMs. Two other suppliers include Performance Semiconductor and UMC. The supply base for fast 4K SRAMs should continue to narrow over time, and the 4K slow SRAM product has been phased out.

Supply Base for 16K SRAMs

North American, European, and Japanese users of fast 16K SRAMs continue to face a generally favorable supply situation through 1992; supply should tighten somewhat afterward. Users of slow 16K SRAMs face an increasingly difficult supply situation during the 1990 to 1992 period.

Figure 1 reveals that, as of 1990, 16K SRAM products are in the lengthy decline stage of their life cycle. Supply base managers with systems that utilize 16K fast SRAMs can plan for system redesign during the 1993 to 1994 period. Users of slow 16K SRAMs are likely to make the migration one or two years earlier.

The extended life cycle of the fast 16K device reflects the performance-driven attributes of the fast SRAM business. For example, the phaseout stage of the life cycle for fast 16K SRAMs should stretch to the 1994 to 1996 time frame.

Users can look to a wide global supplier base for these fast devices. Table 1 shows that Cypress Semiconductor and SGS-Thomson rank as leading suppliers. Other leading suppliers of fast 16K SRAMs include Hitachi, IDT, Matra-Harris, and Motorola.

As shown in Table 1, North American and European users of 16K slow SRAMs should seek long-term arrangements with suppliers such as Hitachi, Sanyo, Seiko, Sharp, Sony, or UMC.

Supply Base for 64K SRAMs

North American and European users of 64K SRAMs continue to face a generally favorable long-term supply situation.

Figure 1 shows that the life cycle for 64K fast SRAMs is expected to stretch to the year 2000. Production of CMOS fast 64Kx1 devices has peaked. By contrast, CMOS fast 16Kx4 devices and CMOS fast 8Kx8 products should move through the maturity (or peak) stage during 1990 and 1991. The BiCMOS 64K fast SRAM now is moving through its growth stage. Users who have designed CMOS fast 64K parts or BiCMOS fast 64K products into systems can expect an ample supply of parts from a wide supplier base.

Figure 1 shows that the slow 64K SRAM product has entered the lengthy decline stage. As noted, the decline/phase out stages should extend into the mid-1990s.

As shown in Table 1, a growing number of suppliers plan to serve long-term demand for CMOS fast 64K SRAMs. Two Japanese companies—Hitachi and Fujitsu—rank first and second, respectively, among suppliers. The diverse supplier base includes SGS-Thomson in third place, Motorola in fourth, Toshiba in fifth, and Cypress Semiconductor in sixth. Table 1 shows the full range of suppliers.

Fujitsu, Hitachi, and NEC, among others, have committed plans for supplying BiCMOS products. By contrast, the supplier base for slow 64K SRAMs fitfully contracted and expanded during the 1988 to 1990 period. Table 1 shows (in order) that Toshiba, NEC, Hitachi, Sanyo, Sharp, and Sony rank as leading suppliers of this device.

Dataquest Recommendation on 64K Slow SRAMs

Because of possible supply base contraction (as suppliers periodically move to other more lucrative memory ICs such as DRAMs), Dataquest recommends that users of 64K slow SRAMs work closely with suppliers regarding accurate supply-and-demand forecasts. Users should be prepared to forge special long-term arrangements with suppliers to ensure a steady supply of this device.

Users of 128Kx8 slow SRAMs are likely to experience similar supply constraints during the 1991 to 1993 period.

Supply Base for 256K SRAMs

Users of 256K SRAMs face a favorable long-term supply base. As shown in Figure 1, slow 256K SRAMs are moving into the maturity stage. The slow 256K SRAM life cycle is expected to extend to the 2001 to 2002 time frame. Figure 1 also shows that as of 1990 fast 256K SRAM products are moving through the growth (or ramp) stage of their life cycle. The fast 256K SRAM cycle should extend until 2005.

In terms of fast SRAM product configurations, suppliers first ramped up the CMOS 256Kx1 products and CMOS 64Kx4 devices. The 64Kx4 part is expected to emerge as the predominant organization. Production of the CMOS 32Kx8 device should ramp up during 1990 and 1991. These products also are available in the BiCMOS technology from a number of suppliers.

Table 1 shows that a large number of suppliers provide fast 256K SRAMs. Table 1 shows that Fujitsu, Hitachi, Mitsubishi, IDT, Micron, Sony, MOSel, National Semiconductor Corporation, Cypress Semiconductor, and Sharp rank as leading suppliers of this device, in that order.

Table 1 depicts a more narrow supplier base for slow 256K SRAMs. Vertically integrated Japanese companies Hitachi, Mitsubishi, NEC, Fujitsu, Toshiba, Sony, Seiko, and Sharp rank as the leading suppliers of this product, in that order.

Supply Base for 1Mb SRAMs

As shown in Figure 1, slow 1Mb SRAMs stand at the early growth (or ramp) stage of the life cycle. Figure 1 also reveals that 1990 marks the introduction stage of the life cycle for CMOS fast 1Mb SRAMs. BiCMOS fast 1Mb SRAMs will be introduced during 1991. The fast 1Mb SRAM life cycle should extend until the 2007 to 2010 time frame.

Table 1 depicts narrower supplier base for slow 1Mb SRAMs. The vertically integrated Japanese companies—Sony, Hitachi, Toshiba, NEC, Fujitsu, and Mitsubishi, in that order—rank as leading suppliers.

For users of fast 1Mb SRAMs, Dataquest expects the 256Kx4 organization to emerge as the leader in terms of unit production and design wins. The BiCMOS process will compete aggressively against CMOS for design applications.

INDUSTRY ISSUES AFFECTING USERS OF MOS SRAMs

This section analyzes major industry issues that should influence the choice of vendors and devices by users of SRAMs during the 1990 to 1995 period. In terms of technology, a major trend during the 1990s should be the growth in production and consumption of fast BiCMOS SRAMs.

Fast SRAMs

A Wide Supplier Base for Fast SRAMs

More than 20 suppliers now serve worldwide demand for fast SRAMs. Product differentiation in terms of speed and configuration continues to drive the market and creates supplier opportunities in terms of profitable speed-based niche markets.

Entrepreneurial companies such as Cypress Semiconductor and IDT can focus on achieving state-of-the-art speeds in lowest-density or higher-density parts. Nevertheless, dangers exist for start-ups. For example, Saratoga Semiconductor went bankrupt as it tried to usher in the new BiCMOS process. Big companies such as Motorola or National Semiconductor can gain or regain market share within several years by forging the appropriate strategy.

BiCMOS SRAMs

Hitachi introduced the BiCMOS process to the fast SRAM merchant market in 1985. The BiCMOS process combines the speed of bipolar with the reduced power consumption and greater circuitry density of CMOS technology. The BiCMOS supplier baser should continue to expand during the 1990s. For example, suppliers such as Fujitsu, Hitachi, Motorola, National Semiconductor, and NEC firmly target the fast BiCMOS SRAM business as part of their long-term product strategies.

The costly BiCMOS manufacturing procedure (which involves nearly 20 masking steps) has limited the use of the BiCMOS process to high-performance semiconductors. Within that constraint, the BiCMOS process seems certain to win a healthy share of the very high-speed fast SRAM marketplace (sub-35ns access time) over the long term.

Systems design engineers continue to look at BiCMOS fast SRAMs as an alternate to bipolar ECL devices or gallium arsenide chips for use in supercomputers. BiCMOS fast SRAMs are winning a growing share of the marketplace for cache memory in new high-performance computer systems and designs.

SLOW SRAMs

Why Not a Source of US-Japan Trade Friction?

Developments in the slow SRAM business have been lost in the glare of publicity surrounding the US-Japan trade dispute. Two reasons explain this "oversight." First, slow SRAMs do not serve as the technology-process driver for semiconductor companies; DRAMs or fast SRAMs play that role. Second, only vertically integrated manufacturers from Japan can compete effectively in the slow SRAM marketplace, where the scale of commodity production mandates service to captive as well as merchant market demand.

A Concentrated Supplier Base

The slow SRAM supplier base is largely concentrated among less than ten companies. The "Big Six" are Hitachi, Fujitsu, Mitsubishi, NEC, Toshiba, and Sony. Sanyo, Seiko, and Sharp are other significant suppliers.

For users of 8Kx8 slow SRAMs or 32Kx8 slow SRAMs, the factors just described can translate into periodic shortages of these devices as suppliers either turn fab capacity away from slow SRAM production to production of the more lucrative DRAMs or fast SRAMs, or begin serving internal captive demand for slow SRAMs, DRAMs, or fast SRAMs. Users of 128Kx8 slow SRAMs are likely to experience similar supply constraints during the 1991 to 1993 period.

Slow SRAM Product Trends

PRODUCTS

The "Products" section of the Semiconductor User Information Service strives to provide semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendors, and at what price. In terms of supply base management, this section focuses primarily on the choice of the right slow SRAM for a given system, and from which vendor.

Slow MOS SRAMs (hereafter, slow SRAMs) are defined as those static RAMs that operate at access times of greater than 70 nanoseconds (ns). This segment includes most SRAMs organized in the x8 configuration.

This particular section on slow SRAMs contains four parts. The first part develops a guide to timely, cost-effective purchasing of 16K through 1Mb slow SRAMs using a slow SRAM product life cycle analysis. The second part examines the product strategies, market postures, and strategic alliances of the leading suppliers of slow SRAMs. This information will help North American and European users assess with which vendors the users should align themselves to secure a dependable supply of these devices. The third part combines the analyses of the slow SRAM vendor base and slow SRAM product life cycles, and gives users a practical way of assessing their ability to obtain supplies of different densities of this product from 1989 to 1993. The fourth part looks at the prominent industry issues affecting slow SRAM users now and in the future.

Cumulatively, the information in this section enables North American and European users to develop a sound strategy for satisfying slow SRAM demand on a consistent cost-conscious basis over the long term, despite shifts in supplier base.

SLOW SRAM PRODUCT LIFE CYCLES

This section uses slow SRAM product life cycles as a guide to assist North American and European users in making cost-effective adjustment to forces affecting the marketplace. This section also provides the basis for other analyses based on slow SRAM life cycle curves.

Typical Life Cycles for Slow SRAM Products

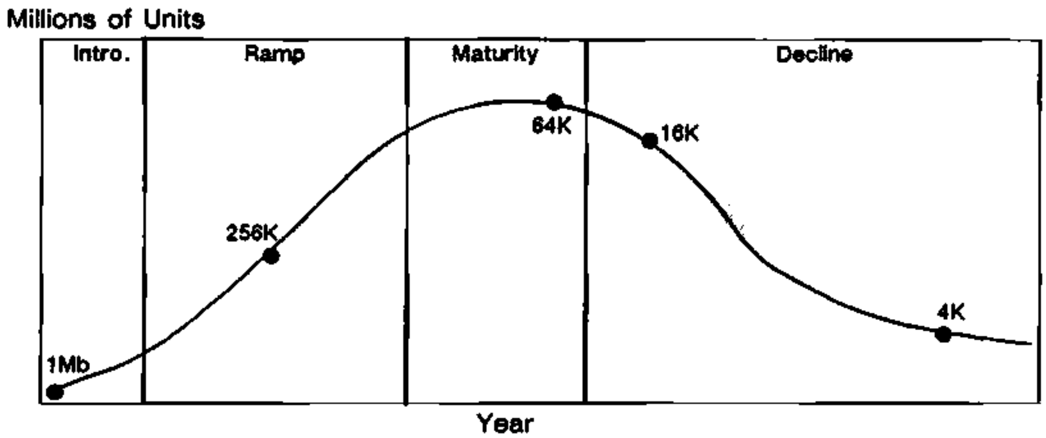
Figure 1 shows slow SRAM product life cycles for 4K, 16K, 64K, 256K, and 1Mb devices. This figure also shows at which stage of the life cycle each density stands as of 1989 and presents a life cycle forecast for 1992 regarding 16K to 4Mb devices.

Slow SRAM products typically have a long growth (or ramp) stage, followed by a shorter maturity stage and then an extended decline/phase-out stage (see Figure 1). Generally, slow SRAM production peaks in the sixth year of the life cycle.

Slow SRAM Product Trends

Figure 1

Typical Slow MOS SRAM Product Life Cycle
As of 1989



Stage	Introduction	Ramp	Maturity	Decline
Typical Number of Years	2	3	2	9
1989 Products	1Mb	256K	64K	16K 4K
1992 Products	4Mb	1Mb		256K 64K 16K

0003710-1

Source: Dataquest
May 1989

Planning for the Next Generation of Slow SRAM

The interval of two years between the introduction of the 16K and 64K densities of slow SRAMs lengthened to three years with the shift from 64K to 256K devices. That three-year interval now has become steady. For example, the CMOS 1Mb slow SRAM was introduced by several suppliers during 1988, or three years after the 1985 introduction of the 256K device. The CMOS 4Mb part should be introduced during 1991 after another three-year interval since the entry of the prior generation 1Mb product.

Slow SRAM Product Trends

SUPPLIER ANALYSIS

This section provides an analysis of the product and market strategies of the leading suppliers of slow SRAM. This analysis covers each company's slow SRAM product positioning, market ranking, and long-term product strategy.

At the outset, it should be noted that slow SRAMs do not serve primarily as technology-process drivers for most manufacturers of these devices; DRAMs or fast SRAMs fulfill that strategic objective. Rather, slow SRAMs serve as "fab-fillers," helping suppliers (typically vertically integrated manufacturers) meet internal captive demand and simultaneously keep fabs operating at higher capacity levels. The slow SRAM supplier base is limited vis-a-vis other semiconductor products, because of the captive demand element.

The Top-Ranked Suppliers

Table 1 shows the 1987 ranking in terms of total "dollarized sales" of the seven top-ranked suppliers of slow SRAMs. The dollarized units are calculated by multiplying the units in each density offered by that density's average selling price (ASP) for that year. The product of the two numbers is added to the products of the other densities, resulting in the total slow MOS SRAM dollarized units.

Table 1

1987 Rankings of Top Seven Slow SRAM Suppliers by Density

	16K		64K		256K	1Mb
Company	NMOS	CMOS	NMOS	CMOS	CMOS	(Introduction)
Hitachi		1		1*	1*	1988
NEC	2	4	2**	2*	2*	1988
Toshiba	1	2	1	3**	4*	1988
Fujitsu		7		4	3	1989
Sony		3		6	7	1989
Mitsubishi				5	5	1989
Seiko/SMOS		8		7	6	1989

*Includes pseudo-SRAM
**Includes mix MOS

Source: Dataquest
May 1989

This table also presents each company's ranking in terms of 1987 unit sales at the 16K, 64K, and 256K density levels as well as each supplier's actual or expected year of introduction of the 1Mb product. The information in this table serves as the background for the analysis of each supplier.

Hitachi

North American and European users of slow SRAM can expect 1987's leading supplier to confront the continual dilemma of seizing opportunities in the DRAM business while also maintaining its commitment to users of slow SRAMs. Because Hitatchi is a vertically integrated company, captive demand heightens it's strategic importance over the long term of holding a leadership position in the global merchant marketplace for slow SRAMs.

Hitachi's strength in the CMOS slow SRAM business is reflected in terms of unit shipments by the company's 1987 first place rankings in the CMOS 16K, 64K, and 256K densities. Hitachi's overall expertise in CMOS technology continues to be the key to its strategy for the slow SRAM market. Using a four-transistor cell design, Hitachi is a competitive supplier of slow SRAMs in the 8Kx8 and 32Kx8 configurations.

For North American and European users, however, the lure of lucrative DRAM production has cut into Hitachi's ability to supply slow SRAMs such as the 8Kx8 and 32Kx8 products. Even so, this supplier introduced 1Mb slow SRAM during 1988, and the firm's future product direction calls for an early move (1990) to the 4Mb device. The product strategy includes experimentation with design approaches such as pseudo-SRAM (PSRAM).

NEC

This second-ranked supplier has been making a steady advance in the slow SRAM market. During 1987, NEC ranked second in the NMOS 16K density, fourth at the CMOS 16K level, second in the 64K density, and second in the 256K segment.

North American and European users of slow SRAMs can expect a continuing commitment by NEC to serving the demands of users in this segment of the semiconductor memory business. NEC supplies a six-transistor CMOS 8Kx8 part as well as 64K devices that incorporate a four-transistor NMOS memory cell with CMOS peripherals. NEC ranks with Toshiba as a major supplier of six-transistor CMOS slow SRAMs. The firm has emerged as a leader in the 32Kx8 arena.

The future product direction of this vertically integrated manufacturer mandates a continued push into megabit slow SRAMs. NEC introduced 1Mb slow SRAMs during 1988 and will be a supplier of 4Mb devices.

Slow SRAM Product Trends

Toshiba

Third-ranked Toshiba's recent performance in the slow SRAM business shows little slippage despite the firm's intense strategic commitment to high-density DRAMs and fast MOS SRAMs. As a vertically integrated manufacturer, Toshiba will remain a long-term force in the slow SRAM business.

For North American and European users, Toshiba continues to be a leading supplier of slow SRAMs. Specifically, during 1987 Toshiba ranked first in the NMOS 16K density and second in the CMOS 16K arena, first at the NMOS 64K level and third in the CMOS 64K segment, and fourth in the 256K segment.

The lure of the DRAM marketplace, however, reduces Toshiba's capacity for meeting user demands for slow SRAM products such as the 8Kx8 or 32Kx8 devices. The company also faces trade challenges from the sale of sensitive submarine technology to the U.S.S.R.

In terms of future product direction, Toshiba offers a competitive product line based on a six-transistor cell design. Toshiba introduced 1Mb slow SRAMs during 1988 and will battle for early market leadership in the 4Mb arena.

Fujitsu

Like Hitachi and Toshiba, DRAMs and fast SRAMs serve as the technology process drivers for fourth-ranked Fujitsu, consequently impinging upon the ability of this vertically integrated producer to serve demand for 8Kx8 or 32Kx8 devices. Even so, Fujitsu maintains a solid reputation as a supplier of slow SRAMs.

Fujitsu has a solid grasp on the fourth-place position in terms of dollarized sales among suppliers of slow SRAMs. During 1987, Fujitsu ranked seventh in terms of unit sales, at the CMOS 16K density, fourth in the mainstream CMOS 64K segment, and third in the 256K segment.

The introduction of Fujitsu's 1Mb devices should occur in 1989.

Sony

Fifth-ranked Sony (another vertically integrated supplier) has steadily advanced into the worldwide merchant market for slow SRAMs.

The firm's future strategy calls for continued exclusive commitment to the CMOS business. As shown by its 1987 rankings, it is third in the 16K density, sixth in the 64K arena, and seventh in the 256K segment. North American and European users can look to Sony as a supplier of the supply-limited 64K slow SRAM.

Sony is expected to introduce 1Mb slow SRAMs during 1989.

Mitsubishi

This vertically integrated manufacturer ranked sixth during 1987 in terms of dollarized sales of slow SRAMs. Mitsubishi has developed into a formidable competitor in the slow SRAM business. During 1987, Mitsubishi ranked fifth in terms of unit sales of both CMOS 64K and CMOS 256K devices.

North American and European users of this device can expect a long-term commitment by Mitsubishi to serving slow SRAM demand. During 1989, Mitsubishi is expected to ramp supply of the 32Kx8 device.

In terms of future product direction, the firm is expected to introduce its 1Mb product during 1989, setting the stage for its involvement in the megabit density slow SRAM business.

Seiko-SMOS

This supplier ranks seventh among worldwide suppliers of slow SRAMs. Seiko-SMOS is a vertically integrated manufacturer with a firm long-term commitment to the global slow SRAM merchant marketplace.

During 1987, Seiko-SMOS ranked eighth in the CMOS 16K density, seventh in the CMOS 64K segment, and sixth at the 256K level.

North American and European users can target Seiko-SMOS for supply of 8x8 slow SRAMs. The firm made a timely introduction of the 256K device, and an equally timely introduction of the 1Mb device is expected during 1989.

SUPPLY BASE ANALYSIS

This section uses information on slow SRAM product life cycles and vendors to present an evaluation of the supply base for these devices in the 16K, 64K, 256K, and 1Mb densities over the medium and long term. This section provides users with a convenient way of analyzing the long-term supply base and with guidelines for choosing suppliers.

Succinctly, the supplier base for slow SRAMs has expanded more slowly than other segments of the semiconductor business. North American and European users of these devices will have to choose among a rather limited range of Japanese or Korean suppliers, with some new faces expected at the megabit density levels.

Product life cycle analysis serves as the basis for a concise assessment (from the user's viewpoint) of the anticipated supply base for each density of slow SRAM. Factors influencing the supply base, such as vendor strategies, are analyzed. Each subsection includes a brief statement as to whether the user faces a favorable or critical supply base for each slow SRAM density.

Slow SRAM Product Trends

The product life cycle information presented in Figure 1 and the supplier information contained in Table 1 serve as a reference background for this section.

16K Slow SRAM Supply Base

North American and European users of 16K slow SRAMs face an increasingly difficult supply situation.

Although the life cycle for this product unexpectedly has peaked twice, worldwide merchant market supply should contract from 80 million units during 1988 to 20 million units by 1992 as the device moves through the later stages of the cycle. North American and European users must remain aware that most production will be consumed by Japanese manufacturers of compact discs, point of sale (POS) systems, and electronic games.

North American and European users of CMOS 16K parts should turn to suppliers like Hyundai, MOSEL, Sanyo, Sharp, Sony, or UMC for special long-term supply arrangements. Users of NMOS devices can turn only to Toshiba (the leading supplier) or NEC.

64K Slow SRAM Supply Base

North American and European users of 64K slow SRAMs face a shifting tighter/looser supply situation over the long term. The product now stands at the maturity (or peak) stage of its life cycle.

Short-Term Relief for Users of 8Kx8 Devices

Nineteen eighty-seven's tightening supply of 64K products (this was partly because of the shift to DRAM production) failed to ease during 1988. For North American and European users of 8KxK slow SRAMs, the tight supply scenario should ease by the third quarter of 1989, but that relief might not last long. Events in the DRAM business and the general supplier migration to higher-density (256K and above) slow SRAMs will continue to have a direct, negative impact on users of 64K slow SRAMs.

Users of 8Kx8 slow SRAMs should look to several worldwide suppliers as part of the effort to source this supply-constrained device. These suppliers include Japanese-based firms such as Seiko-SMOS, Sharp, and Sony, Korean companies such as Hyundai and Samsung, and a European supplier, SGS-Thomsen.

Supply Contraction During 1990

North American and European users of 8Kx8 devices should expect the product life cycle of the 64K part to be less prolonged than had been the case with lower-density slow SRAMs. The supply of 64K products will improve during 1989 versus 1988 availability; however, North American and European users can expect another sharp drop in 64K slow SRAM output during 1990. Supply continues to contract thereafter as this device moves through the decline and phase-out stages of the life cycle.

256K Slow SRAM Supply Base

North American and European users of 32Kx8 slow SRAMs can expect a relatively ample long-term supply of these devices. This product is now moving through the growth (or ramp) stage of the life cycle. The 256K product life cycle extends well into the 1990s.

As the DRAM crunch eases during 1989, the 32Kx8 slow SRAM should become more readily available. Vertically integrated suppliers such as NEC and Mitsubishi are committed to meeting demands for these slow SRAMs; Motorola has the fab capability to manufacture 32Kx8 devices. Worldwide output of 256K slow SRAMs should exceed 100 million units during 1988, and peak at 180 million units during 1992.

1M Slow SRAM Supply Base

For North American and European users of 1Mb slow SRAMs, 1988 marked the introduction of this product by Hitachi, Inova, NEC, and Toshiba. During 1989, Fujitsu, Mitsubishi, Motorola, Oki, Samsung, Seiko-SMOS, and Sony are expected to join this supplier base.

As of the first half of 1989, the CMOS 1Mb product still stands at the introduction stage of its life cycle. The growth stage should begin by the end of this year.

INDUSTRY ISSUES AFFECTING USERS OF SLOW SRAMs

This section analyzes the major industry issues that will influence the slow SRAM users' choice of vendors and devices from 1989 through 1993. To date, the 1986 U.S.-Japan semiconductor trade agreement has had an indirect impact on the supplier/supply base.

Two key factors, described in the following subsections, drive developments in the slow SRAM business.

The Role of Slow SRAM in the Technology Process

First, slow SRAMs do not serve as primary technology-process drivers for most semiconductor firms. To some extent, exceptions such as Hitachi exist, but for most semiconductor memory suppliers, DRAMs or fast SRAMs typically serve as technology drivers.

For users of 8Kx8 or 32Kx8 slow SRAMs, this factor translates into shortages of these devices as suppliers turn fab capacity away from slow SRAM production to producing the more lucrative DRAMs or fast SRAMs. With this in mind, prospective users of the 128Kx8 slow SRAM must closely track developments in the 1Mb/4Mb DRAM marketplace over the long term to gauge the impact of megabit DRAM demand on future availability of 256K and 1Mb slow SRAM products.

An Asian Supplier Base

Secondly, vertically integrated Japanese and Korean manufacturers dominate the slow SRAM supplier base. Large-scale commodity production of slow SRAMs dictates demand from internal captive users as well as the merchant market.

Except for Motorola or Inova, North American and European users of slow SRAMs have little alternative but to link themselves with Japanese or Korean suppliers of slow SRAMs. Japanese vendors—Hitachi, NEC, Toshiba, Fujitsu, Sony, Mitsubishi, Seiko-SMOS—hold a firm lock on the top positions in the worldwide market. Two new players—Hyundai and Samsung—are vertically integrated Korean suppliers of electronics. Samsung now ranks among top-ten worldwide suppliers of semiconductors.

EPROM Product Trends

PRODUCTS

The "Products" section of the Semiconductor User Information Service binder provides semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendors, and at what price.

This particular section on MOS EPROMs contains four subsections. The first subsection looks at the prominent industry issues affecting EPROM users now and in the future. The second subsection develops a guide to cost-effective EPROM purchasing by using EPROM product life-cycle analyses. The third subsection examines the product strategies and market positions of the leading EPROM vendors. The fourth subsection combines the analyses of the EPROM vendor base and EPROM product life cycles. It gives users a practical way of assessing their ability to obtain a supply of the different densities of EPROMs during the 1990 through 1994 period.

Cumulatively, the information in this section enables EPROM users to develop a sound strategy for satisfying EPROM demand on a cost-effective basis over the long term despite shifts in the supplier base.

OUTLOOK FOR 1990

The most important aspect of the 1990 outlook is expected to be average selling price (ASP) dynamics: The greater the EPROM density, the greater the expected rate of price decrease. As a result of ASP dynamics, Dataquest forecasts the following:

- Users of the 1Mb and greater density devices can look forward to the greatest price declines.
- Prices for 512K CMOS EPROMs should fall through the end of 1991 and slowly rise thereafter.
- Users of 128K and 256K CMOS parts should anticipate prices declining in the short term, reaching their minimum in 1990, and slowly rising thereafter.
- Users of 16K, 32K, 64K, and 128K NMOS devices can expect a continuous long-term increase in prices for these parts.
- The 256K part is still the largest-volume EPROM in production and should remain so in 1990.
- Production of 512K and 1Mb parts will continue to ramp up.
- Although demand for 1Mb 64Kx16 is increasing, volume of the 1Mb 128Kx8 configuration will be in large demand through 1990. The expected mix by volume in 1990 is 67 percent for the x8 device and 33 percent for the x16 product.
- Japanese EPROM suppliers continue to shift focus away from densities of 256K and below and to emphasize densities of 512K through 4Mb. The Japanese should continue to dominate the high-density market.
- User demand for higher EPROM performance is density driven with respect to 512K through 4Mb parts and is speed driven in the 256K, 64K, and 16K markets.

COST-EFFECTIVE EPROMS

This subsection uses EPROM product life-cycle curves to develop a guide for cost-effective purchasing of EPROMs. It also serves as the basis for other analyses based on EPROM product life cycles.

EPROM Product Life Cycles

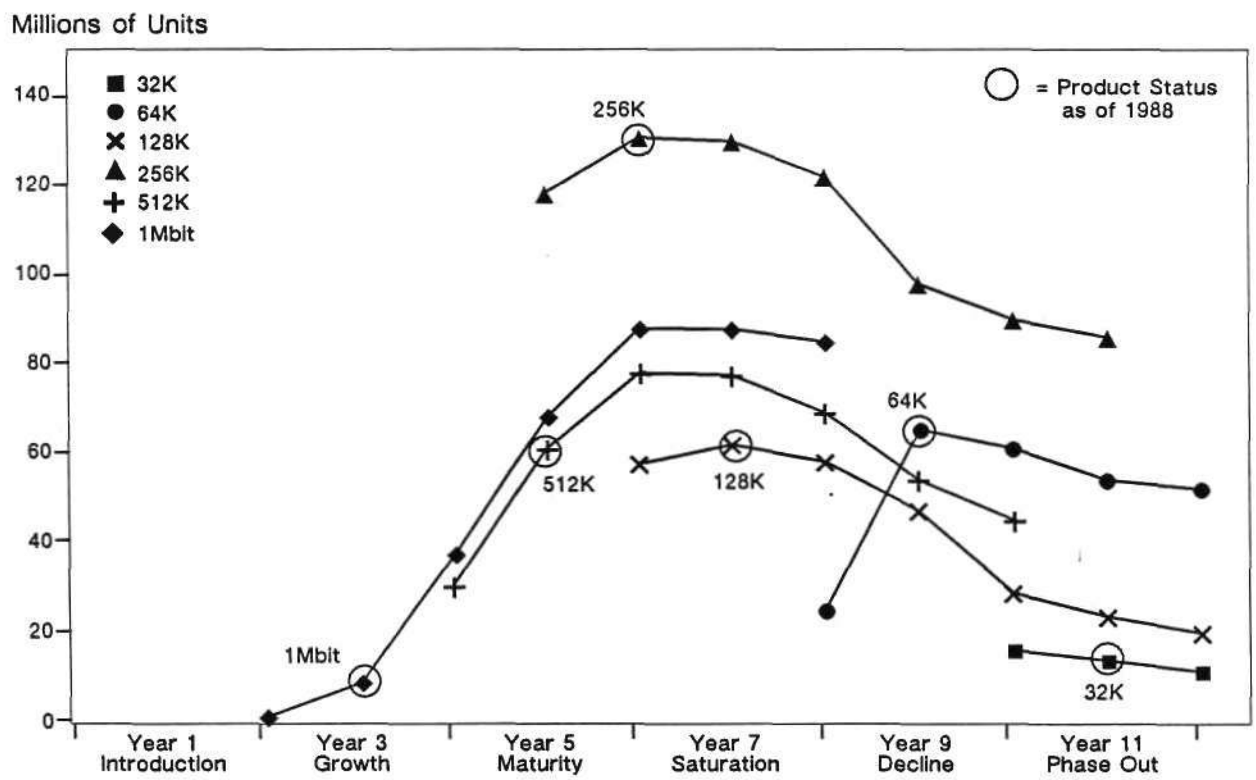
Figure 1 shows a series of six curves that depict the product life cycles of EPROMs with densities of 32K to 1Mb. These curves indicate that the third, fourth, and fifth years should show growth in terms of EPROM supply and demand. Generally, EPROMs reach maturity stage of the product life cycle in the sixth year of production. Users can expect annual production of 256K and 1Mb devices to exceed 100 million units during the cycle's peak stages.

Dataquest expects production of 256K CMOS devices to peak at 84 million units in 1991 and 1Mb CMOS products to achieve a 100 million unit rate that year. In contrast, output of 512K CMOS parts will grow modestly, with NMOS version production already declining. Growth stage of the cycle for 2Mb EPROMs should begin during 1990.

Figure 2 presents EPROM product life cycles on a density/technology basis over time, breaking each stage of the 15- to 16-year EPROM life cycle into specific time intervals.

Figure 1

MOS EPROM Product Life Cycles by Density



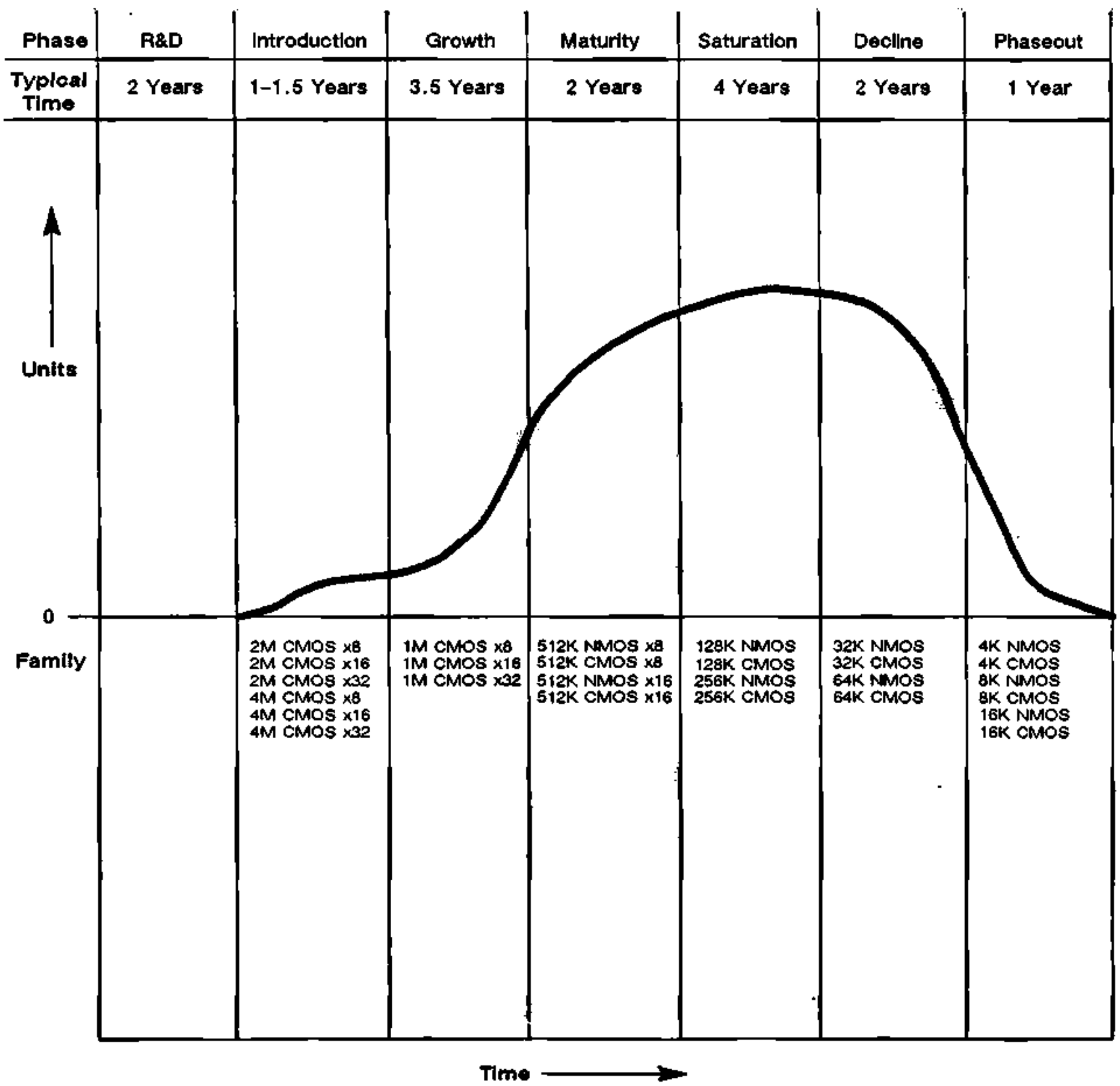
0005850-1

Source: Dataquest
February 1990

Figure 2 shows that 4K, 8K, and 16K EPROMs (except high-speed devices) are being phased out by suppliers now and that 32K devices will be phased out in the next two years. Users of 64K and 128K EPROMs can expect these parts to hit the phaseout stage by 1992. The life cycle of 256K and 512K CMOS EPROMs should extend to 1995, with a shorter life cycle for NMOS versions. High-speed variations of these densities probably will lengthen these parts' life cycles. The cycle of 1Mb EPROMs stretches to the 1998 to 2000 time frame, and the anticipated cycle for 2Mb and 4Mb EPROMs extends into the next century.

Figure 2

1989 EPROM Life Cycle by Product/Technology



0005850-2

Source: Dataquest
February 1990

SUPPLIER ANALYSIS

This subsection analyzes the product and market strategies of the leading suppliers of EPROMs (as measured in units) during 1988. It examines each company's EPROM product positioning, market ranking, long-term product strategy, and relevant strategic alliances.

Table 1 shows the 1988 rankings by unit shipments of the leading EPROM suppliers. The table presents each company's ranking by EPROM density level (32K to 1Mb) and its 1988 position. The information in this table serves as the background for the analysis of each supplier.

Intel

For market leader Intel, the EPROM continues to be the technology driver because of the relationship between Intel's microprocessor (MPU) and EPROM businesses. Intel aims at being known in the North American and European markets as a full-range supplier of MOS EPROMs, including one-time programmables (OTPs). Intel is now making the strategic migration from the NMOS process technology to the CMOS process.

The company's strength in the EPROM market is evident from its rankings. Intel ranks first in NMOS EPROM unit shipments at the 32K, 256K, 512K, and 1Mb densities. The company also is the leading supplier of MOS OTP EPROMs. The U.S.-Japan trade pact further strengthened Intel's long-term prospects as a full-range supplier of EPROMs.

A major challenge for Intel involves its move from NMOS EPROMs to CMOS devices. During 1988, Intel ranked third among suppliers of 64K CMOS EPROMs, fourth at the 128K density, and ninth at the 256K density. As part of Intel's challenge in the CMOS EPROM arena, the company must set its sights on the long-term opportunity in the 1Mb segment while serving demand for both CMOS and NMOS versions of 64K through 256K devices. During 1988, Intel's unit shipments of 32K, 64K, and 128K NMOS devices increased, as did shipments of 128K and 256K CMOS devices. Shipments of 64K CMOS parts, however, declined.

Intel introduced 2Mb and 4Mb EPROMS in 1989 and has distinguished itself as the only U.S. manufacturer supplying these parts. The company has no new product introductions planned for 1990 in the 16K to 4Mb density range.

SGS-Thomson

SGS-Thomson moved from tenth place among EPROM suppliers in 1987 to second place in 1988. SGS-Thomson's market strategy is to be a major supplier of lower-density devices, as other suppliers have retreated from these segments. This strategy has served the company well. In 1988, it ranked as the market's leading supplier of 64K and 128K NMOS EPROMs, the second-largest supplier of 32K CMOS and 256K NMOS EPROMs, and the third-largest supplier of 32K NMOS EPROMs. In 1988, the company's shipments of 32K NMOS, 64K NMOS/CMOS, 128K NMOS, 256K NMOS, 512K NMOS, and 1K CMOS increased; shipments of 32K CMOS declined.

SGS-Thomson plans to enter the flash EPROM market in 1990. It also plans to introduce 2Mb and 4Mb EPROM products in late 1990.

Table 1

MOS EPROM Suppliers—Ranking by Density/Technology

1988 Overall Ranking	Company	32K NMOS	32K CMOS	64K NMOS	64K CMOS	128K NMOS	128K CMOS	256K NMOS	256K CMOS	512K NMOS	512K CMOS	1Mb NMOS	1Mb CMOS
1	Intel	1		2	3	2	4	1	9	1		1	
2	SGS-Thomson	3	2	1	5	1		2	11	6			7
3	Fujitsu			10	9	6	3	7	2		1		3
4	Mitsubishi			4		5	6	4	6	3	6		2
5	AMD	4		3		3	8	3	10	5	4		6
6	Toshiba			6		4		5	4	4	6		5
7	TI	2		5	7	9	1		3		2		
8	National		1		1		5		1				
9	Microchip (GI)				4		2	6	5		5		
10	NEC	5			6	8		9	8		3		1
	Cypress				10				14				
	Hitachi	L		9		L		L		2			4
	Oki			7		7		8		7			
	SEEQ			8		10			13				
	Signetics				2				7				
	WaferScale				8		7		12		8		
	Total Shipments (Millions of Units)	11.9	2.0	38.3	27.0	44.1	17.8	58.0	72.8	39.2	21.3	1.3	7.8

L = Left the market during 1987

Source: Dataquest
February 1990

Fujitsu

Fujitsu moved up to third place among EPROM suppliers in 1988 from its 1987 fifth-place ranking. Fujitsu has successfully made the transition from the 64K and 128K CMOS marketplace, which it dominated in 1987, to the higher-density CMOS segments. During 1988, Fujitsu ranked first in the 512K CMOS segment, maintained its second-place standing in the 256K CMOS segment, and placed third among suppliers of 1Mb CMOS devices. Currently, the 4Mb EPROM is Fujitsu's highest-density offering.

Mitsubishi

During 1988, Mitsubishi fell to fourth place among EPROM suppliers from its third-place ranking in 1987. The U.S.-Japan trade arrangement blunted Mitsubishi's goal of being a full-range supplier of EPROMs to North American and European users. Specifically, Mitsubishi has responded to the trade pact by focusing on the higher-density segments of the North American business.

Mitsubishi's strategy for advancing in the EPROM marketplace is reflected by its 1988 performance results. During 1988, Mitsubishi increased unit shipments of higher-density devices (i.e., 256K and 1Mb CMOS and 512K NMOS devices) and reduced shipments of lower-density parts (i.e., 64K and 128K NMOS parts). Reduced shipments in 256K NMOS devices reflect the company's shift toward 256K CMOS devices. During 1988, the company ranked second in the 1Mb CMOS EPROM marketplace after entering it only one year earlier. Mitsubishi currently is shipping 2Mb and 4Mb EPROMs.

AMD

AMD moved from its sixth-place ranking in 1987 to fifth place in 1988. The company has been a direct beneficiary of the semiconductor trade agreement, which enhanced its ability to maintain its strategic posture as a supplier of MOS EPROMs.

For users of NMOS EPROMs, AMD increased 1988 unit shipments of 128K and 512K devices while cutting output of 32K, 64K, and 256K parts. For users of CMOS EPROMs, AMD's move to the CMOS technology hits home in the 1Mb segment. AMD maintained its fourth-place rank among suppliers of 1Mb CMOS EPROMs during 1988 and was the first in the market with x16 1Mb CMOS EPROMs. AMD, via the ICT agreement, will have the fastest 1Mb EPROM on the market in 1990. AMD is expected to begin shipment of 2Mb and 4Mb EPROMs in 1990.

Toshiba

Among EPROM suppliers, Toshiba declined from fourth place in 1987 to sixth place in 1988. Its tough going is illustrated by its high-density rankings: fourth in the 256K CMOS and 512K NMOS segments, fifth in the 256K NMOS segment and 1Mb CMOS segments, and sixth in the 512K CMOS segment. Toshiba also is entering the flash market. Currently, the 4Mb EPROM is Toshiba's highest-density offering.

Texas Instruments

Texas Instruments (TI) maintained its ranking as the seventh-largest supplier of EPROMs during 1988. Its future in EPROMs rests on high-speed/high-density CMOS devices. This North American producer uses the U.S.-Japan trade agreement as a window of opportunity for gaining share in the EPROM business.

Even so, DRAMs remain the technology driver for Texas Instruments. The profitable experience for suppliers of DRAMs during 1988 and 1989 reinforces TI's long-term strategic focus on DRAMs over other memory products.

During 1987, TI boosted its output of 128K NMOS/CMOS, 256K, and 512K CMOS EPROMs while decreasing unit shipments of 32K and 64K NMOS devices. TI's focus on higher-density CMOS devices becomes clear with its rankings information. The company ranked first among suppliers of 128K CMOS devices, second in the 512K CMOS segment (its highest-density offering), and third in the 256K CMOS segment. Texas Instruments currently is entering the flash EPROM market.

National Semiconductor Corporation

During 1988, National Semiconductor Corporation used its strategic alliance with VLSI Technology as a springboard into market leadership in the 32K, 64K, and 256K CMOS EPROM segments. The company lost some ground in the 128K CMOS EPROM segment, however, moving down from fourth place in 1987 to fifth place in 1988. National increased its unit shipments of 64K, 128K, 256K, and 512K CMOS devices in 1988; shipments of 32K CMOS devices declined in 1988. With first-place rankings in 32K, 64K, and 256K CMOS EPROMs, National's offerings clearly are concentrated in the older, lower-density devices.

Microchip Technology

Microchip Technology has gone through many changes in ownership. Most recently, the company was bought out by Sequoia Partners from a foundry agreement with Hyundai. The majority of Microchip Technology's revenue stems from EPROM sales.

In 1988, Microchip Technology moved up to ninth place among the top 10 EPROM suppliers. Also in 1988, the company ranked second as a supplier of 128K CMOS EPROM devices. Microchip Technology increased its unit shipments of 64K, 128K, 256K, and 512K CMOS devices and 256K NMOS devices in 1988.

NEC

The trade pact and related challenges hindered NEC's advance into the North American and European markets for EPROMs. NEC now ranks tenth in terms of 1988 EPROM unit shipments, whereas it ranked eighth in EPROM unit shipments during 1987.

During 1988, NEC reduced shipments of 32K, 64K, 128K, and 256K NMOS EPROMs, as well as 64K, 256K, and 512K CMOS devices, as evidence of its strategy to phase out its lower-density offerings.

The company is steadfast in its effort to shift to high-density devices, but the strategy is being met with mixed results. The trade agreement is a major deterrent, hampering NEC's—and other Japanese manufacturers'—growth in North America. As a result, NEC dropped from sixth place among 256K CMOS EPROM suppliers in 1987 to eighth place in 1988, and from second place among 512K CMOS EPROM suppliers in 1987 to third place in 1988. In the fast-growing 1Mb CMOS EPROM market, however, NEC did increase unit shipments and, as a consequence, maintained its first-place ranking as supplier. NEC's highest-density offering is a 4Mb CMOS EPROM.

Other Suppliers

Like Texas Instruments and Japanese producers, other EPROM manufacturers are focusing on production of the higher-speed and/or higher-density CMOS EPROMs. These suppliers include Cypress Technology and WaferScale, the largest suppliers of high-speed EPROMs.

Hitachi, Oki, SEEQ, and Signetics have fallen in their respective market share rankings. None of these companies' total EPROM revenue places them in the top 10 ranking.

SUPPLY BASE ANALYSIS

This subsection uses information on EPROM product life cycles and EPROM vendors to present a density-by-density evaluation of the supply base for these devices over the medium and long terms. Users of EPROMs must remain aware of market shifts that stem from industry forces such as the U.S.-Japan Semiconductor Trade Arrangement, which expires in 1996. This subsection provides users with a practical way of determining what the long-term supply base will be for a given EPROM density and gives directions for selecting vendors.

The EPROM product life cycle information shown in Figures 1 and 2 serves as the basis for a summary assessment from the users' perspective of the expected supply base for each density of EPROM.

Tables 2 and 3 provide unit shipment forecasts on 32K through 1Mb NMOS EPROMs and 32K through 1Mb CMOS EPROMs, respectively. These forecasts augment the supply base discussion. Table 3 serves as the basis for relevant supplier analysis.

The supply base trend analysis includes a succinct description as to whether EPROM users face a favorable or critical supply base of EPROMs at densities running from 32K to 1Mb. Factors affecting the supply base, such as vendor strategies and changes in product life cycles, are discussed in connection with each density.

Table 2

Worldwide NMOS EPROM Market—Total (UV and OTP)
(Millions of Units)

	1986	1987	1988	1989	1990	1991	1992	1993
4K	0	0	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0
16K	14.7	7.3	5.6	3.5	2.9	2.4	1.9	1.7
32K	18.9	13.1	11.9	9.3	7.0	5.8	5.0	4.3
64K	82.5	48.5	38.3	24.0	15.0	11.5	8.5	5.4
128K	55.4	46.3	44.1	36.1	26.8	14.1	10.1	7.6
256K	53.8	71.6	58.0	38.0	28.0	19.0	18.8	11.5
512K	5.4	22.2	39.2	37.5	27.5	19.4	11.0	6.0
1Mb	0.1	0.3	1.3	5.2	5.0	2.8	2.0	1.7
2Mb	0	0	0	0	0	0	0	0
4Mb	0	0	0	0	0	0	0	0
8Mb	0	0	0	0	0	0	0	0
Total	230.9	209.3	198.3	153.6	112.2	75.0	57.3	38.2

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
February 1990

Table 3

Worldwide CMOS EPROM Market—Total (UV and OTP)
(Millions of Units)

	1986	1987	1988	1989	1990	1991	1992	1993
4K	0	0	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0
16K	0	2.4	3.1	4.3	4.1	4.4	4.5	4.5
32K	2.7	3.1	2.0	2.3	3.0	3.0	3.0	3.0
64K	17.1	27.2	27.0	37.0	39.0	40.5	31.5	22.6
128K	1.9	11.2	17.8	21.9	20.2	14.7	13.5	12.5
256K	16.2	46.9	72.8	92.0	94.0	83.0	76.2	74.5
512K	0.3	8.7	21.7	40.5	50.0	49.6	43.0	39.0
1Mb	0.1	1.4	7.8	32.0	63.0	85.2	85.8	83.3
2Mb	0	0	0	0.3	1.4	10.0	50.0	82.0
4Mb	0	0	0.2	1.7	7.0	36.0	81.0	126.0
8Mb	0	0	0	0	0	0	0.1	4.0
Total	38.3	100.8	152.4	232.0	281.7	326.4	388.6	451.4

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
February 1990

32K EPROMs

Users of 32K EPROMs face a critical situation in terms of supply. Both NMOS and CMOS devices are at the decline stage of the product life cycle. The 32K EPROM is being phased out and will likely be obsolete by 1991.

Japanese vendors such as Fujitsu, Hitachi, and Mitsubishi left the 32K EPROM business during 1987. Unit shipments by AMD, National Semiconductor, and Texas Instruments decreased during 1988. However, unit shipments by Intel and SGS-Thomson increased. In Intel's case, this increase is in line with its strategy to become known in the North American and European markets as a leading full-range supplier of MOS EPROMs. In SGS-Thomson's case, the increase reflects the company's strategy to be a major supplier of the lower-density devices from which other manufacturers have retreated.

64K EPROMs

Although 64K EPROMs have moved into the decline stage of the life cycle, faster speeds should slow their rate of decline and thus extend their life expectancy.

Japanese vendors such as Fujitsu and Mitsubishi reduced their output of 64K NMOS devices in 1988. This trend is expected to continue as Japanese manufacturers shift their focus to the higher densities.

In response to the Japanese companies vacating the lower densities, National Semiconductor increased its shipments of 64K CMOS parts in 1988, and SGS-Thomson increased its 64K NMOS and CMOS shipments.

Intel, Microchip Technology, Mitsubishi, Oki, SGS-Thomson, and Toshiba supply OTPs. NEC is phasing out its OTP production.

128K EPROMs

The shortened life cycle of the 128K EPROM vis-à-vis other EPROMs makes the supply situation less than completely favorable for users of this part. The 128K EPROM reached the peak stage of the life cycle sooner and for a shorter duration than expected. The result has been a narrower supplier base over the long term than other EPROM products have had. The 128K NMOS EPROM is moving into the decline stage of its product life cycle. Users can expect 128K EPROMs to phase out by 1992 to 1993.

Hitachi withdrew from the 128K EPROM export market during 1987. Other Japanese companies such as Fujitsu, Mitsubishi, NEC, and Toshiba decreased their shipments during 1988, while Oki increased output of OTPs.

North American and European manufacturers have stepped in to fill the void created by the Japanese companies' exit. For example, SGS-Thomson now is the leading supplier of 128K NMOS EPROMs. Also, the rankings of Texas Instruments (first place), Microchip Technology (second place), and Fujitsu (third place) in the 128K CMOS EPROM arena reflect their long-term EPROM marketing strategies of focusing on CMOS process technology.

During 1987, Intel entered the 128K CMOS EPROM business. Intel's 128K NMOS and CMOS EPROM shipments increased in 1988. Intel also supplies 128K OTP EPROMs, shipments of which also increased in 1988. AMD increased unit shipments of 128K NMOS devices during 1987.

Like other Japanese suppliers, Mitsubishi's ability to serve North American and European users with 128K EPROMs was limited by international trade friction.

256K EPROMs

Users of 256K EPROMs face a favorable supply situation as the product moves from the maturity to the saturation stage of its product life cycle. The 256K devices are currently the relatively high-volume EPROM in production and will remain so in 1990. The decline stage for 256K parts should be long—in effect, extending the life cycle to 1995. Quicker speeds will help extend product life.

Intel is the leading supplier of 256K NMOS EPROMs. The company also intends to meet user demand for CMOS devices in line with its strategy of being a full-range supplier of MOS EPROMs. Intel's output of both 256K NMOS and CMOS devices continues to increase. Intel also offers 256K OTPs. AMD reduced unit shipments of 256K NMOS EPROMs but increased shipments of 256K CMOS EPROMs in 1988.

As a result of the semiconductor trade pact, Japanese suppliers of 256K EPROMs generally limit their export efforts to CMOS versions. Hitachi withdrew from the 256K EPROM export market during 1987, and its plans for a return to this market remain uncertain. Along with Intel and Microchip Technology, Mitsubishi, Oki, SGS-Thomson, Texas Instruments, and Toshiba supply 256K OTPs.

Several North American suppliers base the 256K EPROM strategy squarely on the CMOS process technology. Specifically, National Semiconductor and Texas Instruments produce only CMOS devices.

512K EPROMs

In 1988, the 512K MOS EPROM moved from the growth stage to the maturity stage of its product life cycle. Users of CMOS devices face a favorable supply base for this device.

Intel ranks first among suppliers of 512K NMOS EPROMs. Hitachi, Mitsubishi, Toshiba (OTPs), AMD, SGS-Thomson, and Oki (OTPs) are the other leading suppliers of 512K NMOS parts.

Like the 128K device, the 512K EPROM is an intermediate-density product (i.e., between the predominant 64K, 256K, and 1Mb generations). Suppliers have been less committed to these intermediate-density parts, so users can expect a narrowing of the supplier base in the long term.

The success or Japanese companies in the 512K CMOS EPROM market stems from Japan's 1987 shift of export production to higher-speed, higher-density CMOS devices. Fujitsu leads among suppliers of 512K CMOS devices with Texas Instruments ranked second, followed by NEC and AMD.

1Mb EPROMs

The 1Mb EPROM is at the growth stage of its product life cycle. Users face a favorable situation in terms of long-term supply of these devices, with output expected to reach 88 million units by 1991. As shown in Figure 2, the 1Mb life cycle should extend from 1998 through 2000.

All manufacturers except Intel, Microchip Technology, National Semiconductor, and Texas Instruments supply CMOS devices.

Users can expect continued commitment to this product from North American suppliers such as Intel and AMD. For these companies, production of 1Mb EPROMs solidifies their reputations as full-range suppliers of MOS EPROMs and serves as the stepping-stone to higher-density devices. Even so, the 1Mb devices are likely to be eclipsed in popularity by the 2Mb and 4Mb devices that now are in the introductory phase.

Users must choose between x8 configurations (offered by Fujitsu, Hitachi, Intel, Mitsubishi, NEC, Oki, and Toshiba) and x16 configurations (offered by AMD, Fujitsu, Hitachi, Intel, Mitsubishi, NEC, Oki, and Toshiba).

Users can expect Japanese producers to maintain their positions fiercely in the 1Mb EPROM market.

2Mb EPROMs

The 2Mb EPROM is at the growth stage of its product life cycle. Users should expect the life cycle to extend well beyond the year 2000.

Many users have elected to make the jump from 1Mb EPROMs to 4Mb EPROMs, and as a result, popularity of the 2Mb part has not been as great as was expected. Intel, Mitsubishi, and NEC currently are shipping 2Mb parts; AMD is expected to begin shipment in 1990.

4Mb EPROMs

The 4Mb EPROM is at the growth stage of its product life cycle. Users should expect the life cycle to extend well beyond the year 2000.

Popularity of the 4Mb EPROM has been greater than expected as users have opted to make the transition in density from 1Mb directly to 4Mb. Fujitsu, Intel, Mitsubishi, NEC, and Toshiba currently are shipping 4Mb parts; AMD and WaferScale are expected to begin shipment in 1990.

Application-Specific Integrated Circuit (ASIC) Product Trends

The "Products" section of the Semiconductor User Information Service provides semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendors, and at what price.

Dataquest defines ASICs as including gate arrays, programmable logic devices (PLDs), cell-based integrated circuits (CBICs), and full-custom ICs. This section focuses on gate arrays, PLDs, and CBICs, and includes coverage of standard logic products and full-custom ICs as appropriate.

(For an ASIC family tree and detailed definitions, please refer to the Semiconductor User Information Service binder entitled "Industry Trends," turn to the "Products" tab and review the "Product Overview" section.)

This section on application-specific integrated circuits (ASICs) contains two subsections. The first subsection develops a guide to cost-effective usage of ASICs by analysis of ASIC technology progression and ASIC price information. The second subsection examines the current and future product strategies, merchant/captive market postures, and strategic alliances of the leading ASIC suppliers. This information helps North American and European users to assess which vendors the users should align themselves with in the aftermath of the U.S.-Japan semiconductor agreement. Cumulatively, this information enables users to develop a sound strategy for satisfying ASIC demand on a consistent cost-conscious basis over the long term, despite shifts in supplier base.

ASIC TECHNOLOGY ADVANCES

This section uses information on ASIC technology advances (in terms of the suppliers' ability to overcome technological barriers over time) and pricing trends as a guide to assist North American and European users in adjusting to forces affecting the marketplace.

Advances in ASIC Technologies

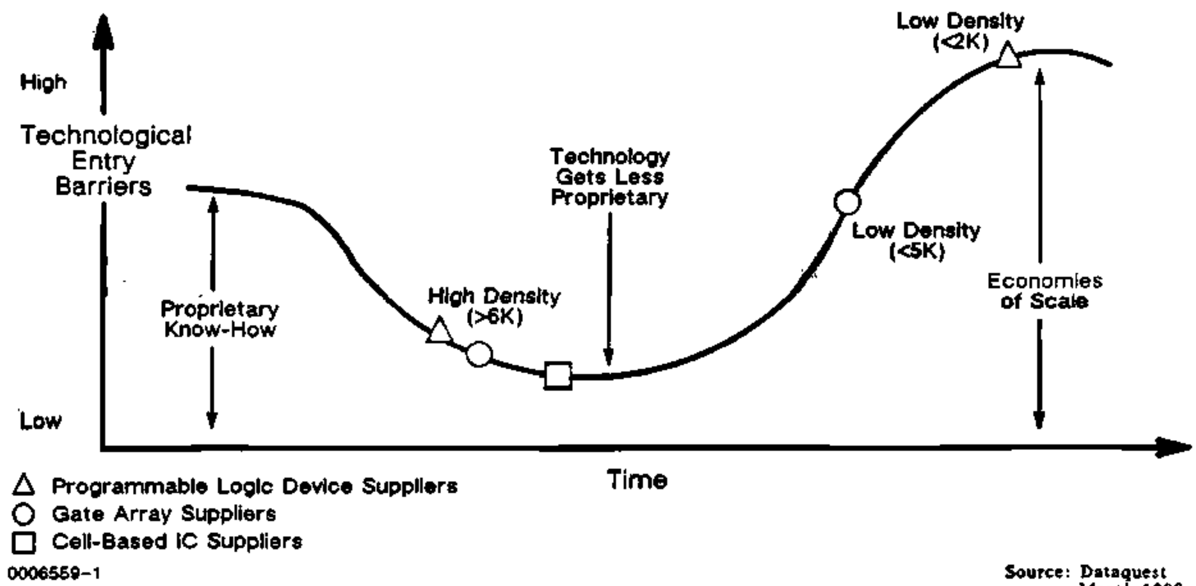
The ASIC business is an entirely different business than the standard products business. In contrast to other semiconductor products (e.g., memory), ASICs do not readily lend themselves to product life cycle analysis because an ASIC is as much a technology as a product.

To best analyze the ASIC product/technology trends that will affect the users' choice of ASICs, this section uses an ASIC technology progression curve (not an ASIC product life cycle curve) as a central analytical tool. Users who need ASIC product life cycle information can find that information in the Semiconductor User Information Service binder entitled "Industry Trends," behind the "Products" tab, in the "Product Overview" section.

Figure 1 depicts the state of ASIC technology progression as of 1990 for gate arrays (both low and high density), PLDs, and CBICs. Essentially, this figure shows the progress made by actual and prospective ASIC suppliers in overcoming the technological barriers to ASIC production. The figure shows that suppliers of low-density gate arrays (<6 gate count) have made the greatest progress to date in overcoming the market entry barrier. For ASIC users, this means that the low-density gate array has moved the farthest along the curve toward the goal of the economies of scale associated with high-volume production. CBICs have also made considerable progress toward that objective. Conversely, suppliers of high-density gate arrays (>5 gate count) and PLDs are quickly moving toward improved economies of scale.

Figure 1

ASIC Technology Barriers



Source: Dataquest
March 1990

Cost-Effective ASIC Purchasing

For ASIC users, the information in Figure 1 serves as the basis for analysis directed toward the goal of cost-effective ASIC purchasing. ASIC usage involves trade-offs in terms of both price-for-performance and price-for-timeliness of enhanced performance. The next set of figures provides information on these trade-offs. This particular analysis covers standard products, gate arrays, PLDs, CBICs, and full-custom ICs.

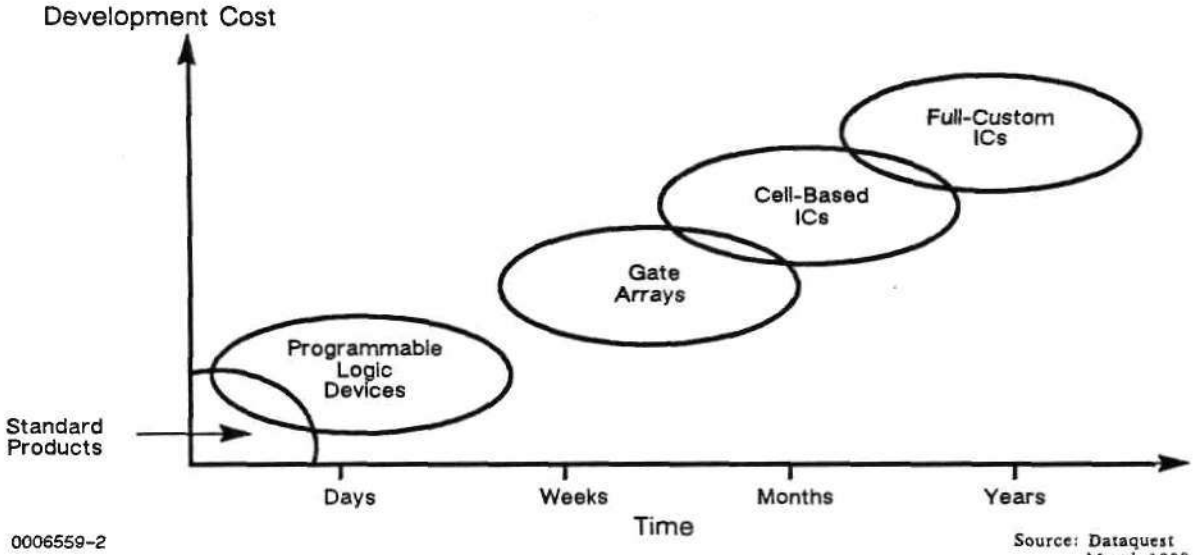
Figure 2 shows the relative amount of time required to implement standard logic products and ASICs into a user's system. The figure shows that standard products and some PLDs (e.g., EEPLDs) can be incorporated into a system within days, whereas a full year or longer passes between the time of design and the incorporation of a full-custom IC into a system. The figure demonstrates that PLDs typically are incorporated into a system in several weeks, while gate arrays can require several weeks (for low-density gate counts) or several months (for high-density gate counts). The range of time required for the implementation of CBICs into users' systems runs from several weeks to nearly one year, depending on density.

Figure 3 depicts the trade-offs available to users (i.e., ASICs versus standard products) in terms of cost/volume alternatives. The figure shows that the extra time required to incorporate full-custom ICs or CBICs into systems can translate into substantial savings vis-à-vis standard products or PLDs over the course of a system's life cycle. Gate arrays, and now some high-density PLDs, stand in an intermediate position between standard products/PLDs and full-custom ICs/CBICs in terms of these total cost/performance trade-offs.

Table 1 summarizes the ASIC trade-offs in matrix form.

Figure 2

ASIC Development Cost/Time Alternatives



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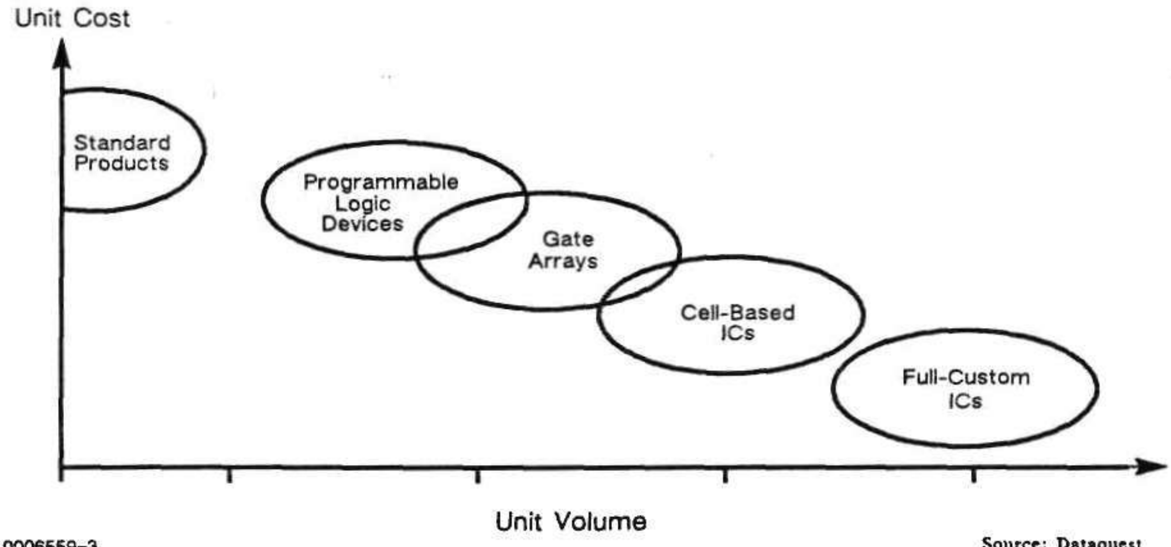
Source: Dataquest
March 1990

Figure 3

ASIC Unit Cost/Volume Alternatives



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Source: Dataquest
March 1990

Table 1

ASIC Trade-Off Matrix

Methodology	Design Time	Design Cost	Price per Gate	Efficiency
Programmable Logic Devices	Shortest	Lowest	Highest	Lowest
Gate Arrays	Short	Low	Low	Medium
Cell-Based ICs	Long	High	Lower	High
Full-Custom ICs	Longest	Highest	Lowest	Highest

Source: Dataquest
March 1990

The Cost Advantage of ASICs over Standard Logic Products

The system cost advantage of ASICs over standard logic products is discussed but not directly analyzed in this subsection. By incorporating several standard functions on a single chip, the ASIC design approach enables users to reduce system size, cost, and development time, while enhancing system performance, reliability, and security.

Table 2 illustrates the cost savings that users can achieve by incorporating ASICs (e.g., gate arrays or CBICs) into their systems instead of standard products (TTLs). The information in this table illustrates the total system cost savings associated with ASIC use. The table reveals that the cost advantage of ASICs over standard products such as TTL parts derives partially from the tremendous reduction in the number of ICs required per system. As this table demonstrates, a dozen "costly" ASICs ($30 to $45 per piece plus development expenses) cost far less *on a total system cost basis* than nearly 1,700 "inexpensive" TTL parts ($3 to $4 total IC cost).

Table 2

Estimated Cost Comparison of Standard Logic/ASIC Design Approaches

	TTL Parts	Gate Arrays	CBICs
System Complexity	20,000 gates	20,000 gates	20,000 gates
Nonrecurring Engineering Development Cost	0	$95,000	$80,000
Number of ICs	1,667	13	7
Average IC Cost (At 10,000 Units/Year)	$0.50	$10.00	$15.00
Other Cost per IC	$2.83	$20.00	$30.00
Total Manufacturing Cost per Unit	$5,551	$390	$315
Total Cost (10,000 Units)	$55.5 million	$3.9 million	$3.2 million
Cost Saving	0	93%	94%

Source: Dataquest
March 1990

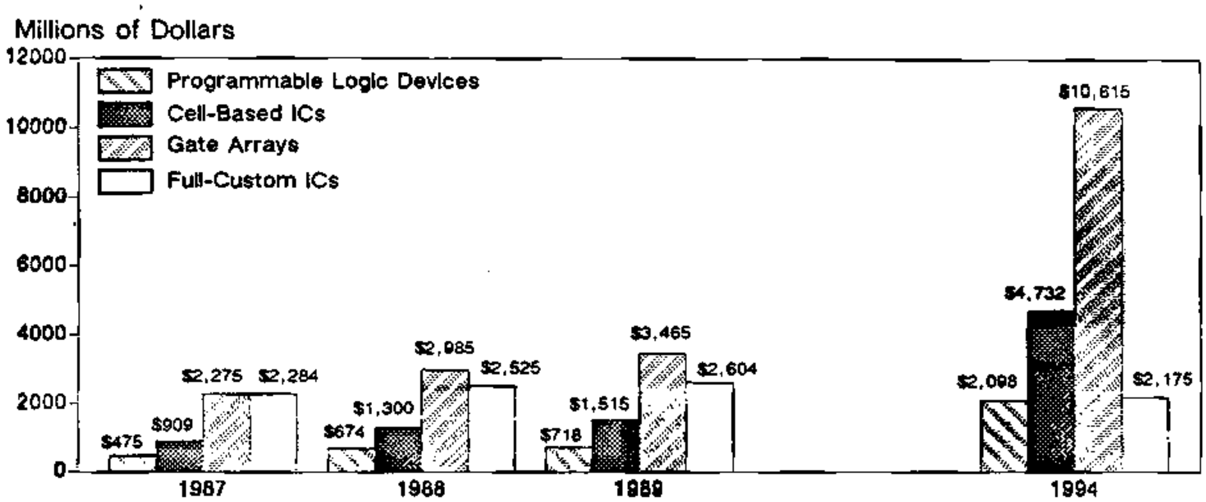
ASIC FORECAST

Figure 4 illustrates the forecast for growth in the worldwide ASIC market (as measured in millions of dollars). This market's compound annual growth rate (CAGR) from 1987 through 1992 is projected to be 17.6 percent.

Dataquest expects substantial growth in worldwide consumption of gate arrays, CBICs, and PLDs. The exception to this trend is consumption of full-custom ICs, which is expected to decline over the long term as cost- and function-efficient CBICs replace this design approach.

Figure 4

Estimated Worldwide ASIC Consumption



0006559-4

Source: Dataquest March 1990

TOP FIVE SUPPLIER ANALYSIS

This section analyzes the product and market strategies of the leading ASIC suppliers, as measured in total revenue. This analysis covers each company's ASIC product positioning, merchant/captive market positioning, long-term product strategy, trade agreement effects, and strategic alliances.

Table 3 shows the 1983 and 1989 ASIC market rankings in terms of revenue of the top 10 ASIC suppliers. This table illustrates the gains made by Japanese suppliers such as NEC, Toshiba, and Hitachi in the ASIC marketplace during the 1983 through 1989 period.

Fujitsu is the top-ranked supplier of ASICs in terms of total revenue (i.e., captive consumption plus merchant market sales), while LSI Logic leads in terms of merchant market sales. Captive consumption of ASICs represents by far the largest chunk of AT&T's revenue.

Table 3

Top 10 ASIC Suppliers

1983 ASIC Market Ranking	1989 ASIC Market Ranking	1989 ASIC Revenue (Millions of Dollars)
1. Fujitsu	1. Fujitsu	$669
2. AT&T	2. NEC	$575
3. MMI	3. LSI Logic	$457
4. Signetics	4. Toshiba	$400
5. NEC	5. AMD	$338
6. Ferranti Electronics	6. AT&T	$303
7. LSI Logic	7. Texas Instruments	$274
8. Ferranti Interdesign	8. Hitachi	$269
9. Fairchild	9. VLSI Technology	$169
10. Texas Instruments	10. National Semiconductor	$160

Source: Dataquest
March 1990

Fujitsu

Top-ranked Fujitsu's position as a vertically integrated manufacturer of electronics equipment and components has helped it achieve economies of scale in ASIC production and thus serve both captive and merchant market demand. Fujitsu entered the gate array business in the 1960s and was the first Japanese company to do so. The company's product strategy calls for high-volume output of low-density gate arrays (i.e., less than 6K gates). It is one of the leaders in the high-density gate market also. Fujitsu has earned an excellent reputation in the merchant marketplace as a supplier of bipolar ECL and TTL gate arrays. Fujitsu maintains a strategic alliance (including ownership interest) with Amdahl for supplying ECL gate array products that are designed into Amdahl's high-performance computers.

ASIC users can expect a firm commitment by Fujitsu to serve the demand for these products. The company's future product strategy targets high-density CMOS gate arrays (20K gates and higher) and continuing enhancements in bipolar ECL gate array products. Fujitsu also will supply BiCMOS gate arrays. Its ASIC product portfolio also extends to include cell-based integrated circuits (CBICs).

NEC

Second-ranked NEC also capitalizes on its position as a vertically integrated manufacturer to achieve economies of scale in ASIC production. This company is the leading producer of personal computers in Japan, and it serves captive and merchant market demand in roughly equal portions.

NEC's current product strategy also will be its future product direction. NEC commits itself now and in the future to supplying users with CMOS, bipolar ECL, and BiCMOS gate arrays. Currently, NEC supplies a large volume of low-density gate arrays (less than 6K gate counts) with the future focus on higher-density devices (i.e., 20K gates and higher). NEC's product portfolio includes CBICs.

LSI Logic

Third-ranked LSI Logic ranks first in terms of merchant market sales of ASICs. The company's current product strategy focuses on CMOS gate arrays. LSI Logic aims to be the biggest and the best in ASICs. This strategy calls for ASIC technology to be pushed as fast as possible into submicron line geometries and into high-density configurations (e.g., 100K+ gate arrays). The company has earned a reputation in the marketplace for the excellence of its software, including silicon compilers. The product portfolio includes CBICs.

This nonvertically integrated manufacturer places great reliance on strategic alliances as a way of strengthening its competitive position in the ASIC business. Although an alliance with Toshiba enabled the Japanese company to make greater gains in the ASIC marketplace than LSI had expected, alliances with firms like Raytheon and SGS remain a keystone of LSI's competitive strategy.

LSI Logic's future product direction in ASICs calls for more of the same: pushing the development of CMOS gate arrays and CBICs in terms of technology, performance, and software.

Toshiba

Like the other leading Japanese ASIC suppliers, fourth-ranked Toshiba draws upon its stature as a vertically integrated manufacturer to achieve economies of scale in ASIC production. Although Toshiba's level of vertical integration is less dramatic than that of top-ranked Fujitsu, it is still impressive. For CMOS ASIC users, Toshiba's business structure translates into a company that earns a large share of its ASIC revenue from merchant market demand.

Toshiba's current product position as a supplier of CMOS gate arrays stems in part from its strategic alliance with LSI Logic. Drawing upon an LSI Logic/Toshiba alliance that provides Toshiba with an excellent combination of software and second-source product sales, Toshiba has been winning more designs into 20K-plus gate array applications than its Japanese competitors such as Fujitsu and NEC.

The company's future product direction targets high-count CMOS gate arrays and CMOS CBICs. Toshiba continues to refine its software toward the objective of user-friendly design of high-density ASICs.

Toshiba's expanding relationship with Motorola serves as the basis for a long-term advance into the global ASIC marketplace. Toshiba's alliance with Motorola is intended to provide North American and European ASIC users with a "one-stop shopping" opportunity. For Toshiba, the Motorola/Toshiba alliance provides Toshiba with access to Motorola's microprocessor cores for the Toshiba cell library.

AMD

The future product strategy for fifth-ranked AMD calls for a full spectrum of PLDs—in the bipolar, CMOS, and BiCMOS technologies—and for CMOS CBICs. Users of these devices can expect a strong AMD commitment to the merchant marketplace.

THE FULL SPECTRUM OF ASIC SUPPLIERS

Dataquest has identified more than 120 ASIC suppliers, and others are planning to enter the business. Table 4 provides information regarding each ASIC supplier and its ASIC product offerings (PLDs, gate arrays, CBICs) by technology (MOS, bipolar).

Table 4

Worldwide ASIC Suppliers

Companies by Region	PLDs MOS	PLDs Bipolar	Gate Arrays MOS	Gate Arrays Bipolar	CBICs MOS	CBICs Bipolar
Worldwide Total	24	5	46	26	55	11
North American Companies	18	5	22	15	34	7
AT&T Technologies	0	0	0	1	1	0
Actel	1	0	0	0	0	0
Advanced Micro Devices	1	1	0	1	0	0
Altera	1	0	0	0	0	0
Applied Micro Circuits Corp.	0	0	1	1	0	1
Aspen Semiconductor	0	1	0	0	0	0
Atmel	1	0	0	0	0	0
California Micro Devices	0	0	1	0	1	0
Cherry Semiconductor	0	0	0	1	0	0
Cirrus Logic	1	0	0	0	0	0
Custom Silicon	0	0	1	0	1	0
Cypress Semiconductor	1	0	0	0	0	0
Exar Integrated Systems	0	0	0	1	1	0
Exel Microelectronics	1	0	0	0	0	0
Gould Semiconductors	1	0	1	0	1	0
Harris Semiconductor	1	0	1	1	1	0
Holt Integrated Circuits	0	0	0	0	1	0
Honeywell	0	0	1	1	1	0
Hughes Solid State	0	0	1	0	1	0
ICI Array Technology	0	0	1	0	1	0
Intel	1	0	0	0	1	0
International CMOS Technology	1	0	0	0	0	0
International Microcircuits Inc. (IMI)	0	0	1	0	1	0
International Microelect. Products (IMP)	0	0	0	0	1	1
LSI Logic	0	0	1	0	1	0
Lattice Semiconductor	1	0	0	0	0	0
Matra Design Semiconductor	0	0	1	0	1	0
Micro Linear	0	0	0	1	1	1
Micro Electronics	0	0	1	0	0	0

(Continued)

Table 4 (Continued)

Worldwide ASIC Suppliers

Companies by Region	PLDs MOS	PLDs Bipolar	Gate Arrays MOS	Gate Arrays Bipolar	CBICs MOS	CBICs Bipolar
North American Companies (Continued)						
Micro Power Systems	0	0	0	0	1	1
Microcircuits Technology	0	0	1	0	1	0
Motorola	0	0	1	1	1	1
NCR	0	0	1	0	1	0
National Semiconductor	1	1	1	1	1	1
Philips/Signetics	1	1	1	1	1	0
Polycore Electronics	0	0	0	1	0	0
Raytheon	0	0	1	1	0	0
Seattle Silicon	0	0	0	0	1	0
SEEQ Technology	1	0	0	0	0	0
Sierra Semiconductor	0	0	0	0	1	0
Silicon Systems	0	0	0	0	1	0
SIPEX (Barvon Res and Data Lin)	0	0	0	1	1	0
Standard Microsystems Corp.	0	0	0	0	1	0
Texas Instruments	1	1	1	1	1	0
Universal Semiconductor	0	0	1	1	1	0
United Technologies	0	0	1	0	0	0
VLSI Technology Inc.	0	0	1	0	1	0
VTC	0	0	1	0	1	1
WaferScale Integration	1	0	0	0	1	0
Xilinx	1	0	0	0	0	0
ZyMOS	0	0	0	0	1	0
Others						
Japanese Companies	2	0	9	6	10	0
Asahi	0	0	0	0	1	0
Fujitsu	1	0	1	1	0	0
Hitachi	0	0	1	1	1	0
Matsushita Electronics	0	0	1	0	1	0
Mitsubishi Electronics	0	0	1	1	1	0
NEC	0	0	1	1	1	0
Oki	0	0	1	1	1	0
Ricoh-Panatech	1	0	1	0	1	0
Seiko/SMOS	0	0	1	0	1	0
Toshiba	0	0	1	1	1	0
Yamaha	0	0	0	0	1	0

(Continued)

Table 4 (Continued)

Worldwide ASIC Suppliers

Companies by Region	PLDs MOS	PLDs Bipolar	Gate Arrays MOS	Gate Arrays Bipolar	CBICs MOS	CBICs Bipolar
Others						
European Companies	2	0	13	5	11	4
ASEA HAFO Inc.	0	0	0	0	1	0
Austria Mikro-System	0	0	1	0	0	0
Electronic Technology Corp. (ETC)	0	0	0	0	1	0
Ericsson Components	0	0	0	0	1	0
European Silicon Structure	0	0	0	0	1	0
Eurosil GmbH	0	0	1	0	1	0
Heuer Microtechnology (HMT)	0	0	1	0	0	0
Marconi Electronic Devices	0	0	1	0	1	0
Matra-Harris Semiconductors	0	0	1	0	0	0
Micro Circuits Engineering (MCE)	0	0	1	1	1	1
Mietec	0	0	1	0	1	1
Philips	0	0	1	1	1	0
Plessey	1	0	1	1	1	1
Racal Electronics Ltd.	0	0	1	0	0	0
SGS-Thomson	1	0	1	1	1	1
Siemens	0	0	1	1	0	0
Smiths	0	0	1	0	0	0
Others						
ROW Companies	2	0	2	0	0	0
ERSO	0	0	1	0	0	0
Goldstar Semiconductor	0	0	1	0	0	0
Hyundai	1	0	0	0	0	0
Samsung	1	0	0	0	0	0
Others						

Source: Dataquest
March 1990

INDUSTRY ISSUES AFFECTING ASIC USERS

This section analyzes the major industry issues that will influence the ASIC users' choice of vendors and products/technologies during the 1989 through 1992 time period. For current and prospective ASIC users, major issues concern not only technical challenges such as the packaging and testing of ASICs and the "routing" of interconnects in high gate-count arrays, but also practical matters such as the turnaround time between a buyer's "netlist" (to the vendor) and the delivery of the ASIC prototype to the user.

ASICs: An Entirely Different Business

As current ASIC users know and as prospective users will learn, the ASIC business is entirely different from the standard logic business. The ASIC user must determine at the very outset with which supplier the user is going to do business for the long term. Whereas the supplier decision can be made after the device decision in the standard products arena (and can be changed later), the ASIC product and vendor decisions must be made simultaneously and based on careful deliberation.

Another major difference to consider is that computer software issues connect directly with the ASIC vendor/product decisions.

Testability

ASIC procurement differs radically from standard product procurement. For current and prospective ASIC users, one great difference centers on the user's responsibility for proper testing of ASICs. Just as ASIC users take responsibility for writing the functional data sheet, they must also generate the test program.

Front-End Testability

Designers must give full consideration to testability during the early design stage of highly complex ASICs. The front-end design of testability into an ASIC minimizes the chance of later problems such as nontestability or infeasible testing requirements.

Modular Testing

The cost to the user of locating and solving a device fault or failure increases by an order of magnitude with each successive stage of VLSI product integration. Modular (or incremental) testing offers designers an excellent approach for achieving the related goals of front-end testability and early fault detection.

Users (i.e., ASIC designers) should use a modular test design approach for highly complex ASICs. Basically, this approach entails including circuitry that permits subportions of the ASIC to be tested separately. Designers can achieve this objective by using techniques such as logical (or physical) partitioning, synchronous architecture design, and structured design. The users benefit from the dramatic reduction in ASIC test time, cost, and associated problems.

Other Test Issues

ASIC users confront other complex issues in designing ASICs that can be quickly, effectively, and feasibly tested. First, the user must balance capital budget constraints against the long-term benefits provided by the costly ASIC test equipment. Next, an ASIC test program requires "fault gradings" to measure the program's effectiveness. Users must analyze whether or not their ASIC test equipment can handle the speed requirements of this process, or if the user should turn to ASIC vendors' high-speed computer/accelerators. Also, ASIC users must be aware of, and try to use wherever possible, the growing supply of CAE/CAD equipment/software that enables ASIC designers to generate, test, and capture test program "vectors" through simulation techniques.

Technology Trends

ASIC users must decide early in the ASIC design stage what technologies will be demanded by the user over the long term as well as in the short term. The user must choose an ASIC vendor that will be able to support the user's long-term migration in terms of ASIC technology (e.g., from pure bipolar or CMOS to BiCMOS). Similarly, the user must select a vendor that can support the user's move in terms of technological applications (e.g., from purely digital applications to mixed analog-digital signal use).

CMOS Technology Trends

The well-documented trend toward increasing consumption of CMOS-based semiconductors includes ASICs, and MOS ASICs represent a major growth segment. By 1994, MOS technology will command a 75 percent market share of ASIC consumption, with the lion's share being CMOS.

Bipolar/BiCMOS Technology Trends

Bipolar technology, primarily in the form of bipolar ECL gate arrays, will experience long-term growth, particularly in high-performance applications. Conversely, the TTL technology will continue to lose market share.

The BiCMOS process technology is emerging as a viable choice for ASIC users. No longer a product of tomorrow, a host of BiCMOS ASICs were introduced in 1987 from dependable North American and Japanese suppliers such as AT&T, Fujitsu, Hitachi, Motorola, National, and Texas Instruments. These suppliers are firmly committed to winning a share of the currently small but expanding BiCMOS ASIC business.

Uncertain Future for Gallium Arsenide (GaAs) ASICs

The same level of market confidence is now growing for gallium arsenide ASICs. Many players have entered (or plan to enter) this segment, but as of early 1990, the gallium arsenide ASIC revenue base is small.

Quick Turnaround Times

In the ASIC business, "turnaround time" is the time between the time the user submits a verified logic schematic to the supplier and the time that the supplier delivers the ASIC prototype to the user. Currently, gate array turnaround times range from 7 to 10 weeks, and CBIC turnaround times average 8 to 14 weeks.

Users clearly want a quicker turnaround time, meaning most ASIC vendors are under pressure to cut this time. For an additional NRE charge over regular rates, several ASIC suppliers are providing a two-week or less turnaround time for ASICs.

PLDs have the advantage of instant turnaround time. However, users pay for this premium through higher unit prices and performance sacrifices. For example, PLDs are lower in complexity, and thus performance, than complex gate arrays and CBICs. High-gate-count CMOS PLDs are encroaching somewhat into the <5K gate array market. Direct-write e-beam systems and late-mask laser processing systems provide vendors of gate arrays and CBICs with the tools they need for shortening their ASIC turnaround time.

ASIC Packaging Trends

Two major trends in ASIC packaging affect users of these circuits. These trends relate to through-hole and surface-mount packaging technologies.

Through-Hole Packaging Trends

There is a clear trend toward increasing use of pin-grid arrays (PGAs), which are suitable as packaging for higher-pin-count ASICs. Currently, ceramic PGAs are being offered for ASICs with pin counts as high as 308 pins. The long-term trend will be toward development of PGAs for ASICs with pin counts in excess of 500 pins.

Because ceramic PGAs are expensive to make, suppliers are trying to develop less expensive plastic PGAs. Dataquest believes that a long-term trend will be the development of plastic PGAs as less expensive alternatives to the ceramic packages for high-pin-count applications.

Surface-Mount Packaging Trends

Surface-mount technology (SMT) of ASICs has become more firmly entrenched in the marketplace. The initial high cost of SMT equipment and continuing confusion about SMT standards (despite proponent claims to the contrary) still present obstacles for prospective users of this packaging technology. For these reasons, many users resort to subcontractors for surface mounting of ASICs. Government regulations regarding chloro flouro carbons (CFCs) currently required for SMT cleaning also cloud the long-term future of SMT packaging. Tape automated bonding (TAB) is emerging as an alternative to direct-wire bonding techniques for high-pin-count devices. As used here, TAB refers to tape automated bonding as the genuine (and currently expensive) packaging approach, not to National Semiconductor Corporation's less expensive TapePak assembly-oriented approach.

Japanese and European users have an advantage over North American users regarding TAB suppliers, equipment, and overall service base. As in the case of SMT, North American users are turning to subcontractors for TAB packaging because of the initial high cost and relative scarcity of TAB equipment. In Japan, however, TAB equipment is available and, although expensive, is moving down the cost/learning curve.

Technical Challenges to Use of High-Density Gate Arrays

User demand for high-performance ASICs suitable for the users' advanced systems underlies the trend toward growing consumption of high-density gate arrays (specifically, CMOS arrays, but extending to bipolar ECL devices over the long term).

The use of high-density CMOS gate arrays (40K and above) presents technical challenges in terms of interconnections (hardware issue) and simulation (software issue). Specifically, the higher the density of the gate array, the greater the delay associated with the interconnects. In high-density gate arrays, the interconnect delay increases in relation to the gate-switching delay.

ASIC vendors are developing solutions to the interconnection challenge. First, ASIC manufacturers are offering additional layers of metal, which reduces interconnections. These ASIC vendors have moved beyond double layers to triple and quadruple layers of metal.

A second solution is the use of TAB packaging. Basically, TAB makes possible the use of shorter leads in ASICs, thus reducing delays deriving from interconnection problems (i.e., input/output pins).

Standard Logic Product Trends

The "Products" section of the Semiconductor User Information Service binder provides semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendor (or vendors), and at what price.

This section on standard logic contains four subsections. The first subsection develops a guide to effective long-term procurement of standard logic devices by use of product life cycle analysis. The second subsection examines the leading suppliers of standard logic devices. This part helps users to assess which vendors they should align themselves with. The third subsection combines the analyses of the standard logic vendor base and product life cycles and gives users a practical way of assessing their ability to obtain a supply of standard logic products from various manufacturers during the 1990 through 1995 time period. The fourth subsection looks at the prominent industry issues affecting users of standard logic now and in the future.

Cumulatively, the information in this section enables users to develop a sound strategy for satisfying demand for standard logic on a consistent, cost-conscious basis over the long term despite shifts in the supplier base.

STANDARD LOGIC PRODUCTS

Dataquest defines standard logic as a semiconductor logic device that is of typically less than 500 gates and is available in industry-standard functions. Standard logic devices typically are grouped into families of like electrical characteristics following the 74XXX catalog definitions.

The use of standard logic in military systems is very broad, as it is found in almost every type of equipment. Older system architectures use 50 to 60 percent of their standard logic for control and glue logic and the remainder for bus interface. Newer system designs are using application-specific integrated circuits (ASICs) for control and glue logic functions, with 70 percent or more of the standard logic used for local and backplane bus applications.

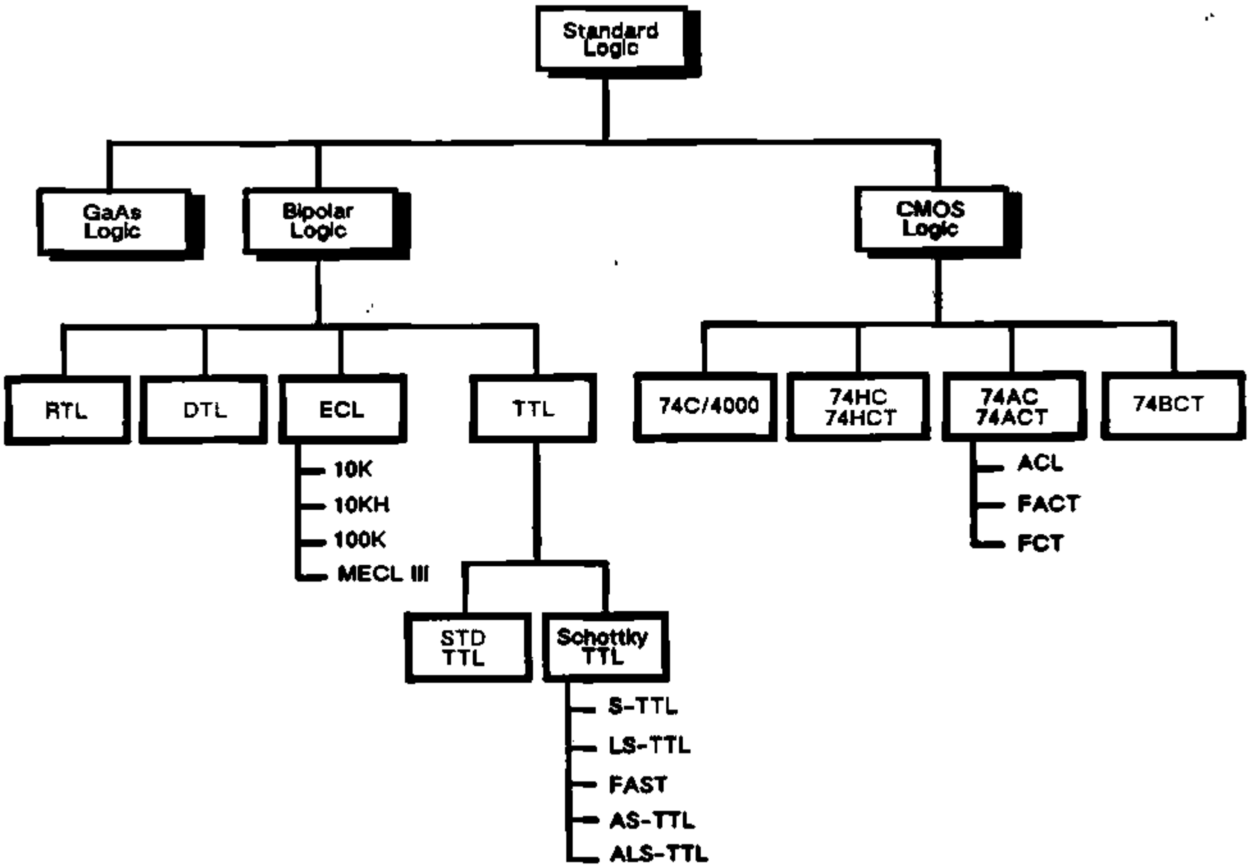
In general, the most significant trend is a decline in use of bipolar transistor-transistor logic (TTL) as it is displaced by ASICs and advanced CMOS logic. The desire to reduce board space, power consumption, and, most recently, obsolescence problems has become paramount in avionic and electronic warfare systems. New and upgraded systems are using ASIC solutions and advanced standard logic families.

Product and Technology Trends

Figure 1 illustrates the standard logic family tree. Figure 2 presents a comparison of selected standard logic technologies and the application performance ranges they most commonly serve.

Figure 1

Standard Logic Family Tree

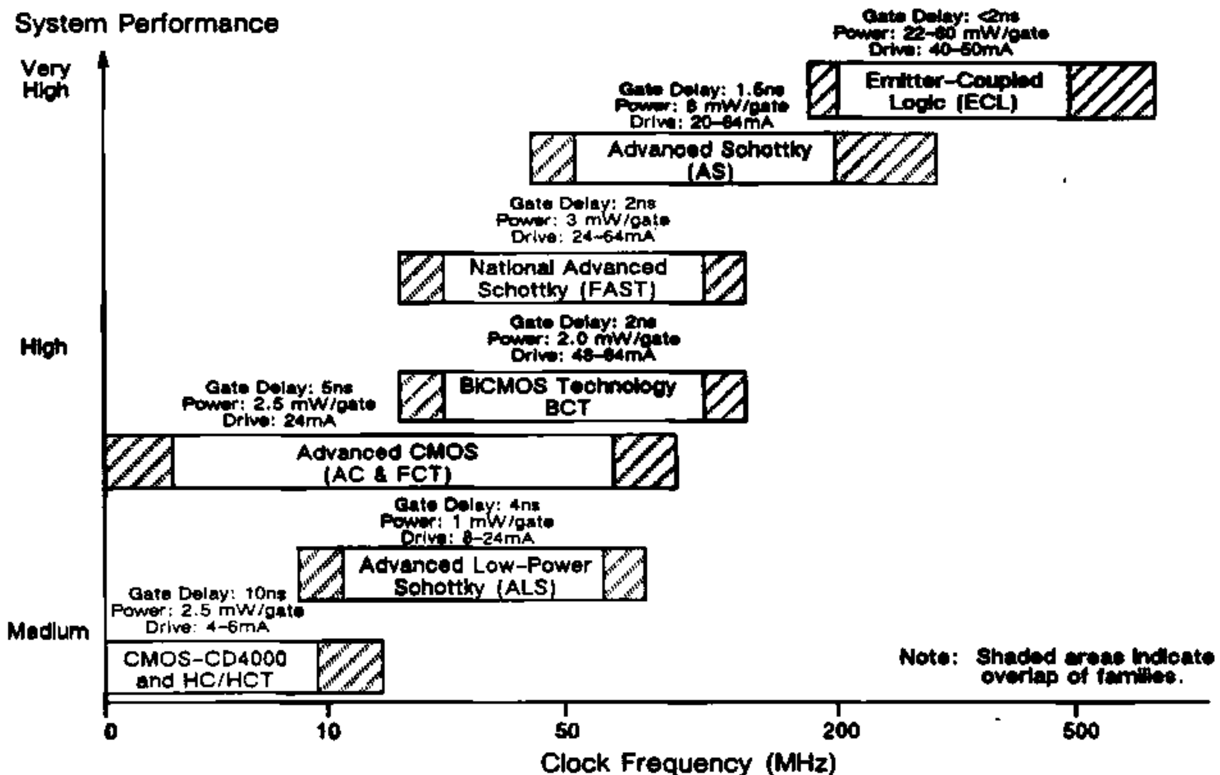


0006730-1

Source: Dataquest
May 1990

Figure 2

Standard Logic Components
Spectrum of Use Based on System Performance and Frequency



0006730-2

Source: Dataquest May 1990

Standard Logic Product Life Cycles

This section uses information on standard logic life cycles as a guide to assist users in adjusting to the forces that affect the marketplace. This section also lays the basis for other analyses based on product life cycle curves.

Figure 3 shows the position of the following families of standard logic on the product life cycle curve as of August 1989:

- 74/74L
- 74S/74LS
- 74AS

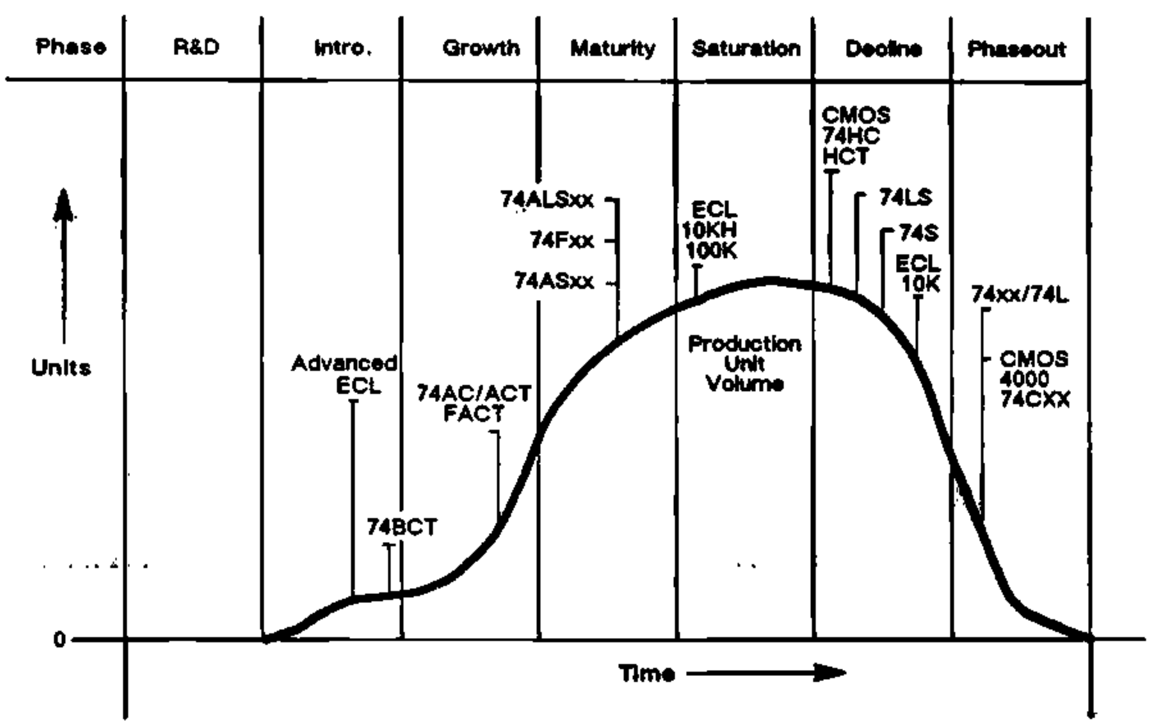
- 74ALS
- 74F (FAST)
- 74C/4000
- 74HC/HCT
- 74AC/ACT and FACT
- ECL 10K
- ECL 10KH
- ECL 100K
- Advanced ECL
- 74BCT

Users of standard logic products should keep the following two main points in mind regarding the life cycle of these devices:

- Long life cycles
- Orderly life cycles

Figure 3

Standard Logic Life Cycle



0006730-3

Source: Dataquest May 1990

Long Life Cycles

Typically, the product life cycle of standard logic devices is 15 years. The cycle is marked by relatively long maturity, saturation, and decline phases (about three years each). Conversely, the research and development (R&D) and growth stages are short—one year each. The phase-out period lasts one to two years. For users, product behavior like this translates into a 10-year period during which users can expect to be served dependably by suppliers of a given standard logic part before product availability becomes a major challenge.

Orderly Life Cycles

Notwithstanding the influence of ASICs, standard logic product life cycles are orderly in the sense that both the introduction and the growth of new products typically have a direct and measurable impact on older products. That is, the upward movement of a newer family of standard logic devices on the life cycle curve usually means a related downward curve for an older family that is being displaced in terms of design-ins and applications.

Table 1 summarizes the relationship between standard logic products that are moving up the life cycle curve (by winning design-ins) and the products that are moving down the curve as they are designed out of users' systems. Users that are redesigning systems now (or plan to do so soon) can use Table 1 as a guide for keeping their systems' needs for standard logic in line with the contractions and expansions in supply of these products.

Table 1

Standard Logic Design-In Trends*

Design Out	Design In
74C/4000	74AC/ACT and FACT
74	74AS, 74F (FAST)
ECL 10K/100K	ECL 10KH/BiCMOS
74S	74AS, 74F (FAST)

*Application-specific ICs (ASICs) also displace standard logic products.

Source: Dataquest
May 1990

SUPPLIER ANALYSIS

This section analyzes the product and market strategies of the top five and the remaining suppliers of standard logic products. This analysis covers each company's product positioning, market ranking, long-term product strategy, and strategic alliances.

The principal suppliers of standard logic are listed in Table 2. Harris Semiconductor, National Semiconductor, Motorola, Philips-Signetics, and Texas Instruments are the dominant suppliers of family standard logic. IDT, with its FCT family, has become a leading supplier of advanced CMOS logic. Many suppliers offer a limited product line (most often bus interface octals) to round out their product lines. Suppliers such as Lansdale and Teledyne MIL are part of a growing list of aftermarket suppliers that address the DMS problem. Distributors such as Rochester Electronics inventory discontinued products (finished wafers and die) from companies such as National and Texas Instruments.

Table 3 shows the 1989 rankings in terms of revenue of the top 10 suppliers of standard logic products. Supplier leadership in the maturing standard logic business stems from market share. The top six suppliers remain the same as they were in 1987.

Table 2

Principal Standard Logic Suppliers

	Bipolar	CMOS	GaAs	BiCMOS
AMD	I/F, S, LS	AC/ACT, I/F		
Analog Devices	I/F			
Circuit Technology		HC/HCT		
Fujitsu	S, LS, ECL-10KH	HC, ACT	GaAs	
Gigabit			GaAs	
Goldstar	S, LS	4000, HC, HCT		
Harris	I/F	HC/HCT, AC/ACT, 4000		
Hitachi	S, AS, LS, ECL-10K/10KH	HC, HCT, ACT	GaAs	BCT
Hughes	I/F			
IDT		FCT		
Lansdale	STD, H, DTL			
Logic Devices		I/F		
Marconi		HC/HCT, I/F		
Matra-Harris		HC/HCT		
Matsushita	AS, ALS, LS	4000, HC		
Micrel		4000		
Mitsubishi	AS, ALS, LS	4000, HC		
Motorola	LS, ALS, F, 10K 10KH, MECL III ECLinPS	HC/HCT, FACT 14XXX		

(Continued)

Table 2 (Continued)

Principal Standard Logic Suppliers

	Bipolar	CMOS	GaAs	BiCMOS
National	STD, L, S, LS, ALS, AS, F, 100K, DTL	74C, FACT, HC/HCT FCT		
NEC	LS, ECL 10K	4000, HC	GaAs	
Oki		4000	GaAs	
Performance		PCT		
Philips-Signetics	STD, S, LS, F	AC/ACT		
Plessey	I/F	I/F, dividers		
Raytheon	I/F			
Samsung		HCT, ACT		
SGS-Thomson	LS	4000, HC		
Sprague		4000		
Supertex		HC/HCT		
Teledyne	10K	AC/ACT		
Texas Instruments	STD, S, LS, ALS, AS, F	HC/HCT, AC/ACT		BCT
Toshiba		4000, HC, ACT	GaAs	BCT
TriQuint			I/F	
Universal		HC/HCT		
VTC		AC/ACT, FCT		

AC/ACT = Advanced CMOS
ALS = Advanced Low-Power Schottky
AS = Advanced Schottky
F = FAST
LS = Low-Power Schottky
S = Schottky
STD = 54XX
I/F = Bus Interface

Source: Dataquest
May 1990

Table 3

1989 Top 10 Worldwide Suppliers of Standard Logic

Rank	Supplier	Revenue (Millions of Dollars)
1	Texas Instruments	613
2	National Semiconductor	428
3	Motorola	402
4	Philips-Signetics	260
5	Hitachi	242
6	Toshiba	212
7	Advanced Micro Devices	147
8	NEC	145
9	Fujitsu	109
10	Harris	97

Source: Dataquest
May 1990

Texas Instruments

In terms of revenue, Texas Instruments (TI) is the number-one supplier of standard logic integrated circuits in the world. TI draws upon its economy-of-scale production in standard logic, which gives it an approximate 2:1 cost advantage over competitors, as a key to its success in this business.

TI currently supplies a full range of bipolar standard logic products. TI also has a foothold in the expanding CMOS segment. For example, 94 percent of the company's 1989 standard logic revenue was derived from bipolar product sales. The bipolar product portfolio includes the STD-TTL, S-TTL, FAST, AS, LS-TTL, ALS, and DTL families. Texas Instruments' MOS standard logic products include the 74HC and AC/ACT families. TI's current strategy emphasizes bipolar ALS and growth in the CMOS families (74HC, AC/ACT) and the emerging BiCMOS arena.

Users of standard logic products can expect a long-term commitment from TI regarding the supply of 74HC, AC/ACT, and ALS devices. The company's strategic alliance with Philips-Signetics regarding AC/ACT strengthens TI's position in this market segment. The company also aims to be a leader in the BiCMOS segment (74BCT).

National Semiconductor

National Semiconductor now supplies a full range of bipolar and MOS standard logic products. The current bipolar product portfolio includes STD-TTL, S-TTL, AS, FAST, LS-TTL, ALS, ECL 10KH/100K, and DTL. The MOS standard logic portfolio extends from the old 4000/74C family of parts through the mature 74HC/74HCT families to the growing AC/ACT family, which includes FACT, ACL, and FCT.

National Semiconductor-Fairchild's current product strategy focuses on bipolar ALS (from National Semiconductor) and bipolar ECL 100K (from Fairchild). Overall, users of standard logic devices can expect a firm commitment by National Semiconductor to serving long-term demand for a full line of bipolar and CMOS standard logic products.

Motorola

Although Motorola ranks third in terms of bipolar standard logic revenue, it ranks second in worldwide CMOS sales. Currently, Motorola's bipolar product strategy focuses on MECL III, ECLinPS, and ECL-10K/10KH as well as FAST and LS-TTL. Its current MOS standard logic product portfolio is being extended from the 4000/74C and 74HC/74HCT devices to inclusion of the AC/ACT family of standard logic.

Voted again in 1990 the Dataquest Semiconductor Supplier of the Year by procurement managers, Motorola will continue to be a dependable, long-term supplier of standard logic products. This supplier's future product direction mandates continuing to add enhancements to its family of bipolar ECL logic devices, an area of competitive strength. Motorola also is committed to the CMOS standard logic business.

Philips-Signetics

Fourth-ranked Philips-Signetics shows the same kind of balance in the standard logic business as Motorola; while Philips-Signetics ranks fifth regarding worldwide bipolar standard logic sales, it ranks eighth in terms of MOS logic revenue.

Philips-Signetics' current product strategy offers a complete line of standard logic. The bipolar product portfolio includes STD-TTL, S-TTL, FAST, LS-TTL, ALS, and ECL-10K/100K.

The company's current strategy for the MOS standard logic business is to supply the 74HC/HCT and AC/ACT families of products. Its position as the second source for TI's (center pin) AC/ACT family of standard logic makes Philips-Signetics a key force in this segment of the market.

This supplier's future product direction builds upon its current portfolio. North American and European users of standard logic will be well served by Philips-Signetics. We believe that Philips-Signetics will remain a leading supplier over the long term of FAST, ECL-10K, and ECL-10KH/100K.

Hitachi

Fifth-ranked Hitachi, a vertically integrated manufacturer, draws a large portion of its standard logic revenue from captive consumption. The Japanese supplier ranks fourth in terms of bipolar product sales and tenth in the MOS segment. The bipolar product portfolio includes the S-TTL, AS, LS-TTL, ECL-10K, and ECL-10KH/100K product line. The MOS standard logic effort focuses on 74HC.

Hitachi faces a challenge in terms of dependably supplying the needs of North American and European users of standard logic. During periods of peak demand, internal demand for standard logic wins over merchant market demand. Regarding the company's entire semiconductor portfolio, other, more lucrative opportunities (e.g., high-density DRAM) also compete against standard logic regarding the allocation of corporate resources.

Remainder of Standard Logic Suppliers

The overall standard logic supplier base is going through major changes as the large U.S. companies consolidate their mature product offerings and shift to advanced logic products. Some of the mature logic families that are being phased out by suppliers are being supported by Korean and Taiwanese companies. Many of the smaller domestic and foreign suppliers are focusing on the advanced products and thus fill a need for higher speeds and lower power. Adoption of BiCMOS and advanced CMOS families of logic (FACT, ACT, and FCT) by major users is accelerating the growth of this market and focusing pricing based on value rather than the historical cost-based method.

Although, as a whole, the standard logic market is mature, new system designs will continue to use these flexible solutions in conjunction with ASIC devices. Users need to review their older logic supply base continually (more so than most semiconductor families) and ensure that a balance is met between their system life and their component supply.

SUPPLY BASE ANALYSIS

This section uses information on standard logic product life cycles and suppliers to present a product-by-product evaluation of the supply base for these devices for the medium and long term. North American and European users will be under pressure to monitor and adjust the supplier base as a result of industry forces such as the trends toward vendor base consolidation and closer vendor-user relationships. This section provides users with a practical way of gauging the long-term supply base for a given standard logic product and gives direction for selecting vendors of a product.

Bipolar TTL

For the last 10 years, low-power Schottky (LS) has been the dominant TTL logic family for military and commercial applications. Now, however, it is being displaced rapidly by ASICs and newer logic families that have most of LS's benefits along with faster switching times. In higher-performance systems, the Fairchild Advanced Schottky TTL (FAST) family has found wide design-in acceptance and has become the second most commonly used family for military applications. Advanced low-power Schottky (ALS) has found good acceptance in medium-performance applications where power is a more critical factor. Schottky and the 54XX standard families continue to be designed out slowly.

In response to the requirements of MIL-M-38510 for electrostatic discharge (ESD) marking, some manufacturers are modifying their product lines to withstand at least 4,000 volts. Much of the investment regarding ESD redesign appears to be going toward the FAST family.

CMOS TTL

Introduced commercially in 1985 and 1986, these products provide the speed of the midrange bipolar offerings but at a fraction of the gate power.

The advanced CMOS (AC/ACT) product lines offer 24mA output drive current, and the FCT line offers 48mA. The ACL family from Texas Instruments and Philips-Signetics offers an alternate to the traditional JEDEC end-pin pin-out scheme as a solution to switching noise found with high-performance logic. National Semiconductor recently announced a redesigned version of the FACT family called QS, or Quiet Series, as a solution to the noise problem.

The HC/HCT family, like LS, is being replaced by ASICs and advanced CMOS families in many new system designs.

BiCMOS

Commercially introduced by Texas Instruments and Toshiba in 1987, this technology offers advanced bipolar propagation delays and 64mA output drive capability at an estimated 60 percent power savings. BiCMOS has been primarily targeted at backplane bus applications. Texas Instruments has also introduced a version of BiCMOS octal that incorporates the Joint Test Action Group (JTAG) standard scan test capability. These JTAG (aka IEEE 1149.1) octals are designed to be incorporated into JTAG board designs along with ASICs.

Advanced ECL

A sub-500ps bipolar logic is emerging from several companies. In general, these bipolar logic families represent a new generation of ECL standard logic that will displace the older families with substantial reductions in power consumption and increased switching speeds. The Motorola ECLinPS line is an example of one of the new families available in MIL-STD-883 versions. The principal uses of ECL standard logic are as complements to ASIC implementations and as building blocks in DSP or bit-slice applications.

Gallium Arsenide (GaAs)

Used initially in high-performance computing, GaAs standard logic is finding its way into military and aerospace applications. GaAs is well suited for applications requiring sub-200ps switching. It is principally available as a catalog replacement for ECL 100K I/O logic and as multiplexers, counters, and dividers for applications with high data rates. Selected mil-spec versions are available.

INDUSTRY ISSUES AFFECTING USERS OF STANDARD LOGIC

This section analyzes the major industry issues that will influence the standard logic product users' choices of vendors and devices during the 1990 through 1995 period. A predominant issue will be product crossovers by users; namely, the crossover from standard logic devices in the later stages of the life cycle to logic families that are in the earlier phases of the cycle, and the alternative crossover (from standard logic) to ASICs.

The Trend toward Supplier-Base Concentration and Product Offering Consolidation

Perhaps the major issue facing consumers of mature standard logic is the continued deterioration of availability of the older bipolar families such as DTL, HTTL, LTTL, standard gold-doped TTL, and Schottky TTL, as well as early CMOS families such as 4000 and 74C. The situation has been worsened by eroding profitability of the these product families as the commercial and military markets turn to ASICs and newer logic families.

In many situations, last-time buys have been announced and many of the families have only a partial catalog available. The emergence of various aftermarket suppliers that buy equipment and masks from the initial manufacturers has helped alleviate the problem.

The Product Crossovers

For users, the issue with greatest economic as well as technological impact involves the various standard logic product crossovers and the crossover from standard logic to ASICs.

The Crossover to ASICs

The year 1989 marked the continued crossover by users of logic products from standard logic to ASICs, as measured in number of gates. All semiconductor logic users must carefully weigh the relative long-term advantages of ASICs (PLSs, gate arrays, and cell-based designs) vis-à-vis standard logic as users design and redesign systems. The standard logic business is large and will not disappear. However, certain standard products are being phased out now, and the life cycle of others should expire during the next decade.

Standard Logic Product Crossovers

Users of standard logic must be aware that some segments of the business are expanding and that major producers are dedicated to serving long-term demand for these growing families of products.

Specifically, as shown in Table 1, the 74AC/ACT and FACT, 74AS/74F (FAST), ECL 10KH/100K, and 74AS/74F (FAST) families displace, respectively, the 74C/4000, 74, ECL 10K, and 74S families.

Emerging Areas of Growth in Standard Logic

The advanced ECL and BiCMOS/advanced BiCMOS product technologies are the most recently emerged growth segments in the standard logic business. The BiCMOS family of products is highly suitable for interface applications and is becoming the driver end of the CMOS segment. Texas Instruments has taken the lead in the BiCMOS segment of the standard logic business.

The Trend toward Surface-Mount Technology (SMT)

The trend toward increasing use of surface-mount technologies for the packaging of standard logic products is well under way. This trend has accelerated at a faster rate than originally expected; by the mid-1990s, SMT is expected to become the predominant technology, exceeding dual-in-line packages (DIPs) in volume.

MOS Microcomponent Product Trends

INTRODUCTION

The "Products" section of the Semiconductor User Information Service provides semiconductor users with both practical and strategic information for choosing which semiconductor devices to use, from which vendor (or vendors), and at what price.

MOS microcomponents are defined by Dataquest as including MOS microprocessors, MOS microcontrollers, and MOS microperipherals. This section focuses on 8-bit, 16-bit, and 32-bit microprocessors; 4-bit, 8-bit, and 16-bit microcontrollers; and, more generally, microperipherals.

For an overview discussion of microcomponents (also known as microcomputing devices), users are referred to the Semiconductor User Information Service binder entitled *Industry Trends*, therein to the "Product Overview" section following the "Products" tab.

This particular section on MOS microcomponents contains four subsections. The first subsection develops a guide to cost-effective, long-term procurement of these devices through the use of product life cycle analysis. The second subsection on the 10 top-ranked suppliers examines the current and future product strategies, merchant and captive market postures, trade environment effects, and strategic alliances of the leading suppliers of these devices. The third subsection combines the analyses of the MOS microcomponent vendor base and product life cycles. This information gives users a practical way of assessing their ability to obtain a supply of these devices during the 1989 to 1995 time period. The fourth subsection looks at the prominent industry issues affecting users of these devices now and in the future.

Cumulatively, the information in these sections enables users to develop a sound strategy for satisfying demand for MOS microcomponents on a consistent, cost-conscious basis over the long term, despite shifts in the supplier base.

MOS MICROCOMPONENT PRODUCT LIFE CYCLES

This section uses information on MOS microprocessor and microcontroller product life cycles as a guide to assist users in adjusting to forces affecting the marketplace over both the short and long term. This section also lays the basis for other analyses based on MOS microcomponent life cycle curves.

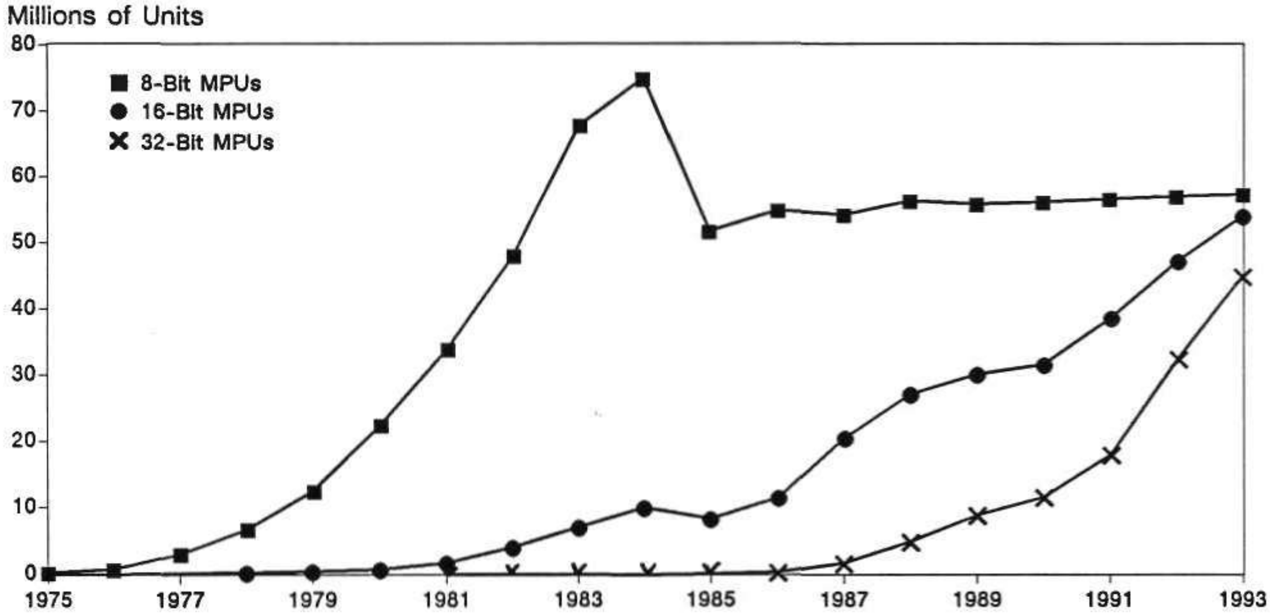
Typical Life Cycles for MOS Microcomponent Products

Figure 1 presents product life cycles for 8-, 16- and 32-bit MOS microprocessors. It represents a combination of historical shipments data and the latest Dataquest unit shipments forecast. The figure shows that MOS microcomponents typically experience longer product life cycles than other semiconductor devices. In fact, MOS microprocessor life cycles can last as long as 18 to 20 years.

Furthermore, microcontrollers can have even longer life cycles than microprocessors. Figure 2 shows product life cycles for 4-, 8- and 16-bit MOS microcontrollers. This figure clearly shows that MOS microcontroller product life cycles are much longer that those of most other semiconductor products.

Figure 1

Unit Shipments of 8-, 16- and 32-Bit Microprocessors

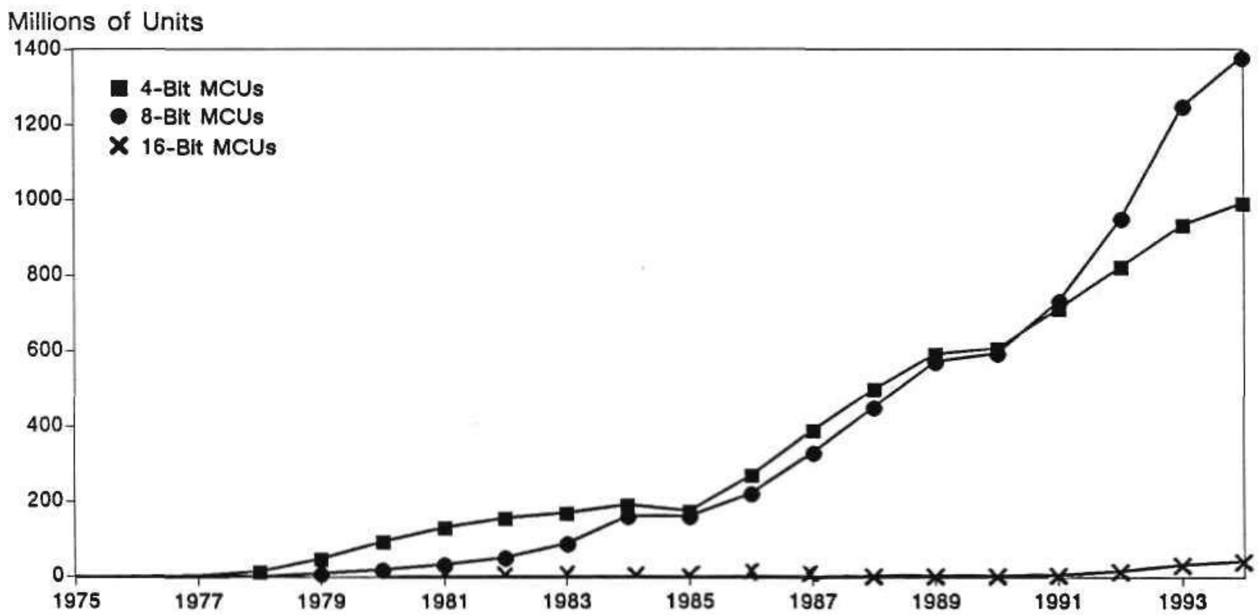


0005165-1

Source: Dataquest
November 1989

Figure 2

Unit Shipments of 4-, 8- and 16-Bit Microcontrollers



0005165-2

Source: Dataquest
November 1989

Although there are dramatic examples of individual devices that quickly peaked and then suddenly dropped in demand (e.g., the CP1600), Figures 1 and 2 reflect the predominant market reality in terms of lengthy product life cycles. This is that after a long R&D phase, MOS microcomponent products move through a relatively short introductory stage (6 to 18 months) and then spend 10 to 12 years winding through the growth, maturity, saturation, and decline stages of the cycle. The phaseout period can last as long as five to seven years.

The 4-bit microcontroller provides a good example of this kind of MOS microcomponent life cycle. Dataquest data show that the first shipments of this type of device began in 1973. As of 1989, the product is moving through the saturation stage, with phaseout not expected until the mid-1990s.

For users, the lengthy R&D stage provides a valuable opportunity to monitor the vendor's pace of technical achievement as well as the supplier's timetable for bringing the state-of-the-art device to the marketplace. Designers of high-performance systems that call for leading-edge devices should communicate with prospective vendors as early in a MOS microcomponent's product life as possible in order to minimize users' learning-curve headaches.

At the other end of the product life cycle, the prolonged phaseout stage generates time during which users can redesign systems (or otherwise adapt system life cycles) in line with the impending obsolescence of a given MOS microcomponent device.

SUPPLIER ANALYSIS

This section analyzes the product and market strategies of the leading suppliers of MOS microcomponents. This analysis covers each company's current product positioning, market rankings, long-term product strategy, trade agreement effects, legalissues, and strategic alliances.

Table 1 shows Dataquest's preliminary 1988 worldwide MOS microcomponent market share rankings (by revenue) of the top 10 suppliers. As the table shows, the 6 top-ranked suppliers again maintained the previous year's rankings, reflecting stability among the market leaders in this segment of the semiconductor business. The strength of these companies in holding market rankings reflects the high degree of concentration in the MOS microcomponent arena: the top 10 suppliers command more than 75 percent of total market share.

Intel

This top-ranked supplier of MOS microcomponents commanded more than one-quarter of this growing market in 1988. Intel cemented its ownership of the top spot by leading the industry in year-to-year growth. Intel's 1987 revenue lead over NEC amounted to $521 million. In 1988, this lead grew to an astonishing $1.04 billion.

Intel's product strategy calls for the constant pushing for state-of-the-art of density, functionality, and performance. This strategy can yield spectacular results at times. Currently, the 80286 and the 80386 microprocessors (16- and 32-bit devices, respectively) provide the company with an awesome stream of revenue. Intel has given no indication that it will license other suppliers to produce the lucrative 80386, 80486, 80860, or any of its advanced 80960 products for merchant market sales. Intel also maintains a strong position in the microcontroller segment of the MOS market, particularly in the 8- and 16-bit segments of the microcontroller arena. In the microperipherals field, Intel has secured a leadership role through its graphics, keyboard, and printer processors. The company has also begun moving aggressively in the PC logic chip set area.

Table 1

Worldwide MOS Microprocessor Market Share Rankings

1987 Rank	1988 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Intel	$1,087	$1,835	68.8%
2	2	NEC	$ 566	$ 790	39.6%
3	3	Motorola	$ 520	$ 699	34.4%
4	4	Hitachi	$ 402	$ 525	30.6%
5	5	Mitsubishi	$ 267	$ 381	42.7%
6	6	Toshiba	$ 283	$ 346	22.3%
9	7	Texas Instruments	$ 169	$ 234	38.5%
7	8	Matsushita	$ 199	$ 230	15.6%
10	9	Fujitsu	$ 146	$ 202	38.4%
8	10	Advanced Micro Devices	$ 178	$ 183	2.8%

Source: Dataquest
November 1989

Intel's future product direction calls for greater use of the CMOS process technology in new devices. The company can be expected to battle fiercely into the 1990s for the competitive edge in MOS microcomponent technology. In addition to a commitment to faster and more powerful 32- and 64-bit microprocessors, Intel has already moved into the development of 32-bit microcontrollers.

Intel's most far-reaching strategic alliance encompasses a variety of special agreements with IBM, its largest customer. For example, IBM is the only company licensed to produce the 80386 microprocessor. The license gives IBM the opportunity to meet captive demand for these parts, although the agreement apparently does not permit merchant market sales.

Intel's second largest customer for microcontrollers is Ford. This supplier-buyer relationship gives Intel a solid position from which to expand its long-term commitment to serving automotive and other transportation applications.

The company has also entered into an alliance with Samsung of Korea regarding 8-bit microcontrollers. This agreement provides users with a long-term second source of these devices, while allowing Intel to concentrate its technology efforts in other areas.

NEC

Like other Japanese suppliers of MOS microcomponents, second-ranked NEC draws upon its position as a vertically integrated supplier to guide its strategy for serving the merchant market. Large captive needs help NEC remain at the forefront of microcomponent technology. For example, NEC has positioned itself well for the long term regarding use of the CMOS process technology in microcomponent production.

In its current product portfolio, NEC's V-series of 8-, 16-, and 32-bit microprocessors anchors its strategy for serving this market. Now that the legal problems surrounding the V-series have been resolved, NEC may move more aggressively in this area. No such problems have occurred in the microcontroller area, where NEC enjoys a leadership position. The company's full range of microperipherals includes a noteworthy floppy disk controller, the 765A.

As a full-line semiconductor supplier, NEC remains fully committed to being a major participant in the global microcomponent business. NEC's expensive and protracted legal difficulties slowed market acceptance of its products but did not diminish this resolve.

NEC's market strength is currently weighted quite heavily in the microcontroller area. Buyers can expect to see the company moving to strengthen its position on the microprocessor side.

Motorola

Third-ranked Motorola has targeted the microcomponent segment as being vital to its current and long-term strategic objectives. Although not vertically integrated to the same degree an many Japanese suppliers, Motorola does draw on the experience and insights gained as a captive producer to a wide variety of electronic equipment markets to offer a full range of competitive MOS microcomponents.

Motorola's scientific and engineering efforts win the company an excellent reputation as a supplier of 8-, 16-, and 32-bit microprocessors, in addition to 8-bit microcontrollers and a variety of microperipherals. Motorola has enjoyed considerable success in penetrating the fast-growing technical workstation market with its high-performance 32-bit microprocessors.

Like Intel, Motorola is experiencing growing competition from innovative new RISC architectures. The company has responded to these challenges by continuing to advance its CISC-based 68000 line of 32-bit processors and by developing its own reduced-instruction-set computing (RISC) processor, the 88000 series.

Hitachi

Hitachi draws on its position as a vertically integrated manufacturer and its expertise in the CMOS technology as keys to its fourth-place ranking in the world-wide MOS microcomponent business. Hitachi's current product direction stems largely from its role as a second source for several major MOS microcomponents.

A significant portion of the company's 8-bit microprocessor revenue is derived from the sale of the 64180, a device developed by Hitachi from Zilog's Z80 architecture. (Hitachi subsequently licensed the 64180 to Zilog.) Hitachi second-sources Motorola's 6800 line of 8-bit microprocessors (e.g., 6800, 6802, and 6809) and 68000 series of 16-bit microprocessors. Hitachi also offers a line of proprietary 4- and 8-bit microcontrollers.

Hitachi has played a major role in Japan's The Real-Time Operating Nucleus (TRON) project. This project is a collaborative effort by Japanese semiconductor manufacturers (specifically, Hitachi, Fujitsu, and Mitsubishi, but also extending to Matsushita and Toshiba) to become independent of U.S. microcomponent technology. This government-backed effort by Japanese suppliers has aimed at the development of a workable operating system and architecture for microprocessors and microcontrollers to break Japan's dependence on U.S. standards.

The TRON project serves as the basis for Hitachi's future product direction in the MOS microcomponent marketplace. TRON offers Hitachi the ability to move upward to 32- and 64-bit microprocessors, as expected, and also downward to 16-bit devices, should there be a profitable opportunity. In addition, Hitachi recently licensed HP's RISC architecture for use in its own line of workstations and PCs.

Mitsubishi

Like other Japanese producers. fifth-ranked Mitsubishi draws upon its position as a vertically integrated manufacturer and its expertise in CMOS technology to guide its strategy for serving the demand for MOS microcomponents.

In terms of current product direction, Mitsubishi has forged a strong position in the CMOS 4- and 8-bit segments of the microcontroller marketplace. Mitsubishi also second-sources some of Intel's NMOS versions of these devices. Regarding microprocessors, Mitsubishi serves as a second source of Intel's 8- (8085 and 8088) and 16-bit microprocessors (8086).

Mitsubishi's future product direction in the microcomponent business calls for continuing strong commitment to users of 4- and 8-bit microcontrollers. No major advances are on the horizon regarding 16- and 32-bit microcontrollers.

This supplier has staked its claim in the 32-bit microprocessor business on participation in Japan's TRON project. Mitsubishi codeveloped the TRON chip along with Fujitsu and Hitachi. As of this writing, Mitsubishi has not announced the licensing of any of the new RISC technologies.

Toshiba

Toshiba, a vertically integrated manufacturer, has claimed the sixth-place ranking in the microcomponent marketplace through its expertise in the CMOS process technology and its NMOS products. The strength of Toshiba's current product portfolio centers on a CMOS line of Z80 (8-bit) microprocessors, 4- and 8-bit microcontrollers (mostly CMOS), and system-support-oriented microperipherals.

Toshiba's future product direction in this business will be an outgrowth of its participation in the TRON project. In terms of microprocessors, the TRON project puts Toshiba in a position to migrate directly to the 32-bit segment without offering a 16-bit product. CMOS remains the key technology over the long term regarding microcontroller and microperipheral product development.

Strategic alliances play a major role in Toshiba's achievements in this marketplace, and they will continue to do so. As noted, Toshiba developed Zilog's Z80 microprocessor into a line of CMOS devices. As part of that process, Toshiba received so-called "pass-through" rights enabling it to license the CMOS Z80 product to SGS (now SGS-Thomson).

Toshiba's strategic alliance with Motorola might ultimately have a great effect on Toshiba's future product direction in the MOS microcomponent market. The Toshiba-Motorola alliance so far has garnered greatest attention with regard to the transfer of semiconductor memory technology by Toshiba to Motorola; however, in exchange, Toshiba receives unspecified microcomponent technology from Motorola. This technology exchange alliance strengthens Toshiba's long-term prospects for serving users of these devices.

Toshiba's recent licensing of SPARC technology from Sun Microsystems opens yet another strategic product direction although it is too soon to tell where SPARC may lead the company. Toshiba's future 32-bit microprocessor product portfolio could include TRON-, Motorola, and SPARC-based devices.

Texas Instruments (TI)

Seventh-ranked TI targets the demand for specialized microprocessors and microperipherals as the key to its MOS microcomponent strategy. This industry giant joins Motorola as one of the only two U.S.-based microcomponent vendors that are fully vertically integrated. Although neither company is integrated to the same extent as their Japanese competitors, this integration nevertheless translates into a technological advantage in terms of identifying and serving specialized microcomputing needs.

TI's current product portfolio does not place the company among the mainstream suppliers of microprocessors. Formerly the leader in the 4-bit NMOS microcontroller segment, TI now participates in the market for these devices as well as for NMOS and CMOS 8-bit microcontrollers. Its major efforts in the microcomponents arena are in supplying microprocessors and microperipherals for graphics, speech, DSP, and other specialized applications. TI is the world's leading supplier of DSP devices.

TI's future product portfolio will offer a wide range of CMOS devices. The company can be expected to continue to supply the demand for 4- and 8-bit microcontrollers; however, it is likely to place future emphasis on specialized microprocessor such as the 34010 and 34020 (TIGA) chips. TI is also moving aggressively into the PC logic chip set business.

Matsushita

Like other Japanese suppliers, Matsushita draws on its strength as a vertically integrated manufacturer and its skill in CMOS technology to achieve its eighth-place ranking in MOS microcomponents. Matsushita's current product strategy focuses on supplying 4-bit microcontrollers, which account for the bulk of their microcontroller shipments.

Vertical integration plays a key role in shaping Matsushita's strategy for serving the demand for MOS microcomponents. The company makes and markets consumer electronics under the following names: National, Panasonic, Quasar, and Technics. Matsushita also owns a share of JVC (another consumer electronics company). By supplying lower-density CMOS microcontrollers for internal consumption, Matsushita positions itself for serving the merchant market demand for these parts.

Participation in Japan's TRON project represents Matsushita's most vital strategic alliance in the MOS microcomponent arena. The alliance with other Japanese suppliers puts Matsushita in a long-term position to migrate to more lucrative 32-bit microprocessors.

Matsushita's future product direction should feature more of the same. The company will evolve the product line along with consumer application market demand; consequently, Matsushita should emerge as a key supplier of 8-bit microcontrollers.

Fujitsu

Ninth-ranked Fujitsu enjoys the same advantages (i.e., a high degree of vertical integration, CMOS process expertise) as do other Japanese suppliers for serving the MOS microcomponent market. Trade tension, however, has made it difficult for Fujitsu to forge critical alliances and to make other strategic positioning moves. Although Fujitsu's proposed acquisition of Fairchild Semiconductor Corporation would not have had an immediately visible impact in the MOS microcomponent business, the scuttling of the deal stifled a major advance by Fujitsu into the direct pipeline to North American and European semiconductor product users.

Fujitsu's current microprocessor product portfolio centers on the 80286 device. The company maintains a reputation in the marketplace as a formidable supplier of 4- and 8-bit microcontrollers.

Two alliances loom as keys to Fujitsu's future microprocessor product direction. The TRON alliance offers the promise of a long-term alternative, while Fujitsu's SPARC licensing agreement with Sun Microsystems offers the company a new high-performance product direction in the near term.

Fujitsu's strategy for participating in the microcontroller and microperipheral markets calls for a stake in the emerging DSP segment of the business. Fujitsu already supplies DSP devices.

Advanced Micro Devices (AMD)

Tenth-ranked Advanced Micro Devices (AMD) is a company facing a difficult transition. Past microcomponent product strategies relied heavily on superior sales, marketing, and product improvements on second-sourced devices.

AMD's current MOS microcomponent product portfolio is derived largely from Intel microprocessor architectures. AMD commands a reputation as a reliable second source for Intel's 8- (8088) and 16-bit microprocessors (8086 and 80286), including enhanced versions. For example, AMD offers the fastest 80286 device available. AMD also second-sources 8-bit microcontrollers from Intel. The company supplies a spectrum of systems-support microperipherals as well.

The future product direction calls for new microcomponent devices to be designed in CMOS, with the continued support of existing NMOS products. AMD has worked hard to secure a foothold in the emerging 32-bit microprocessor market with its AM29000 product. The company continues to push Intel on the legal front in order to secure the right to second-source the 80386.

SUPPLY BASE ANALYSIS

This subsection uses information on MOS microcomponent product life cycles and suppliers to present a product-by-product evaluation of the supply base over the long term for 8-bit, 16-bit, and 32-bit microprocessors and 4-bit, 8-bit, and 16-bit microcontrollers. Overall, North American and European users will be under less pressure to adjust their MOS microcomponent supplier base (vis-`a-vis other semiconductor products) as a result of the U.S.-Japan trade agreement. North American producers have maintained a technological lead over Japanese competitors in this segment of the semiconductor business, which minimizes the effects of any trade legislation. Nevertheless, design engineers and procurement managers will have new opportunities in terms of dependable long-term suppliers of these devices as North American, Japanese, and European companies battle to win share in this rewarding marketplace. This subsection provides users with a practical means of gauging the long-term supply base for a given MOS microcomponent and direction for selecting vendors of the device.

Each subsection contains a table showing the size of the market (in terms of units shipped), the relative market shares of the predominant devices, and a ranking of the suppliers of these devices.

Product life cycle analysis serves as the basis for a summary assessment from a user's perspective on anticipated supply of each type of MOS microcomponent. The summary includes a succinct statement on whether the user faces a favorable or a critical supply base for each component type. Factors affecting the supply base, such as vendor strategies and strategic alliances, are also discussed in each subsection.

Supply Base for 8-Bit MOS Microprocessors

Table 2 provides information on the market size and leading suppliers of the predominant 8-bit MOS microprocessors as of 1988.

Most of the processors listed in Table 2 were introduced during a time when second-source availability was considered a prerequisite for market acceptance. They were therefore widely licensed, to the clear benefit of buyers who today enjoy the security and low prices of a broad supplier base.

Table 2

Supply Base for 8-Bit Microprocessors

Leading Products	1988 Product Market Share (%)	Sources (Share in Percent)
Z80	44.9%	Zilog
		SGS-Thomson
		Toshiba
		Sharp
		NEC
8085	18.5	NEC
		Harris
		Intel
		Oki
		Toshiba
		Mitsubishi
		Siemens
		AMD

(Continued)

Table 2 (Continued)

Supply Base for 8-Bit Microprocessors

Leading Products	1988 Product Market Share (%)	Sources (Share in Percent)
8088	10.8	Siemens
		Intel
		AMD
		Oki
		Harris
		NEC
		Fujitsu
		Mitsubishi
6809	7.1	Motorola
		Hitachi
		SGS-Thomson
		Fujitsu
6802/08	5.4	Motorola
		Hitachi
		SGS-Thomson
80188	3.4	AMD
		Fujitsu
		Intel
		Siemens
V20	2.8	NEC
		Sharp
Others	7.2	
Total Market Size = 56,500	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest November 1989

Preliminary Dataquest estimates show 8-bit microprocessors to be at or near peak shipment levels, indicating that most products within this category are in the maturity stage of their product life cycle. As of mid-1989, the 8-bit microprocessor is still clearly the largest segment of the microprocessor marketplace as measured in unit shipments.

Users of 8-bit MOS microprocessors face a favorable supply situation over the long term. The life cycle of these devices is expected to extend well into the 1990s.

Supply Base for 16-Bit MOS Microprocessors

Table 3 provides information on the market size and leading suppliers of the predominant 16-bit MOS microprocessors as of 1988.

Table 3

Supply Base for 16-Bit Microprocessors

Leading Products	1988 Market Share (% of 16-Bit Units)	Sources (Share in Percent)
80286	32.0%	Intel
		AMD
		Siemens
		Fujitsu
		Harris
68000	29.6	Motorola
		Signetics
		Hitachi
		SGS-Thomson
		Rockwell
8086	12.5	Intel
		Siemens
		AMD
		Oki
		NEC
		Fujitsu
		Harris
80186	10.6	Intel
		AMD
		Siemens
		Fujitsu
Z8000	5.7	SGS-Thomson
		Toshiba
		Zilog
		Sharp
		AMD
V30	3.9	NEC
		Sharp
68010	2.3	Motorola
		Signetics
320XX	1.6	National
80386SX	1.6	Intel
Others	0.1	
Total Market Share = 29,200	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest
November 1989

Like their 8-bit cousins, 16-bit microprocessors tend to be multisourced. Again, this works to the benefit of users in that they enjoy the better pricing, availability, and security of a strong and diverse vendor base. Considering the pricing and compute power of these devices, 16-bit microprocessors are an excellent value indeed.

Preliminary Dataquest estimates show 16-bit microprocessors to be in the growth phase of their product life cycle. Unit growth has been accompanied by a steady strengthening in the supplier base and dramatic improvements in price.

Recent price improvements are largely attributable to the following three causes:

- Multiple sources of supply
- Competition from 32-bit devices (particularly Intel's 80386)
- Market penetration pricing strategies by certain suppliers

Strong growth in the laptop PC market translates into strong pressure on suppliers to provide a low-power version of their 16-bit microprocessors. Dataquest expects vendors to provide a CMOS version of most of these devices in the near future.

Users of 16-bit MOS microprocessors face a favorable supply situation over the long term. The life cycle of these devices is expected to extend into the late 1990s.

Supply Base for 32-Bit MOS Microprocessors

Table 4 provides information on the market size and leading suppliers of the predominant 32-bit MOS microprocessors as of 1988.

These products are unique in that the most popular devices are sole-sourced. Both Intel and Motorola have successfully broken the linkage between multisourcing and market acceptance. This feat was accomplished by first gaining acceptance for a compute platform at the 8- and 16-bit levels, and then denying licenses to their partners at the 32-bit level.

It is still too early to say whether or not this strategy will ultimately pay off, however. The reaction to both Intel and Motorola's success has been a move to innovative new RISC-based architectures (SPARC and mips) pioneered by computer companies. In addition, several Japanese suppliers have broken away from the pack to pursue their own innovative new architecture, TRON. If success invites competition, then Intel and Motorola may indeed have been successful beyond their wildest expectations.

Users of 32-bit microprocessors face an uncertain supply situation in which they must choose between a sole-source situation and an unproven architecture. Dataquest recommends that users weigh these procurement issues against the benefits of greater compute power when considering jumping to a 32-bit device.

Table 4

Supply Base for 32-Bit Microprocessors

Leading Products	1988 Market Share (% of 32-Bit Units)	Sources (Share in Percent)
80386	54.4%	Intel
68020	27.5	Motorola
68030	5.0	Motorola
32X32	5.3	National
Transputer	2.5	Inmos
Other Microprocessors with Less than 1.0%		
AM29000	*	AMD
R2000/3000	*	IDT
		LSI Logic
SPARC	*	LSI Logic
		Cypress
		Fujitsu
TRON	*	Hitachi
80486	*	Intel
i860	*	Intel
68040	*	Motorola
88000	*	Motorola
Total Market Share = 5,000	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest November 1989

Supply Base for 4-Bit MOS Microcontrollers

Table 5 provides information on the market size and leading suppliers of the predominant 4-bit MOS microcontrollers as of 1988.

The 4-bit microcontroller market is by far the largest microcomponent market in terms of unit volume. Its size, along with the age of this market, serves to keep unit prices quite competitive despite the lack of multiple sources for most products. Another source of price pressure is stiff competition during the design phase not only among 4-bit controllers, but from 8-bit solutions as well.

Dataquest believes that 4-bit microcontrollers are still in the growth phase of their life cycle, with unit shipments growth forecast to continue to grow through the mid-1990s.

Users of 4-bit microcontrollers face a favorable supply situation despite a lack of multisourcing in this market. These products show no signs of phasing out.

Table 5

Supply Base for 4-Bit Microcontrollers

Leading Products	1988 Market Share (% of 4-Bit Units)	Sources
uPD75XX	12.7%	NEC
MN1500	9.9	Matsushita
TLCS-47	8.4	Toshiba
COPS	7.8	National
		SGS-Thomson
HMCS-400	5.3	Hitachi
HMCS-40	4.3	Hitachi
Others	51.6	
Total Market Share = 501,075	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest November 1989

Supply Base for 8-Bit MOS Microcontrollers

Table 6 provides information on the market size and leading suppliers of 8-bit MOS microcontrollers as of 1988.

The 8-bit market seems to be the most competitive and dynamic of the microcontroller markets. With unit shipments projected to overtake those of 4-bit microcontrollers within the next two years, the 8-bit products should dominate the other segments for several years to come. Just as the 16-bit microprocessor is an excellent compute value in the microprocessor marketplace, so too is the 8-bit microcontroller. In a market where sole-sourcing is the exception to the rule, buyers enjoy excellent leverage.

Dataquest believes that 8-bit microcontrollers still are in the growth phase of their life cycle, with unit shipment growth forecast to continue through the mid-1990s.

Users of 8-bit microcontrollers face a very favorable supply situation in which the effects of high-volume production and multisourcing combine to give buyers maximum leverage.

Supply Base for 16-Bit MOS Microcontrollers

Table 7 provides information on the market size and leading suppliers of the predominant 16-bit MOS microcontrollers as of 1988.

Table 6

Supply Base for 8-Bit Microcontrollers

Leading Products	1988 Market Share (% of 8-Bit Units)	Sources
6805/68HC05	16.5%	Hitachi
		Motorola
		SGS-Thomson
8049/39	9.5	Fujitsu
		Intel
		Mitsubishi
		National
		NEC
		Oki
		Philips
		Signetics
		Toshiba
M507XX/M509XX	11.6	Mitsubishi
8051/31	9.7	AMD
		Fujitsu
		Intel
		Matra-Harris
		Oki
		Philips
		Siemens
		Signetics
6801/03	7.1	Hitachi
		Motorola
		SGS-Thomson
uPD78XX	7.1	NEC
Others	47.6	
Total Market Share = 454,022	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest November 1989

Table 7

Supply Base for 16-Bit Microcontrollers

Leading Products	1988 Market Share (% of 16-Bit Units)	Sources
8096	30.4%	Intel
HPC	4.5	National
8098	1.5	Intel
68200	1.2	SGS-Thomson
80C196	1.1	Intel
V35	0.2	NEC
8061	60.5	Various
Others	0.7	
Total Market Share = 5,500	100.0%	

Note: Column may not add to total shown because of rounding.

Source: Dataquest November 1989

Although they have met with some success in penetrating the automotive market, 16-bit microcontrollers have yet to take off. Low unit volumes and the interchangeable sourcing of many devices have impaired the competitiveness of 16-bit products, leaving the bulk of controller applications to 8-bit devices.

Like the 32-bit microprocessor, the 16-bit microcontroller offers a significant increase in power over its predecessor. Unlike the 32-bit microprocessor, however, the 16-bit microcontroller does not currently enjoy a corresponding wealth of high-powered applications waiting to be filled.

Because we believe that the 16-bit microcontroller is still in the introductory phase of the product life cycle, it is too soon to tell whether or not it will ever surpass 8-bit microcontrollers. Current Dataquest forecasts show shipments of 16-bit devices lagging behind those of 8-bit devices for the foreseeable future.

Users of 16-bit microcontrollers face a mixed supply situation in which certain high-volume users enjoy strong leverage and the resultant lower prices, whereas other users are forced to pay premium prices for extra compute power that they may not need.

INDUSTRY ISSUES AFFECTING USERS OF MOS MICROCOMPONENTS

TRON

Early adoption by the computing community is usually a prerequisite for the success of any new microprocessor. This is largely due to the "critical mass" phenomenon, in which software support for a new architecture is dependent on installed base while design wins, which generate the installed base, often turn on the issue of available software!

Because the leading participants of the TRON project are fully integrated into the systems business, they posses the unique ability to "jump start" the TRON architecture by mandating their own internal design wins. This ability greatly enhances TRON's long-term prospects for success. These companies view their own dependence on outside architectures as a critical strategic weakness, and are therefore quite likely to take whatever coordinated action necessary to assure TRON's success.

The strategic implications of this scenario for North American and European users are quite serious. North American computer companies have clearly benefitted from having close ties with leading microprocessor firms. This advantage seems mild, however, when compared to the possible advantage enjoyed by the computer divisions of the fully integrated TRON suppliers.

Dataquest recommends that computer manufacturers keep a close eye on TRON. Should TRON turn out to be the next architectural breakthrough, U.S. and European computer manufacturers will need to move quickly to protect their competitiveness.

RISC versus CISC

Another promising architecture is RISC. Reduced-instruction set computing operates on the principal that it is better to execute a few tasts very well than to execute many tasks just adequately. The power behind RISC lies in the tremendous amount of time saved in this instruction-set streamlining. In most applications, the clock cycles lost to executing a greater number of instructions are more than offset by the ability to execute instructions in a single clock cycle and to run the processor clock at a much faster rate.

Computer companies such as Sun Microsystems and MIPS Computer Systems have led the RISC charge with their respective SPARC and R2000/3000 architectures. The leading CISC-based microprocessor manufacturers, Intel and Motorola, have acknowledged the appropriateness of the RISC approach for certain applications by developing their own RISC-based processors. Although its not yet clear what the architecture of the future will be (there are a variety of instruction set possibilities), it is clear that users eventually will face some problems translating their software base to another architecture.

Is this bad news? Not at all! The RISC versus CISC debate has raised some interesting and critical issues, forcing microprocessor designers to reexamine how these devices are used by systems designers. The resultant turmoil in the computing community is the natural result of rapid technological innovation. Microprocessor users should welcome this innovation and look to new architectures for possible new opportunities of their own.

Embedded Controller Confusion

Much has been made of a large, promising, and hazily defined embedded controller market. In fact, 4- and 8-bit microcontroller sales to nonreprogrammable markets (such as the automotive, consumer, and disk drive markets) have been healthy and substantial for years. The really new markets are those that require more computing power than all but the most powerful microcomponents can supply today.

Applications such as laser printer control and graphics processing are leading an emerging class of *high-performance* embedded microprocessor applications. Users can expect to see new application-specific standard processor product offerings to fulfill these requirements.

Microperipherals

Two predominant trends shape the future in this segment of the MOS microcomponent market. First, vendors are beginning to supply a wider variety of specialized microcomponents in response to user demand. TI, for example, climbed into the rankings without being a major participant in the mainstream segments of the market. Specialized devices reflect the trend toward application-specific standard products in the microcomponent area.

Second, the trend toward greater integration at the chip level translates to greater consolidation of functions at the system level. Microperipherals therefore are incorporating more and more functions that were previously implemented off-chip.

Quality

Quality

The following is a list of the material in this section:

- Quality--February 1990

Quality

INTRODUCTION

Anyone connected with the semiconductor industry has been witnessing a quality control revolution taking place in semiconductor companies. Both users and manufacturers agree that quality control is no longer a competitive distinction, but a requirement of highest priority for future survival in the industry. What isn't agreed on universally is what constitutes quality control in the semiconductor industry. As one prominent engineer and developer of quality control theory stated:

> To practice quality control is to develop, design, produce, and service a quality product which is most economical, most useful, and always satisfactory to the consumer.
>
> To meet this goal, everyone in the company must participate in and promote quality control, including top executives, all divisions within the company, and all employees.

How well semiconductor manufacturers and users implement quality control programs could determine their strength and future direction against worldwide competition.

The objectives of this service section are to discuss the driving forces behind quality control programs and to determine what new methodologies and strategies for improving semiconductor quality are being implemented by manufacturers and users worldwide. While we will not attempt to recommend any one quality program or technique, we believe that it is important to discuss a few of the major participants and their quality improvement programs. We have chosen the following programs for discussion:

- Vendor performance measurements
- Statistical quality control (SQC)
- Just-in-Time (JIT) manufacturing and purchasing
- Zero defect programs

QUALITY CONTROL PROGRAMS

Vendor Performance Measurements

There are three compelling reasons why semiconductor vendors and users are changing the way they do business: demands for high-quality products, better delivery, and lower prices. The vendor and user can meet each other's needs and still make a profit, but this requires closer relationships between vendor and user.

Quality

Digital Equipment Corporation established a Vendor Performance Measurement Program. Digital's program objectives are:

- To facilitate better internal decision-making processes
- To provide accurate feedback to vendors as to how they are perceived and measured
- To generate desired vendor performance

Better internal decisions can be made by measuring a vendor's performance on the following:

- Device design—Can the vendor ramp up to the user's system design?
- Product specification—Can the vendor's product meet the user's system specification?
- Ship-to-stock track record—Can the vendor supply test data to the user verifying product quality levels?
- On-time delivery—Can the user plan inventory around the vendor's delivery performance?
- Total cost—Can the user measure the total cost to design in and use a vendor's product in the end system?

The success of a vendor performance measurement program falls on the user's ability to provide feedback to the vendor by:

- Maintaining a current and continuous flow of accurate data to the vendor
- Maintaining weekly, monthly, and quarterly feedback sessions on the vendor's product performance
- Commending the vendor for on-time deliveries and quality of performance

The goal of a vendor performance measurement system is to generate a desired vendor performance whereby the vendor can:

- Set aggressive and achievable product specifications
- Establish predictable and quick prototype turnaround time
- Maintain consistently excellent quality and reliability
- Commit to timely and dependable delivery

- Provide competitive total cost
- Behave like a business partner

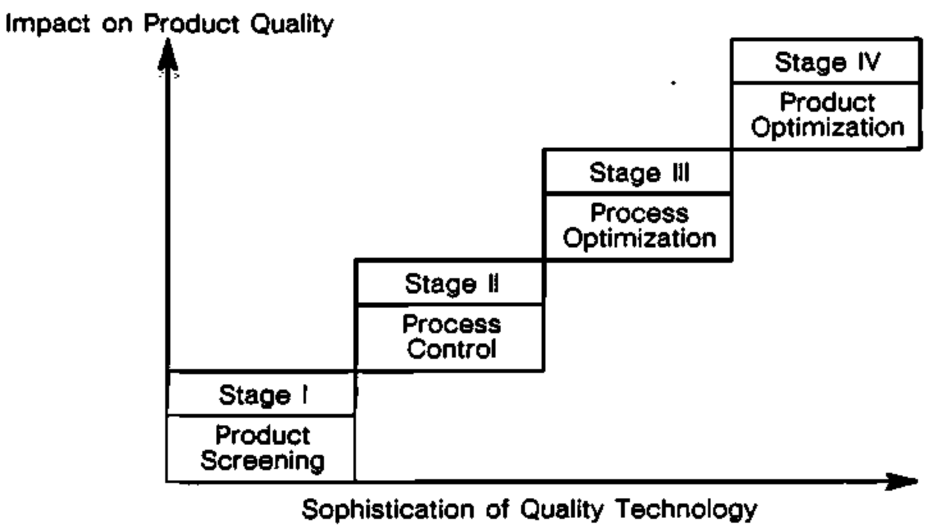
Statistical Quality Control (SQC)

Statistical Quality Control (SQC) is a complex mathematical and statistical technique that, when applied to every step of the manufacturing process, ensures high yields and excellent quality. SQC began in the 1930s with the industrial application of control charts invented by Dr. W.A. Shewhart of the Bell Laboratories. The United States utilized SQC methods during the Second World War to produce military supplies inexpensively and in large volumes. The U.S. method of quality control was introduced to postwar Japan. A major emphasis on quality control in Japan was made during the 1950s when the Japanese implemented the SQC methodologies of the renowned statistician, Dr. W. Edwards Deming.

National Semiconductor Corporation and the semiconductor sector of Harris Corporation are two major manufacturers that have implemented SQC programs in-house and with their suppliers to improve manufacturing operations and to ensure maximum quality in raw materials. As shown in Figure 1, we have divided SQC into four stages, with each stage being an extension of the previous stage.

Figure 1

Stages of Statistical Quality Technology



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Source: Harris Corporation

Quality

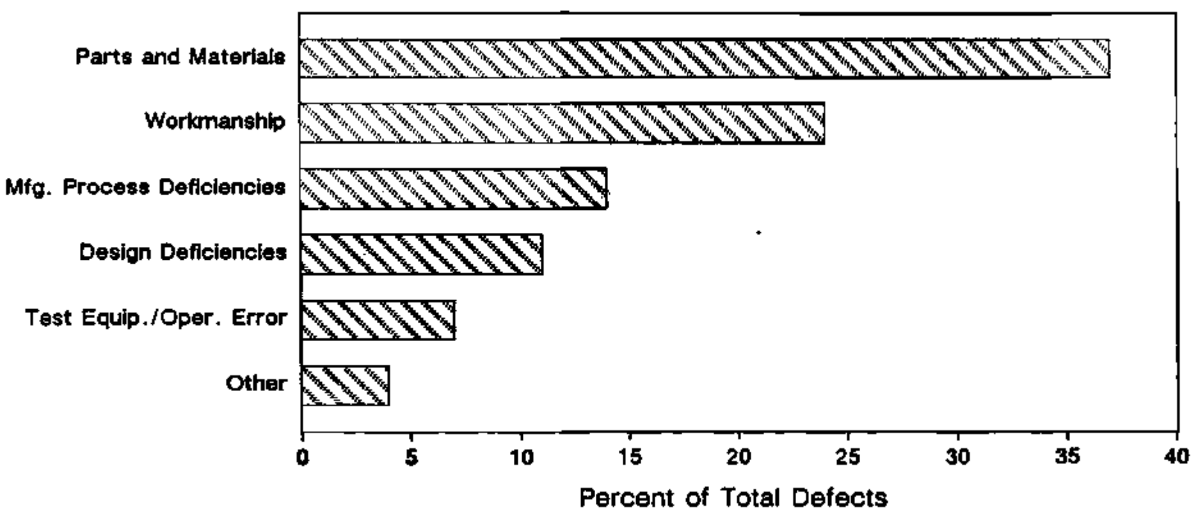
Product Screening

The most rudimentary stage of SQC is product screening. Many of the complex screening and rescreening steps, from incoming inspection through final quality assurance and packaging conformance checks, are still employed by military agencies and contractors. While screening is an effective technique for identifying and eliminating anomalous devices within a given population, it does not prevent device defects, it is not cost effective, and it increases detrimental device handling. During 1984 and 1985, National Semiconductor Corporation discovered that after consolidating all of the military customer returns, more than 67 percent were verified damaged units, mostly from additional handling and testing. Electrostatic discharge (ESD) accounted for more than one-half of the failures.

In an attempt to reduce initial screening, manufacturers have recently implemented environmental stress screening (ESS) programs. ESS is an attempt to control the time and place of system failures caused by defective components, workmanship defects, process errors, or design faults (see Figure 2).

Figure 2

ESS Program Results



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Source: Institute of Environmental Sciences

Quality

Because most failures are a result of component defects, screening devices prior to assembly can result in significant cost savings. While the critical nature of some applications necessitates screening of some parts, there are cases where screening is no longer a cost-effective tool for improving quality. These include cases where:

- Parts are screened by the supplier
- A supplier's process and quality performance is closely monitored by the user
- A supplier's field experience is steady
- Device end use is not critical in nature
- Current screening process is not yielding failures

Statistical Process Control (SPC)

SPC is a technique whereby statistics are used to measure process quality in manufacturing at both the vendor and user levels. Various SPC programs already in progress include the use of:

- Control charts—to determine the inherent variation of machines
- Product samples—either consecutive, random, or systematic sampling
- Machine capability studies
- Process capability studies
- Ongoing process control

By utilizing SPC, companies have achieved the following results:

- Machine scrap rates are reduced
- Production flows improve
- Raw materials meet tighter specifications
- Product yields improve
- Vendor/user relationships improve
- Sources of supply are reduced
- Costs are reduced
- Employee motivation and attitude improve

SPC is a basic W. Edwards Deming method. Japanese manufacturers applied Deming's methods with Dr. J. M. Juran's quality control and quality circle methodologies throughout their industry in the 1960s. The success of these methods propelled Japan to world leadership status in high-quality products in the 1980s. U.S. manufacturers have recently begun using these same methods in their operations. Forty-five General Electric Company (GE) locations have aggressively implemented SPC during the past few years. As a result, GE was able to reduce reject rates on ICs by more than 65 percent in one year.

Westinghouse started forming quality circles in 1979. By 1981, they had established 660 quality circles operating with approximately 6,000 employees solving quality problems. Companies that have implemented the formation of quality circles have discovered that:

- All levels of the work force involved are voicing their opinions
- Tremendous improvements in quality and productivity have been achieved
- Quality circle participants achieve increased self-esteem, dignity, and pride in their company

Process Optimization

Process optimization utilizes advanced statistical techniques, including the use of multivariate analysis, control charts, and design of experiments (DOX). At this stage, the emphasis is on studying the interactions of the many parameters of a manufacturing process and then finding the optimum relationship of these parameters to minimize the inherent variabilities of the process. Process optimization is preventive control in that its influence is before the fact rather than during or after the fact.

Product Optimization

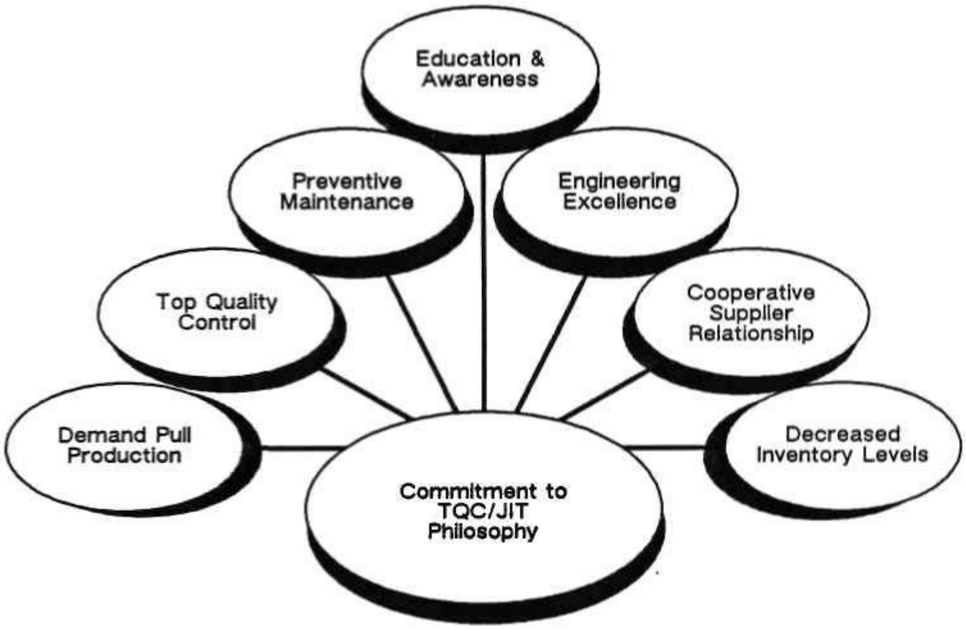
Product optimization is designing products for producibility or designing-in quality from the start. Although the basic concepts exist and elements of the technology exist, the tools that are needed to implement the technology are just emerging. Hewlett-Packard, IBM, and Tektronix are currently leading the way in product optimization through the use of computer-integrated manufacturing (CIM). CIM links all phases of design, manufacturing, and automation, as well as quality, cost, and inventory control into a single computer-centered distributed communications network. Because of the enormous potential of this technology, the United States has the opportunity to leapfrog the competition by actively developing and using product optimization to produce high-quality, low-cost products.

Just-in-Time (JIT) Manufacturing and Purchasing

Just-in-time (JIT) or "demand-pull" manufacturing and purchasing is a philosophy that requires total management commitment to production and quality improvement, across all operational departments in a company's supply chain. JIT has been implemented in the automotive, consumer electronic, computer, and semiconductor industries. Elements of the JIT method are shown in Figure 3.

Figure 3

Elements of the Just-in-Time Method



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Source: Hewlett-Packard Company

Quality

When fully implemented, JIT programs benefit both users and manufacturers. Benefits to the manufacturers include:

- Reduced inventory
- Better space utilization
- Improved budget control
- More efficient labor utilization
- Reduced manufacturing cost
- Closer vendor/user relationships
- Long-term productivity gains
- A potentially automated environment
- Improved raw material quality
- Daily delivery of component materials
- Tightly controlled manufacturing flow

Benefits to the users include:

- Single sourcing
- Longer-term contracts
- Shorter lead times
- Monthly rolling forecasts to vendors (one year out)
- Frequent deliveries—daily/weekly
- 100 percent good quality—on-time, right quantity, no inspection
- Engineering aids, if required
- Frequent visits—minimum one per year
- Use of local sources where possible
- Freight consolidation program
- Minimum paperwork

- Vendor training
- Standard packaging
- End of adversarial relationship

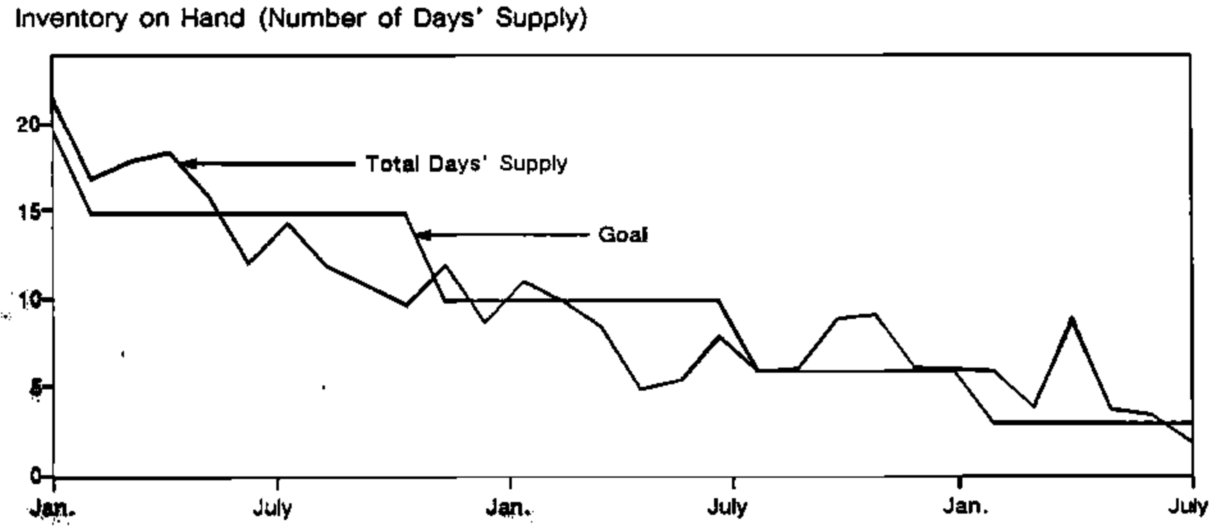
JIT requires a teamwork attitude between vendors and users for success. As more and more companies implement JIT inventory techniques, the role of purchasing will expand. Hewlett-Packard began introducing JIT purchasing at its Greeley Division, Colorado, in 1982; by 1984 the following had been achieved:

- Inventory was reduced from 2.8 months to 1.3 months
- Stockroom space was reduced 50 percent
- Twenty vendors were supplying 45 parts on JIT
- All employees were trained and aware of the JIT program
- A task force was formed to address JIT system needs
- Several lines were converted to progressive build
- Many production efficiency and quality problems were exposed/ solved

Figure 4 illustrates the changes occurring from 1982 through 1984 in inventory control at the Hewlett-Packard Greeley Division.

Figure 4

Hewlett-Packard Company
Greeley, Colorado
JIT Program



	1982	1984
Production Output	$40 Million	$120 Million
Production Space Utilized	86,000 Square Feet	67,000 Square Feet
Number of Vendors	384	200

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Source: Hewlett-Packard Company

JIT Transportation

Successful JIT manufacturing involves lean inventories. Skyway Systems, Inc., located in Santa Cruz, California, is one of a limited number of transportation companies that understands and specializes in JIT delivery. Skyway Systems relies on an extensive computerized system to determine the customers' needs in terms of quantity, delivery time, and location. Skyway estimates that they can save their customers 30 to 40 percent of the total material transportation expenses.

Companies currently enjoying the benefits of JIT transportation include:

- Apple Computer, Inc.
- Hewlett-Packard Company

- IBM Corporation
- National Semiconductor Corporation
- Tandem Computers, Inc.

Zero Defect Programs

In order to achieve outgoing levels of quality on the order of 100 parts per million (PPM), down from an industry practice of 10,000 PPM, Signetics Corporation began implementing its Zero Defect Program in 1979. At this time, only 75 to 85 percent of all raw materials met Signetics' incoming specifications. The company was waiving 15 percent of all raw materials, even though this would possibly be detrimental to yield and could possibly cause field reliability failures. Signetics actually returned only about 5 percent to the supplier and then only after long negotiations. It was not uncommon to have as much as a $500,000 in potential returns lying around for four months. The company received approximately five complaints per week from various assembly plants and fab areas about the use of bad material that had either been waived or passed during incoming inspection. Material procurement priorities were rated in the following order:

- Buy at the lowest price
- Buy according to delivery schedules
- Buy according to quality

Signetics formed a quality improvement team that would work with suppliers to ship defect-free materials. The quality team developed six major programs to deal with the following:

- Vendor specifications
- Vendor certification
- Vendor corrective action
- Vendor communications
- Vendor rating
- File code system

Vendor Specifications

Under this program, Signetics determined which of their vendors could meet Signetics' specifications and requirements prior to making purchase orders.

Vendor Certification

This program consists of five phases. Phase one involves agreement between the vendor and Signetics on inspection measurement procedures, techniques, and the frequency of inspection equipment calibration. Every supplier completing three consecutive months of 100 percent sample and data delivery with each shipment is certified.

Phase two involves material conformance control analysis. Control charts are used to track the vendor's performance to specification. When a vendor exhibits consistent control for a three-month period, the vendor proceeds to phase three.

During phase three, the vendor pulls all of the samples and does a complete outgoing inspection. At Signetics' discretion, the vendor's samples are used—either in part or in total. A vendor exhibiting three-month consistent control in this phase can move on to the next phase.

In phase four, Signetics' incoming inspection team audits the vendor's samples and data for preshipment or skip-lot inspection. In this phase, the vendor supplies control samples and data, complete lot inspection samples and data, and a certificate of compliance. All the data supplied are reviewed for inspection correlation and conformance.

During phase five, the incoming quality control group identifies the continuous monitoring and auditing of phases one through four. Any nonconformance issues and/or inspection correlation problems result in an immediate stop to flexible lot sampling. Resumption occurs when all issues are resolved.

In 1981, 3 out of 20 suppliers chosen by Signetics had completed correlation with Signetics' incoming inspection. By 1986, 46 out of 52 of its vendors were certified.

Vendor Corrective Action

In this program, meetings chaired by the purchasing department are held to review specific shipments of nonconforming material and to determine which suppliers are to be solicited for formal, documented corrective action. The suppliers' responses are thoroughly reviewed to ensure that the true cause of the problem has been addressed and corrected. Band-aid responses are immediately rejected and resolicited. Evidence that permanent solutions are in place is tracked. Vendors are rewarded by way of increased business or penalized by reduced business as a means of highlighting the importance of the company's quality program.

Vendor Communications

The fourth program permits and encourages open lines of communication between Signetics and its suppliers. This program is administered by the purchasing department, and the program provides reports and graphs that track a supplier's quality performance through:

- Performance graphs--illustrating vendor year-to-date lot acceptance and defects in PPM
- Performance summaries—measuring the vendor's on-time delivery by month and year-to-date
- Purchase order history performance
- Quality history performance by purchase order
- Defects history performance by purchase order
- Vendor certification correlation graphs

This information advises suppliers of the quality history for the current month, year-to-date, and trend information aimed at a goal of defect prevention. In addition, quality improvement presentations are developed prior to vendor presentations to redefine quality standards and reaffirm the zero-defect commitment. Open lines of communication keep Signetics and its suppliers aware of quality and availability issues. Defect prevention rather than appraisal is emphasized.

Vendor Rating

Vendor rating was developed to evaluate quality, delivery, and processing costs equally. The numerical rating compares each vendor within a commodity area. Monthly ratings are developed by incoming quality control departments. Quarterly ratings are mailed to suppliers to notify them of their rankings. Signetics devised the following vendor rating formula:

VQR = Vendor quality rating
Q = Quality of material measured at incoming inspection
P = Quality of performance or on-time delivery
C = Cost of inspection and all nonconformance correction time costs

Thus:
$Q + P + C = VQR$

Vendors with the lowest score in each commodity area are recognized twice each year with a plaque and a letter of appreciation. Those scoring well are further awarded by additional business activity. Those scoring poorly are approached to reaffirm their defect-prevention commitment or face the possibility of losing their share of the business.

Quality

File Code System

This system was established to monitor the raw-material performance at Signetics' fab, plating, and assembly operations. The percentage of material that is acceptable and usable in the process, with zero defects, according to specifications, is measured. The formula used is the quantity found defective, divided by the total quantity received, multiplied by 100.

In 1983, Signetics' Zero Defect Program was three years old and deemed successful. The incoming raw material was defect-free and always on time; however, inventory was excessive. Although Signetics had achieved massive improvements in the material quality system, the decision was made to apply a JIT philosophy. Signetics called its JIT program "When It's Needed" (WIN). Signetics created a seven-step approach to implement its WIN program. The steps included:

- Management commitment—Visible management support necessary to meet WIN inventory targets
- A statement of purpose—A policy to form a team to plan, direct, and manage the WIN inventory program worldwide
- Measurement—The measure and display of current and past performance in terms of inventory effectiveness
- Awareness—To ensure that all involved personnel are aware of the ramifications and objectives of the WIN program
- Corrective action—To provide a formal, systematic method of resolving forever the problem identified in the other steps
- Training—To ensure that all directly involved employees completely understand their roles in the WIN program—its effects, benefits, and requirements
- Goal setting—To set time goals to achieve the WIN objectives

When fully implemented, zero defect programs can benefit both users and manufacturers. Benefits to Signetics' suppliers include:

- Guaranteed long-term unchanging schedules
- Improved invoice payment schedules
- Immediate feedback on any quality-related issues
- Improved supplier/vendor relationships

Benefits to Signetics included:

- The lot acceptance rate steadily increased from 80.0 percent in 1980 to 98.1 percent in 1985.
- Lot waivers dropped from 134 in 1980 to none by 1982.
- Less than 0.5 percent of accepted material was found unsuitable.
- Ninety percent of all scheduled deliveries now meet a five-day window; the other 10 percent of deliveries are held up by ship dockage and/or foreign customs clearance.
- Delinquencies to end customers, caused by a lack of raw material, are presently less than 0.5 percent.
- Inventory turns increased from 28 initially to more than 80.
- As a percent of sales, materials fell from 3.5 percent in 1983 to 1.5 percent in 1986.

FUTURE DEVELOPMENTS

In the next few years, automation and robotics will play an increasingly more important role in the semiconductor industry. A computer hierarchy will control the automated assembly areas, and the robots will perform the tasks.

Computer-Integrated Manufacturing

CIM is a computer-centered distributed communications network that links all phases of design, manufacturing, and automation, as well as quality, cost, and inventory control. Dataquest believes that the driving forces behind implementation of CIM include:

- International competition
- Demand for cost reduction
- Demand for improved customer service
- Demand for quality
- Need for flexibility in manufacturing
- Decreasing costs of data processing and storage

Quality

Currently, only a small percent of all semiconductor fabs have committed to a commercially available CIM system. Some of the perceived barriers to the lag in semiconductor automation include:

- High cost of system integration
- Lack of user understanding
- Lack of interface standards
- Need for in-plant sharing of responsibilities

Capabilities of the standard CIM software packages include:

- Work-in-process tracking and management
- Inventory status management
- Equipment status management
- Data collection and storage
- Statistical quality control
- Out-of-specification warnings
- Production reporting
- Complete on-line documentation
- Revision level control of processing specifications
- Engineering analysis

Several major semiconductor manufacturers and users are employing CIM and CIM applications software in assembly areas. National Semiconductor Corporation and Digital Equipment Corporation have recently signed an agreement to jointly develop a factory automation software project, called Odyssey, for semiconductor manufacturing. The Odyssey software is designed to automate the entire IC production process using the Semiconductor Equipment and Materials Institute's (SEMI's) equipment communications standard called SECS.

Other software systems being used for factory management and automation in the semiconductor industry are COMETS and PROMIS. COMETS (Comprehensive On-line Manufacturing and Engineering Tracking System) is produced by Consilium of Palo Alto, California. PROMIS (Process Management and Information Systems) is produced by I.P. Sharp Associates of Canada and marketed by the PROMIS Group of Santa Clara, California. Both software programs allow semiconductor manufacturers to obtain more control over their manufacturing processes with an end result of increased yields in the fabrication of semiconductors. Enhansys, Inc., produces a software system being used by semiconductor manufacturers and users in conjunction with COMETS and PROMIS. The Enhansys system provides extensive mathematical and statistical analysis functions that extend the analysis capability of COMETS and PROMIS.

Glossary

The following is a list of the material in this section:

Glossary--October 1989

Glossary

Accelerated life testing—Operating semiconductors beyond maximum ratings to induce premature failures as an aid to estimating semiconductor life expectancy.

Acceptance sampling—Inspection of a sample for the purpose of predicting the number of defects present in an entire lot of semiconductors.

Access time—The time required to retrieve data from a memory location.

Accumulator—A register or storage location for the result of an arithmetic calculation.

ACT Logic—Advanced CMOS Technology logic.

A/D (Analog to Digital)—A circuit that transforms an analog signal to a digital representation. The digital representation is usually in the binary format of 1s and 0s.

ADPCM (Adaptive Differential Pulse Code Modulation)—A technique for reducing the number of binary-coded samples in PCM systems. (See PCM)

Aligner—A type of wafer fab equipment used for replicating a mask on a wafer.

Alpha particles—A form of radiation emitted by certain radioactive elements or isotopes that has a low penetration ability. Semiconductor devices are susceptible to the presence of alpha particles in package materials.

ALS (Advanced Low-power Schottky)—A logic family of TTL integrated circuits.

ALU (Arithmetic Logic Unit)—(1) An integrated circuit capable of performing arithmetic operations. (2) That part of a microprocessor that carries out arithmetic and Boolean logic operations on data presented in binary form.

Amplifier—An integrated circuit that increases signal amplitude without a significant change in waveform.

Analog—A circuit or system in which the output signals bear a continuous relationship to the input signals, as opposed to a digital circuit.

AQL (Acceptable Quality Level)—A point on the quality continuum of an attribute acceptance sampling plan that is in the region of good quality and reasonably low rejection probability (i.e., a 95 percent accept point on a sample plan). This is established by the percent-defective level acceptable to a set standard.

Array—A regular matrix (gates, cells, devices).

ASIC (Application-Specific Integrated Circuit)—An integrated circuit designed or adapted for a specific application.

ASLP—(Application-Specific Logic Product)—A logic device that fits a defined end-product design requirement.

ASM (Application-Specific Memory)—A memory device designed for a unique application, such as a video RAM.

ASP—Average Selling Price.

ASSP—Application-Specific Standard Product.

Asynchronous—In a computer, a mode of operation in which the performance of any operation starts as the result of a signal that the previous operation was completed, as opposed to a signal from a master clock.

Assembly—The IC manufacturing steps involved in the mounting a die in a package, bonding the pads to the package leads, and sealing the package.

ATE (Automatic Test Equipment)—Equipment that contains provisions for automatically performing a series of preprogrammed tests.

Automatic refresh circuitry—Circuitry that periodically restores the charge in a semiconductor memory cell to maintain data retention.

Base—The control electrode of a bipolar transistor.

Bathtub curve—A plot of the failure rate of an item versus time. The failure rate initially decreases, then stays reasonably constant, then begins to rise rapidly. It has the shape of a bathtub.

Baud rate—The rate at which bits of information are transferred in a communications link. One baud equals one bit per second.

BiFET (Bipolar Field-Effect Transistor)—Refers to a type of semiconductor comprising both bipolar and MOS structures.

BiMOS (Bipolar Metal Oxide Semiconductor)—An IC manufactured with both bipolar and a MOS process that yields a hybrid component with the benefits of both technologies.

Binary—A two-value numbering system that usually uses the symbols 1 and 0. This numbering system is used with computers because computer logic and memory devices are two-valued: on/off or high/low.

Bipolar transistor—A device used to control current flow in solid matter. A small base current controls the large emitter-to-collector current flow, similar to a valve controlling the flow of a liquid.

Bit (Binary digit)—A single binary digit, 1 or 0. A bit is the smallest unit of information that a computer can recognize.

Bit slice—A multichip microprocessor in which the control section is contained on one chip, and one or more identical ALU sections and register sections are contained on separate chips called slices.

Bonding pads—Metallized areas on a semiconductor chip to which lead connections may be made.

Bonding wire—Fine-drawn wire manufactured from gold or aluminum, used for connecting the chip to a package.

Breadboard—A prototype model of an electronic system or circuit that is usually made with off-the-shelf components to test the feasibility of the circuit. Also used as a verb.

Bubble—A polarized magnetic domain, usually representing a binary digit, that looks like a bubble when examined under polarized light at high magnification. Magnetic bubble memories are a nonsemiconductor technology.

Burn-in—Refers to the operation of semiconductor devices at an elevated temperature or temperatures over a time interval, usually with the intent of identifying early-life failures in ICs.

Bus—In an electronic system, a line or pathway for transferring information or control between the elements of the system (i.e., VME and Micro Channel are bus architectures).

Byte—Eight consecutive bits treated as an entity.

Byte mode—A mode of accessing a memory device in which eight bits (one byte) are read at one time.

Cache—A fast, small memory (typically SRAM) used to enhance CPU performance, separate from main processor memory.

CAD (Computer-Aided Design)—The use of a computer for automated industrial design.

CAE—Computer-Aided Engineering.

CAD/CAM—Computer-Aided Design and Computer-Aided Manufacturing.

CAGR—Compound Annual Growth Rate.

CAM—(1) Content-Addressable Memory. (2) Computer-Aided Manufacturing. Use of a computer to aid and improve the manufacturing process.

CASE—Computer Aided Software Engineering.

Capacitor—A device that stores energy in the form of an electrostatic charge.

Captive line—A semiconductor production facility owned by the user of its products.

CAS (Column Address Strobe)—A signal necessary to make a dynamic RAM function. (See RAS.)

CCD (Charge-Coupled Device)—A MOS device used for information storage or imaging applications.

CCITT (Consultive Committee on International Telegrpahy and Telephony)—A European telephone standards organization.

Cell-Based Design—ASIC design technique utilizing nonfixed width or height cells.

CEPT (Conference of European Post Telecommunications)—A European telephone standards organization.

CERDIP—A ceramic DIP-type package utilizing a glass-frit seal.

Chip—A small piece of silicon containing one semiconductor component, circuit, or function ranging from a diode to a microcomputer. (See Die.)

Chip carrier—An IC package that has connections on all four sides. A chip carrier is usually square and can be leaded or leadless, plastic or ceramic.

Chip-on-board (COB)—A package where a chip is directly mounted on a printed circuit board or ceramic board, wire bonded, and encapsulated with a blob of epoxy resin.

Class—(1) Refers to the purity of the atmosphere in the clean room of a semiconductor fabrication facility. Class 100 means a maximum of 100 particles 0.5 microns or larger in each cubic foot of air. (2) Refers to the level of semiconductor screening and documentation for government use, e.g., class S (space and satellite programs), class B (manned flight), and class C (ground support).

Clean room—An environmentally controlled area, usually a wafer fabrication or inspection facility. Temperature, humidity, and purity of the environment are all carefully controlled.

Clock driver—A circuit or component that provides a clean, stabilized timing signal for clocking logic or a system of devices such as a microprocessor, and associated peripherals.

Clock rate—The repetition frequency of the basic timing signal applied to a logic function.

CML (Current-Mode Logic)—A bipolar, emitter-coupled logic form.

CMOS (Complementary MOS)—A semiconductor technology that uses both P-channel and N-channel transistors on the same silicon substrate to gain the primary advantages of very low power and high noise immunity.

CODEC (Coder/Decoder Circuit)—An integrated circuit that codes a voice signal into a binary waveform or decodes a binary waveform into a voice signal. Such circuits are now used in digital communications applications.

Collector—The majority receptor in a transistor; the major source of electrons in a pnp transistor.

Comparator—A type of amplifier that produces a logic output (1 or 0) based on comparison of an input voltage with a fixed reference voltage. A widely used form of linear IC.

Contact—The regions of exposed silicon that are covered during the metallization process to provide electrical access to the device.

Controller—A circuit that controls some function of a machine, device, or piece of equipment.

Coprocessor—A logic device that operates in association with a microprocessor to enhance system performance. Coprocessors are not capable of independent operation.

Cost—The dollar amount realized by the manufacturer to produce a product—not price.

COT (Customer-Owned Tooling)—Usually refers to the masks or pattern-generation tape for a semiconductor device prepared and owned by the customer.

CPGA—Ceramic Pin Grid Array (See Pin Grid Array).

CPU (Central Processing Unit)—A microprocessor or microcontroller.

CP/M (Control Program for Microcomputers)—An operating system developed by Digital Research, Inc., for use on microcomputers.

CRT (Cathode-Ray Tube)—The display element in a computer terminal. Frequently used to mean the terminal itself.

Custom circuit—A semiconductor circuit designed to meet the specific needs of one customer.

CVD (Chemical Vapor Deposition)—In wafer fabrication, a process for the deposition of solid insulators and metals from a chemical reaction in the gas phase.

Cycle time—The minimum interval required to complete a full operation, such as writing into a RAM or performing an instruction.

DAC (Digital to Analog Converter). (See D/A converter.)

D/A converter (Digital to Analog converter)—A circuit that transforms a digital representation to linear (analog) representation.

DESC (Defense Electronics Supply Center)—The U.S. government command responsible for supervising supplier certifications and qualifications.

Design rules—Rules constraining IC topology to assure fab process compatibility.

DI water—Deionized water. High purity water from which all the impurities such as particles, organics, bacteria, and ions have been removed. Used in the manufacture of semiconductors.

Dice—Two or more semiconductor chips (the plural of die).

Dice bank—An inventory of chips maintained as a hedge against delays due to problems in the manufacturing of semiconductors.

Die—One semiconductor chip. (See Chip.)

Dielectric isolation—An IC design and process technique used to improve breakdown characteristics and/or increase resistance to radiation.

Diffusion—The use of a fab furnace to drive an impurity into a wafer.

Digital circuit—A circuit whose values or levels are binary.

Digitizing—(1) Converting an analog signal into a form recognizable by a digital circuit. (2) The process of encoding information into a form recognizable by CAD/CAM equipment.

Diode—A semiconductor element that favors unidirectional current flow; a pn junction.

DIP—Dual In-line Package.

Discrete device—A single circuit element packaged separately (e.g., a transistor or a diode).

DMA (Direct Memory Access)—A computer feature, set up by the CPU, that provides for high-speed direct data transfer from a peripheral device to the computer memory or to magnetic disk or tape storage units.

Dopant—Atoms of materials such as phosphorus, boron, or arsenic that are diffused into silicon to create resistors, diodes, and transistors.

DOS (Disk Operating System)—A program used to manage disk files, supervise all I/O operations with other peripherals, and allocate all the system's resources. MS-DOS is an operating system developed by Microsoft Corporation for microcomputers. PC-DOS is a version of this operating system developed for the IBM personal computer.

Double poly—The use of two layers of polysilicon interconnects for increased IC density.

Drain—The majority carrier collector in a MOS transistor.

DTL (Diode Transistor Logic)—An obsolescent digital IC family.

Dynamic RAM—A random-access memory device that must be electrically refreshed frequently (many times each second) to maintain information storage.

EAROM (Electrically Alterable Read-Only Memory)—Same as EEPROM.

E-beam—A sophisticated system that uses an electron beam for maskmaking or for projecting patterns onto wafers. E-beam equipment allows smaller geometries (typically less than 1 micron) than are possible under other production methods.

ECL (Emitter-Coupled Logic)—A form of integrated circuit used to implement very high speed logic functions.

Edge triggered—A circuit actuated by an input signal transition.

EDI (Electronic Data Interchange)—A computer-to-computer standard that allows companies to place orders electronically with their vendors.

EEPROM (Electrically Erasable Programmable Read-Only Memory)—A non-volatile memory used to store data or programs. EEPROMs can be reprogrammed in circuit.

E²PROM—See EEPROM.

EEROM (Electrically Erasable Read-Only Memory)—Same as E²PROM. IC memory that can be erased electrically and reprogrammed by the user.

EIA (Electronic Industries Association)—An electronics industry trade association located in the United States.

EIAJ—Electronic Industries Association of Japan.

EMI—Electromagnetic Interference.

Emitter—The source of majority carriers in a transistor; the electron receptor in a pnp transistor.

Emulator—Hardware or a combination of hardware and software that exactly reproduces the operation and performance of other hardware.

Epitaxial—Single crystal silicon grown on a crystalline silicon substrate.

EPROM (Erasable Programmable Read-Only Memory)—IC memory that can be erased with an ultraviolet light source and reprogrammed by the user.

Ethernet—A cable-based communication network originated by Xerox Corporation, designed to link office equipment.

Eutectic alloy—That combination of two or more metals that gives the lowest possible sharply definable melting point. Used in bonding chips.

Evaporator—Semiconductor production equipment used for depositing a thin film on a wafer.

Fab—Abbreviation of wafer fabrication.

FAE—Field Applications Engineer.

Failure rate—The number of system or device failures per unit of operating time.

FACT—A Fairchild Semiconductor trademark denoting Fairchild Advanced CMOS Technology.

FAST—A Fairchild Semiconductor trademark denoting Fairchild Advanced Schottky TTL.

FDDI (Fiber Distributed Data Interface)—A new standard for transmitting very high speed data over fiber optic cables.

FERRAM—Ferro-Electric Random Access Memory. A nonvolatile, radiation hard, fast read/write memory that can store data over long periods of time without power.

FET—Field-Effect Transistor (MOS transistor).

FFT (Fast Fourier Transform)—An IC or other circuit used for time-to-frequency domain conversion.

Fiber Optics—A technique of communicating by sending pulses of light through very thin strands of glass or plastic.

Firmware—Instructions committed to some form of ROM hardware.

FITS (Failure In Time)—The number of failures per 10^7 hours.

Flash converter—A type of digital to analog converter that performs a parallel, as opposed to serial, conversion. Used primarily in applications requiring high speed, such as video.

Flat-pack—A type of surface mount IC package that has its leads in a plane parallel to the chip.

Flip-chip—A packaging technique in which the IC chip is mounted face-down on the substrate, primarily used by IBM.

Flip-flop—A circuit capable of assuming one of two steady states, depending upon signals input to the circuit. Also a binary counter.

Flop—Floating point operation. A measure of math processing performance.

Foundry—A semiconductor manufacturer that uses a customer's masks to produce custom ICs for the customer. (See COT.)

FPGA (Field-Programmable Gate Array)—Gate array in which programming is accomplished by blowing fuse links or shorting base-emitter junctions.

FPLA (Field-Programmable Logic Array)—Logic array in which programming is accomplished by blowing fuse links or shorting base-emitter junctions.

FPMH (Failures Per Million Hours)—A measure of system failure rate.

FPU (Floating Point Unit)—A high-speed mathematic coprocessor for a microprocessor.

Frit—Material used to attach a die to a package.

Furnace—Fab equipment that performs diffusion or oxidation at high temperatures.

Fuse links—Structures used in PROMs, PLAs, or other ICs to allow the customer to store data or modify logic functions using programming hardware.

Gain-bandwidth product—A measure of transistor or amplifier performance.

Gang bonding—A replacement for wire bonding using planar copper tape for connecting the chip to the package.

GaAs (Gallium Arsenide)—A type of semiconductor material offering very high speed operation in excess of 10 gigahertz.

Gate—(1) The MOS transistor equivalent of the base electrode in a bipolar transistor; the control electrode of a MOS transistor. (2) Part of an IC that performs a simple logic function such as NAND or NOR.

Gate array—An IC consisting of a structured pattern of logic devices that is processed except for the final interconnect metallization. These devices are offered as a standard product and then customized to meet each customer's unique requirements.

Gate delay—The time required for a gate output to respond to stimulus applied to the input.

Geometry—Sometimes used to refer to the minimum feature size of a semiconductor structure, such as gate length or line width.

Gigahertz (GHz)—One billion cycles per second.

GPIB (General-Purpose Interface Bus)—An interface for passing information and control between a computer and measuring instruments that conforms to I.E.E.E. standard 488.

Gull-wing—A surface-mount package type with out-splayed pins.

Hardware—ICs and other electronics and their associated boards, connectors, and mechanical packaging.

Header—A form of package using glass-metal seals.

Hermetic—A package or seal designed to protect its contents from the effects of adverse environmental conditions such as moisture and chemical contaminants.

Hybrid—A package containing semiconductor chips and passive components, such as resistors and capacitors.

IC—Integrated Circuit.

ICE (In Circuit Emulation)—As of a microprocessor. (See Emulator.)

I.E.E.E—Institute of Electrical and Electronic Engineers.

I_2L (Integrated Injection Logic)—A low-power bipolar IC form.

Inductor—A passive component that stores energy in the form of a magnetic field (flux) around a core body.

Infant mortality—Premature failures occurring at a much greater rate than during the period of useful life prior to the onset of substantial wearout.

Integrated circuit—A semiconductor structure combining the functions of many electronic components (i.e., transistors, resistors, capacitors, and diodes) interconnected on a single chip.

Interrupt—A temporary disruption of the normal operation of a routine by a special signal from the computer.

I/O (Input/Output)—A bidirectional IC lead or port.

I/O port—A place of access to a system or circuit whereby the transmission of information from external hardware to the computer or from the computer to external hardware occurs.

Ion implantation—The use of an ion beam to bombard a silicon wafer, altering the concentrations of p-type or n-type material. This method of doping allows for very precise control of the device parameters.

IRED—Infrared-Emitting Diode.

ISDN (Integrated Services Digital Network)—A new worldwide telephone standard for the 21st century that will make it easier for computers to send data over phone lines.

Isolation—The technique used to electrically separate different parts of a system on a semiconductor die.

J-Lead Package—Surface-mount package with leads bent down and under the package.

JAN (Joint Army Navy)—A registered trademark of the U.S. government used to mark semiconductors that comply with MIL-M-38510.

JEDEC (Joint Electronic Devices Engineering Council)—A U.S. industrial organization working on IC standardization and other industry concerns.

Jellybean—A commodity-type product.

JFET—Junction Field-Effect Transistor.

JJ (Josephson junction)—A form of very high speed circuit that is based on superconductivity at very low temperatures.

Junction—The boundary between a p region and an n region in a semiconductor substrate.

K—(1) 1,000. (2) 1,024, when defining memory size.

Kilobit—1,024 bits.

Kilohertz (KHz)—1,000 cycles per second.

LAN (Local Area Network)—A communications network designed to link office automation equipment. Usually cable based.

LAPD (Link-Access Procedure for D-Channel)—An ISDN telephone standard. (See ISDN)

Laser trimmer—Fab equipment used for opening metal connections on IC chips.

LCC (Leadless Chip Carrier)—A form of high-density packaging for IC chips.

LCCC—Leadless Ceramic Chip Carrier.

LCD—Liquid Crystal Display.

LDCC—Leaded Chip Carrier.

Lead frame—A stamped or etched metal component that connects a chip to larger electrical components through pins.

Lead time—The interval between the date of ordering semiconductor products and the expected time of delivery.

LED—Light-Emitting Diode.

Linear—A semiconductor circuit whose output varies directly with the input. Also, a subset of the analog product category.

Logic—(1) The use of digital signals in structured ways to perform tasks such as addition, accumulation, comparison, and inference. (2) Devices that perform such functions.

Logic Analysis—A technique and instrumentation for evaluating the integrity of a circuit design in real time by sampling various test points and examining for ANOM.

LS (Low-power Schottky)—Usually refers to LSTTL.

LSI (Large-Scale Integration)—ICs comprising 100 to 10,000 gates or gate equivalents.

LSTTL (Low-power Schottky TTL)—A popular bipolar logic IC form.

LTPD (Lot Tolerance Percent Defective)—A point on an acceptance sampling plan which is in the region of bad quality and reasonably low acceptance probability.

MAP (Manufacturing Automation Protocol)—A cable-based communication network originated by General Motors, designed to link factory equipment.

Mask—A thin sheet of material with a design pattern on it, used to selectively expose areas on a wafer during the semiconductor fabrication process. The mask is used in the same way that a photographic negative is used to produce a positive print and may be negative or positive.

Masked ROM—A read-only memory programmed to the customer's specified pattern during the manufacturing process.

Mass storage—Devices for storing large quantities of data for use by a computer. Data cannot usually be accessed directly by the CPU. Common mass storage systems include floppy disks, hard disks, and magnetic tape drives.

Mb (Megabit)—1,048,576 bits.

Megabyte (MB)—1,024,000 bytes or 8,192,000 bits.

MBD—Magnetic Bubble Device.

MBM—Magnetic Bubble Memory.

MCU—Microcontroller Unit.

Megabit (Mb)—1,048,576 bits.

Memory—An IC designed for the storage and retrieval of information in binary form.

Memory management—A technique (and device) for efficiently allocating main processor memory storage upon the issuance of each address request from the CPU.

Memory module—A multiple memory device mounted onto a small PC card.

Metal gate—An older but still popular technique for controlling MOS transistor current flow by applying a control voltage to an aluminum gate.

MMU (Memory Management Unit)—A component (or set of components) that implements the memory management function in a processor-based system.

MHz—Megahertz. One million cycles per second.

Micro—(1) Very small. (2) One millionth.

Microcircuit—An IC.

Microcomputer—A small computer system or circuit board.

Microcontroller—An integrated circuit, containing a CPU, memory, and I/O capability, that can perform the basic functions of a computer.

Micron—One millionth of a meter.

Microperipheral—A support device for a microprocessor or microcontroller that either interfaces external equipment or provides system support.

Microprocessor—A single-chip component or a collection of architecturally interdependent components that function as the CPU in a system. A microprocessor may contain some input/output circuits but does not usually operate in a standalone fashion.

Mil—One thousandth of an inch. Approximately 25.4 microns.

MIL-M-38510—The detailed military specification for military IC qualification.

MMIC (Monolithic Microwave IC)— An integrated circuit that operates at microwave frequencies and usually made out of gallium arsenide materials.

MNOS (Metal Nitride Oxide Semiconductor)—An IC technique used to make some types of EAROMs.

Model—Identifiable variable parameter set with formulas for predicting final costs/price when one or more variables are changed.

Modem (Modulator/Demodulator)—A device that converts audio signals to digital for transmission on telephone lines and converts received digital signals back into audio.

Module—An item that is packaged for ease of maintenance of the next higher level of assembly.

Monolithic—A device constructed from a single piece of material.

MOS—Metal Oxide Silicon.

MOS transistor—A voltage-mode device used to control current flow in solid matter. The device uses a gate conductor, such as silicon or metal (usually aluminum), over a very thin insulator (usually oxide). A voltage applied to the gate controls the flow of current between source and drain.

MOSFET—MOS Field-Effect Transistor.

MPU—Microprocessor Unit.

MSI (Medium-Scale Integration)—ICs comprising 10 to 1,000 gates or gate equivalents.

MTBF (Mean Time Between Failures)—For a particular interval, the total functioning life of a set of items divided by the total numbers of failures within the set of items during the measurement interval.

MTL (Merged Transistor Logic)—A high-density bipolar logic form, also referred to as integrated injection logic (I_2L).

Multichip Module—A package containing two or more semiconductor chips.

Multilayer ceramic—Two or more layers of thin ceramic material, with buried metallization on each layer.

Multiplexed bus—A hardware method, as on a microprocessor, where data and address information share the same set of pins at different times in the processor cycle.

Multiplexor—An IC used to connect more than one set of equivalent inputs to a single set of outputs on a switchable basis.

Multiplier—An IC used for generating the product of two binary numbers. It can be either analog or digital.

NAND gate—Part of an IC that performs the logic function Not-AND.

Nanosecond—One billionth of a second. In this time, electrical pulses travel approximately 12 inches.

N-channel—A type of MOS transistor.

Nibble-mode—An operating mode of a dynamic RAM in which four bits are accessed in sequence at a higher than normal access rate.

Niche market—A small, specialty market, as opposed to the "mainstream" market.

NMOS (N-channel Metal Oxide Silicon)—A type of semiconductor in which the majority carriers are electrons.

Nonmultiplexed bus—A hardware convention, as on a microprocessor, where data and address information each have unique sets of pins for communication.

Nonvolatile—A semiconductor device that does not lose information when power is turned off.

NOR gate—Part of an IC that performs the Not-OR logic function.

npn—A type of bipolar transistor constructed using a p-type base. In such a device, a layer with p-type conductivity is sandwiched between two n-type layers.

ns (nanosecond)—One billionth of a second.

NVRAM (Nonvolatile Random-Access Memory)—A read/write semiconductor memory device that does not lose information when power is turned off.

Op amp (Operational amplifier)—A type of IC that generates an amplified output that is exactly proportional to its input.

Operating system—Computer software that enables a computer and its peripheral systems to work together as a unit.

Opto (Optoelectronic)—A type of IC used for converting electricity to light or vice versa.

Optocoupler—A device that transmits electrical signals, without electrical connection, between a light source and a receiver. Also called an optoisolator.

OTP ROM (One-Time Programmable Read-Only Memory)—An EPROM packaged in plastic without a quartz window for erasure. Such a device is therefore programmable only once.

Package—The container used to encapsulate a semiconductor chip.

Packet Switching—A method of sending data between computers located far apart.

Pad—A metallized area on a chip, usually 10 to 35 square mils, used for bonding or test probing.

Paging—A memory management technique that divides logical memory into equal fixed-size quantities. This is different than segmentation and usually more efficient in memory usage.

PAL (Programmable Array Logic)—PAL is a trademark of AMD, Inc. referring to a family of logic devices that are customer programmable.

Parallel—The simultaneous transmission or processing of the parts of a word, character, or other division of a word in a computer, using separate facilities for each part.

Parasitic effects—The results of the interaction of the stray components in an IC. Such stray components result from the high-speed operation of circuit elements in close proximity.

Parity bit—A binary digit that is added to an array of bits to make the sum always odd or always even, for checking accuracy.

Parts per million (PPM)—PPM is a statement of defect level arrived at by multiplying percent defective by 10,000. (Example: 0.1% = 1,000 PPM)

Passivation—The use of a protective layer on the surface of a chip.

Passive element—An element that is not active (e.g., resistor, capacitor, inductor).

Pattern generator—(1) Equipment used in IC maskmaking. (2) Equipment used to create test sequences.

p-channel—A type of MOS structure in which the majority carriers are holes.

PCC (Plastic Chip Carrier)—A form of high-density surface-mount packaging for IC chips.

PCM (Pulse-Code Modulation)—Digital transmission of analog signals by sending periodic binary-coded samples of the signal values.

PDIP—Plastic Dual In-Line Package.

Peripheral—Equipment that is connected to a computer but is not part of the computer. Examples include printers, terminals, and disk drives.

Photodiode—A junction diode that is responsive to radiant energy.

Photoresist—A light-sensitive coating used in photolithography.

Photolithography—The manufacturing process of coating and selectively exposing a wafer for selective etching.

Phototransistor—A light-sensitive transistor that delivers an electrical output proportional to the light intensity at the input.

Picosecond—One trillionth of a second. Light or electrical pulses travel about 12 mils (0.012 inches) in one picosecond.

Piezoelectric crystal—A crystal that produces a mechanical force when a voltage is applied.

Pin-grid array (PGA)—A package where pins emerge from the bottom of a substrate.

PIO (Parallel Input Output)—A device that transfers data to and from an I/O port in a parallel fashion.

Pipelining—A processor feature where several computer instructions are fetched from memory and stored in an in-line manner (in a pipeline or queue) waiting to be executed.

PLA (Programmable Logic Array)—A form of LSI containing a structured, partially interconnected set of gates and inverters that are fuse programmed.

PLCC—Plastic Leadless Chip Carrier.

PLD—Programmable Logic Device. (See PLA.)

Planar—Refers to a semiconductor structure in which the circuit elements are located within a thin layer near the chip surface.

Plasma etch—Refers to the use of a highly ionized gas (plasma) in the manufacture of high-density semiconductors.

Plastic package—A molded IC package, usually a DIP. The majority of ICs and discretes are manufactured in plastic packages (Example PDIP, PLCC, PPGA).

PLL (Phase-Locked Loop)—A type of linear IC used in frequency-modulated (FM) circuits.

PMOS—p-channel MOS.

pnp—A bipolar transistor that has an n-type base.

Polysilicon—A silicon layer grown on a wafer in a furnace.

Power transistor—A transistor designed for high-current, high-voltage applications.

PPGA—Plastic Grid Array.

PPM (Parts per Million)—Quality reject standard.

PQFP (Plastic Quad Flat Pack)—Japanese standard surface-mount package. Leads are on all four sides.

Price—The dollar amount paid to the manufacturer for a product.

Probe—A test lead designed to make contact with a bonding pad or other test point on a chip. Also used as a verb to describe such testing.

Product Quality Assurance (PQA)—Rejected units supplied by customer to quality assurance for evaluation, verification, and correlation.

Profit—Difference between price and cost.

Projection alignment—An optical alignment procedure in semiconductor fabrication in which the mask does not touch the wafer.

PROM (Programmable Read-Only Memory)—A ROM that may be programmed after manufacture by blowing fuse links or shorting base-emitter junctions.

Propagation delay—Time required for a signal to travel along a wire or to be processed through an IC.

Pseudostatic—A dynamic memory IC that looks like static memory but includes on-chip automatic refresh circuitry.

QFP (Quad Flat Pack)—United States standard surface-mount package. Leads are on all four sides.

QML—Qualified Manufacturers List.

QPL—Qualified Parts List.

Quality control (QC)—The overall system of activities whose purpose is to provide a quality of product or service that meets the needs of users.

RAM (Random-Access Memory)—Read/write random-access memory that can be directly accessed by the CPU.

RAS (Row Address Strobe)—Input signal used by address-multiplexed RAMs.

Rating—The designated operating limits of a device or system in terms of electrical, mechanical, or environmental stress.

Rectifier—A device that converts alternating current into a current that has a large unidirectional component.

Redundancy—The addition of functions that may be substituted for other functions, in the event of a manufacturing defect or a hardware failure, to greatly improve yield, reliability, or both.

Refresh—The restoration of a logic level to its original voltage/current value.

Register—A small, fast, temporary storage location within an MPU or discrete logic.

Reliability—The probability that a device or system will perform satisfactorily according to its specifications for a definite period of time under specified operating conditions.

Resistor—A device that measurably opposes the passage of an electric current (e.g., doped silicon).

Reticle—A master plate from which masks are made.

RF—Radio Frequency.

RFI—Radio Frequency Interference.

RIP—Raster Image Processor.

ROM (Read-Only Memory)—A memory device whose contents can be read but not altered.

RTL (Resistor Transistor Logic)—A form of low-power bipolar IC logic used extensively in the 1960s.

Sampling—(1) Acquiring statistics from a mass of data without taking a complete census of the data. (2) The early phase of a product life cycle in which the supplier provides the user with limited sample quantities for evaluation.

SAW (Surface Acoustic Wave)—An electronic device based on the generation and reception of high-frequency sound waves that travel along the surface of a piezoelectric crystal.

Schottky diode—A type of diode, invented at Bell Laboratories in 1960, that has a relatively fast response time because of its low capacitance.

Schottky TTL—A form of transistor-transistor logic using Schottky diodes as transistor clamps to speed up circuit operation.

SCR—Silicon Controlled Rectifier.

Sea of Gates—A gate array layout architecture utilizing random gates, usually large gate counts (i.e., 40+K gates) as opposed to structured arrays.

Second source—An alternative source of a semiconductor product. A licensed second source is one that has entered into an agreement with the original manufacturer.

Segmentation—A memory allocation technique for dividing logical memory into variable size chunks.

SEM (Scanning Electron Microscope)—A microscope used for semiconductor die examination at very high magnification.

Semiconductor—(1) A material that is neither a good conductor nor a good insulator and whose electrical properties can be altered by the selective introduction of impurities into its crystalline structure. (2) An electronic device made using semiconductor material.

Semicustom—A semiconductor device manufactured using a standard process but alterable to a user's specific needs.

Shift register—An IC used for temporary synchronous storage of data.

Si—Chemical symbol for silicon, the basic ingredient of most semiconductors in use today.

Side-brazed package—A ceramic IC package that has the metal leads brazed to the sides of the package.

Silicide—A metal alloy of silicon used to improve semiconductor performance by reducing resistivity.

Silicon—A nonmetallic element that is the most widely used semiconductor material today. Silicon is used in its crystalline form as the substrate of semiconductor devices.

Silicon dioxide—A material often used as an insulating layer in semiconductor manufacture. It may be formed by heating the silicon wafer in a furnace in the presence of wet or dry oxygen.

Silicon foundry—An IC manufacturer specializing in processing using customer-owned tooling (COT).

Silicon gate MOS—MOS devices that have a controlling electrode (gate) consisting of silicon instead of metal over the oxide.

Silicon software—Computer programs stored in read-only memory (ROM). Also called firmware. (See Firmware.)

SIO (Serial Input Output)—A device or technique where data is transferred to or from an I/O port in a serial or in-line manner.

SIP (Single In-line Package)—An IC package that has a single row of leads.

SIP module—Multiples of SIP packaged memory devices mounted on a small PC card.

Slice—A wafer.

Smart power—A classification of ICs that contain both control logic circuits and power control elements.

SO (Small Outline Package)—A form of high-density surface mount packaging for IC chips.

SONET (Synchronics Optical Network)—A fiber-optic network standard.

SOS (Silicon On Sapphire)—An integrated circuit produced on a sapphire substrate. Such devices, which operate at high speed, are sometimes used for military applications. They are very expensive to manufacture.

Source—(1) In a MOS transistor, the majority carrier emitter. (2) A semiconductor supplier or distributor.

Spread Spectrum—A technique for encoding radio transmissions that reduces interference and eavesdropping.

Sputterer—IC manufacturing equipment used for depositing material on wafers.

SSI (Small-Scale Integration)—IC devices containing fewer than 10 gates or gate equivalents.

STACK (Standard Computer Komponenten)—A European organization of equipment users concerned with semiconductor packaging standards.

Standard product—Semiconductor devices that are readily available from a number of suppliers.

Standard cell—Integrated circuits designed to a customer's specifications using precharacterized cells as building blocks.

Static RAM—A RAM that maintains memory as long as power is applied and does not require refreshing.

Structured Array—Gate array architecture utilizing fixed height and width arrays.

S TTL (Schottky TTL)—A high-speed form of bipolar logic.

Synchronous—In a computer, a mode of operation in which all operations are controlled by signals from a master clock.

TAB (Tape Automated Bonding)—Interconnection process where chips are bonded to leads etched in copper laminated tape.

Threshold—The point at which a semiconductor starts to conduct.

Thyristor—A four-layer semiconductor that can be switched from an ON state to an OFF state, usually by a voltage or current pulse to the gate terminal. The device will then continue to conduct so long as the principal current of the device flows through the thyristor's two main terminals.

Token-Ring—A cable-based communication network designed to link office equipment.

Transistor—An active semiconductor that has three electrodes; used for amplification or switching.

TTL or T^2L (Transistor-Transistor Logic)—A popular form of bipolar logic IC.

UART (Universal Asynchronous Receiver/Transmitter)—A serial I/O device.

USART (Universal Synchronous Asynchronous Receiver/Transmitter)—A serial I/O device.

UNIX—A computer operating system developed by Bell Laboratories.

UV EPROM (Ultraviolet Electrically Programmable ROM)—An EPROM that is erasable with an ultraviolet light source.

VHSIC (Very High Speed Integrated Circuit)—A program that is intended to develop advanced semiconductors for the U.S. government and for defense purposes.

Virtual memory—The presence of logical memory addressing that makes the physical memory space appear much larger than it really is.

VLSI (Very Large Scale Integration)—An IC chip containing more than 10,000 gates or gate equivalents.

Wafer—A thin (10 to 40 mils) disk of semiconductor material from which semiconductors are fabricated.

Wafer fab—The IC production process, from raw wafers through a series of diffusion, etching, photolithographic, and other steps, to finished wafers.

Wafer stepper—Fab equipment used for exposing multiple images of an IC pattern onto a wafer.

Word length—The word length of a microprocessor or microcontroller is defined by the bit width of its external data bus.

Working plates—Masks used in wafer fab.

Yield—The ratio of acceptable parts to total parts attempted; a measure of production efficiency.

Zener—A diode that has a controlled, reverse-voltage/current relationship.