Table 2.8.6-16

ESTIMATED MARKET SHARES OF MOS MEMORY PRODUCERS
(Dollars in Millions)

	Total				RAMs				ROMs				EPROM/EAROM				Other (Shift Registers and CCDs)			
	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976
AMD	$ 2	$ 7	$ 11	$ 25	$ 0	$ 1	$ 4	$ 11	$ 0	$ 0	$ 1	$ 2	$0	$ 0	$ 2	$ 6	$ 2	$ 6	$ 4	$ 6
AMI	22	39	32	32	8	23	18	15	4	5	6	8	0	0	0	1	10	11	8	8
EA	3	3	4	6	0	0	0	0	3	3	4	6	0	0	0	0	0	0	0	0
EMM	0	2	7	10	0	2	6	10	0	0	1	0	0	0	0	0	0	0	0	0
Fairchild	3	6	7	18	1	2	4	13	1	2	2	3	0	0	0	0	1	2	1	2
GI	3	4	6	9	0	0	1	2	2	2	3	4	0	0	0	1	1	2	2	2
Harris	1	2	3	5	0	0	1	2	1	2	2	3	0	0	0	0	0	0	0	0
Hughes	2	3	4	5	0	0	0	0	1	2	2	3	0	0	0	0	1	1	2	2
Intel	37	84	85	110	24	57	50	68	4	6	7	9	5	17	25	30	4	4	3	3
Intersil	7	14	12	18	7	13	10	14	0	0	1	2	0	0	0	0	0	1	1	2
Mostek	16	29	22	36	11	23	19	29	3	4	2	5	0	0	0	0	2	2	1	2
Motorola	3	4	5	11	3	2	2	7	0	1	2	3	0	0	0	0	0	1	1	1
National	8	15	19	28	2	3	5	15	4	6	7	6	0	0	2	4	2	6	5	3
Nitron	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
RCA	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Rockwell	9	13	11	9	0	0	0	0	7	10	9	7	0	0	0	0	2	3	2	2
Signetics	1	1	2	4	0	0	0	2	1	1	2	2	0	0	0	0	0	0	0	0
Synertek	0	0	1	4	0	0	0	1	0	0	1	3	0	0	0	0	0	0	0	0
TI	8	14	23	50	4	8	17	41	1	2	2	4	0	0	0	1	3	4	4	4
Others	19	20	16	17	4	5	5	8	13	14	9	7	0	0	0	0	2	1	2	2
American Companies	$144	$260	$270	$401	$64	$139	$142	$240	$45	$60	$63	$78	$5	$17	$29	$44	$30	$44	$36	$39
Japanese Companies	9	14	20	32	2	4	8	20	4	6	9	8	0	0	0	1	3	4	3	3
European Companies	4	6	5	11	2	3	2	7	1	1	1	2	0	0	0	0	1	2	2	2
Total	$157	$280	$295	$444	$68	$146	$152	$267	$50	$67	$73	$88	$5	$17	$29	$45	$34	$50	$41	$44

Source: DATAQUEST, Inc.

Table 2.8.6-17

ESTIMATED MARKET SHARES OF MOS MEMORY PRODUCERS
(Percent of Total)

	Total				RAMs				ROMs				EPROM/EAROM				Other (Shift Registers and CCDs)			
	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976
AMD	1%	3%	4%	6%	0%	1%	3%	4%	0%	0%	1%	2%	0%	0%	7%	14%	6%	12%	10%	14%
AMI	14	14	11	7	12	16	12	6	8	8	8	10	0	0	0	2	29	22	20	18
EA	2	1	1	1	0	0	0	0	6	5	6	7	0	0	0	0	0	0	0	0
EMM	0	1	2	2	0	1	4	3	0	0	1	0	0	0	0	0	0	0	0	0
Fairchild	2	2	2	4	2	1	3	5	2	3	3	3	0	0	0	0	3	4	2	4
GI	2	1	2	2	0	0	1	1	4	3	4	5	0	0	0	2	3	4	5	4
Harris	1	1	1	1	0	0	1	1	2	3	3	3	0	0	0	0	0	0	0	0
Hughes	1	1	1	1	0	0	0	0	2	3	3	3	0	0	0	0	3	2	5	4
Intel	24	30	29	25	35	39	33	25	8	9	10	10	100	100	86	67	11	8	7	8
Intersil	4	5	4	4	10	9	7	5	0	0	1	2	0	0	0	0	0	2	2	4
Mostek	10	11	8	8	16	16	12	11	6	6	3	6	0	0	0	0	6	4	2	4
Motorola	2	1	2	3	4	1	1	3	0	1	3	3	0	0	0	0	0	2	2	3
National	5	5	6	6	3	2	3	6	8	9	10	7	0	0	7	9	6	12	13	8
Nitron	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0
RCA	0	0	0	0.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Rockwell	6	5	4	2	0	0	0	0	14	15	12	8	0	0	0	0	6	6	5	4
Signetics	1	0[1]	1	1	0	0	0	1	2	1	3	2	0	0	0	0	0	0	0	0
Synertex	0	0	0[1]	1	0	0	0	0[1]	0	0	1	3	0	0	0	0	0	0	0	0
TI	5	5	8	11	6	6	11	15	2	3	3	5	0	0	0	2	9	8	10	9
Others	12	7	5	4	6	3	3	3	26	21	12	8	0	0	0	0	6	2	5	4
American Companies	92%	93%	91%	90%	94%	95%	94%	90%	90%	90%	87%	88%	100%	100%	100%	98%	88%	88%	88%	88%
Japanese Companies	6	5	7	7	3	3	5	7	8	9	12	10	0	0	0	2	9	8	7	8
European Companies	2	2	2	3	3	2	1	3	2	1	1	2	0	0	0	0	3	4	5	4
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

[1] Less than one-half percent.

Source: DATAQUEST, Inc.

2.8.6 Semiconductor Memory Markets

SUMMARY

The semiconductor memory market dates back to the mid 1960s when the first bipolar single chip dual J-K flip-flops and shift registers were made. In 1969, the first metal oxide semiconductor (MOS) memory was introduced by Intel in the form of the 1101 256 bit dynamic RAM. Semiconductor memory has grown from these early beginnings to a market estimated at $753 million in 1977 and growing to an estimated $1,312 million in 1981, which represents a compound annual growth rate of 15 percent.

Although MOS memories appeared later than bipolar memories, they have captured a dominant share of the total semiconductor memory market. We estimate the 1977 worldwide MOS memory consumption at $558 million, or 74 percent of the total semiconductor memory market. In 1981, we estimate that MOS memory will represent $1,007 million or 77 percent of the total. Our estimates of worldwide bipolar memory consumption are $195 million in 1977 growing to $305 million in 1981.

The dynamic growth of the semiconductor memory market has been marked by rapid technological change, continual and rapid price decline, fierce competition, and the advent of increasing foreign competition. Price declines in semiconductor memory have been approximately 30 to 40 percent per year. Early memories such as the 1103 were priced at approximately 1,500 millicents per bit in 1971; today, 4K dynamic MOS RAMs are available at 106 millicents per bit (average selling price). In 1981, we estimate that a 64K dynamic MOS RAM will be available at about 19 millicents per bit. The annual price decline between 1,500 millicents per bit in 1971 and 19 millicents per bit in 1981 is 35 percent.

The early development and popularity of semiconductor memories is largely due to the efforts of Intel Corporation. In 1970, the Company introduced the 1103 1K dynamic RAM, which became the most popular and highest volume single product in semiconductor history up to that time. This popularity has since been overshadowed by the popularity and even higher volume of the 4K dynamic MOS RAM. Intel enjoyed an early competitive lead, but by 1973 a number of other semiconductor firms were entering the MOS memory market, and by 1975 the field was extremely competitive.

Record price declines for semiconductor memory have enabled it to become a price competitive alternative for core memory. In late 1975 a memory system implemented with dynamic MOS RAMs became less expensive than a comparable size magnetic core memory, thereby increasing the demand for semiconductor memory. Despite the volatility of dynamic semiconductor memory versus the nonvolatility of core memory, it has been accepted by most users. The price elastic demand for memory by computer mainframes, minicomputers, peripherals, and communication systems has increased semiconductor memory bit consumption from an estimated 6.6 billion bits in 1971 to an estimated 350 billion bits in 1976. Total semiconductor memory consumption is estimated at 4,976 billion bits in 1981, which represents an average annual growth of 94 percent between 1971 and 1981.

INTRODUCTION AND BACKGROUND

Historical Perspective and Overview

Semiconductor memories date back to the mid 1960s when advances in bipolar integrated circuits produced the first single chip J-K flip-flop. These early flip-flops contained approximately 25 transistors and stored one bit of information. Serial shift registers followed in a couple of years and they in turn were followed by random access memories. The first shift registers and random access memories typically had 16, 64, 128, or 256 bits of storage. MOS memories first appeared in 1969 with Intel's introduction of the 256 bit dynamic MOS RAM (1101). The real milestone for MOS memories. however, was Intel's 1970 introduction of the 1103 1K dynamic MOS RAM. This introduction was a very significant event in semiconductor memory history, because it then became feasible to incorporate semiconductor memory in minicomputers and mainframe computers. Although memory systems implemented with semiconductor memory were initially more expensive than core memory systems, the crossover point was reached by the mid 1970s. The 1103 became the single most popular and highest volume semiconductor device made up to that time; it has since been surpassed in total unit volume by the 4K dynamic MOS RAM.

Table 2.8.6-1 presents a brief history of semiconductor memory, indicating the years in which major product types were introduced. The 1K dynamic MOS RAM was first introduced in 1970, with production quantities following in 1971; the 4K dynamic MOS RAM was introduced in 1974, with production quantities in 1975; and the 16K dynamic MOS RAM was introduced in 1976, with production quantities following in 1977. The first EPROM device was introduced in 1971; it was followed in 1975 by the 8K EPROM and in 1977 by the 16K EPROM.

MOS ROM memories have been available since the early 1970s. They are used primarily to store microprocessor program codes in terminals, calculators, games, and some computers. The first MOS ROM, a 2K device, appeared in 1971 and was followed in 1972 by the 4K ROM and in 1973 by the 8K ROM. The 16K ROM appeared in 1975 and the 32K and 64K ROMs first appeared in 1977. The EAROM was introduced in 1974, but it has not made a considerable sales impact to date. MOS shift registers first appeared in 1969 and have increased in length; they have since been followed by CCD serial access memories. The 16K CCD was introduced in 1975, and the 64K CCD was introduced in 1977.

The early bipolar shift registers were followed by the 64 bit bipolar RAM in 1969, the 256 bit bipolar RAM in 1971, the 512 bit and 1K bipolar RAMs in 1972, and the 4K bipolar RAM in 1976. The 256 bit bipolar PROM was introduced in 1970, and was followed by the 512 bit PROM in 1971, the 1K PROM in 1972, the 4K PROM in 1974, and the 8K PROM in 1977.

In the early 1970s, the semiconductor market was served primarily by American-based firms. Some Japanese firms had MOS memory products as early as 1972. The Japanese companies have steadily improved their memory products as well as their market share to the point where they are now becoming serious contenders in the MOS memory market. European companies have had MOS memory products since the early 1970s but they have not made any significant penetration of the important dynamic and static MOS RAM markets because of their relatively weak position in MOS technology. Their memory strategy now appears to be one of gaining entry by acquiring interests in smaller U.S. companies that already possess the memory technology, as exemplified by Philips' Signetics subsidiary, Bosch's interest in AMI, and Siemens expressed intent to acquire an interest in AMD.

In the first half of the 1970s the semiconductor memory market was dominated by relatively few products—primarily the 1K and 4K dynamic MOS RAMs and the 2K and 8K EPROM devices. The outlook for memory, however, is for a much more varied product mix. We expect that a broader proliferation of memory components will become available with a wide variety of speeds and configurations.

Most companies are beginning to stan-

2.8.6 Semiconductor Memory Markets

Table 2.8.6-1

HISTORY OF SEMICONDUCTOR MEMORY

	MOS RAMs	MOS ROM/PROMs	MOS Other	Bipolar RAMs	Bipolar ROM/PROMs
1964				J-K Flip Flop and Quad Latch	
1968				8 and 10 bit Shift Registers	
1969	256 bit Dynamic RAM		Shift Registers	64 bit RAM	
1970	1K Dynamic RAM		1K bit Shift Register		256 bit PROM
1971		2K ROM 2K EPROM		256 bit RAM	512 bit PROM
1972	1K Static RAM	4K ROM	2K bit Shift Registers	512 bit RAM 1K RAM	1K PROM
1973		8K ROM			
1974	4K Dynamic RAM				4K PROM
1975	4K Static RAM	8K EPROM 16K ROM	16K CCD		
1976	16K Dynamic RAM			4K RAM	
1977		16K EPROM 32K ROM 64K ROM	64K CCD		8K PROM

Source: DATAQUEST, Inc.

dardize on a 16-pin package for the 4K and for the new 16K dynamic MOS RAMs. Other pin configurations and performance standards, however, do exist for memory products, and complete standardization is not expected in this industry. The lack of standardization results because component developments occur in parallel at different companies; therefore, competition rather than cooperation exists in product development. Once a product becomes an accepted standard, however, it is emulated by most, but not all, of the competition.

In the 1960s and early 1970s, most memory applications were fulfilled by magnetic core memory. The introduction of the semiconductor memory made an alternative approach possible, and rapidly declining prices have made semiconductor memory a viable alternative. Two costs should be considered when comparing core and semiconductor memory: (1) the component or device cost, and (2) the total memory system cost. Figure 2.8.6-1 shows the

2.8.6 Semiconductor Memory Markets

estimated component level cost of core and semiconductor random access memory from 1972 through 1981. Additional system level costs for core memory include the cost of drive and sense circuits, address decode circuits, and printed circuit boards. The system level costs for a core memory are 2 to 3 times the component level costs shown in Figure 2.8.6-1. For semiconductor memories system level costs of refresh circuitry, address decoding, and printed circuit boards must be considered. Depending on the speed and size of the semiconductor memory, the system level costs range from 1.5 to 3.0 times the component level costs.

The rapid price decline of semiconductor memory is a major factor contributing to its pervasiveness. In the early 1970s, memory was used in mainframe and minicomputer memories. Memory has now spread to microprocessor systems, calculators, terminals, communications systems, point of sale terminals, and a host of other applications. It is now beginning to enter the home via hobby computers, although it has already been there in the form of electronic calculators and programmable video games.

The major factor in the continued price decline of semiconductor memory is the ability of semiconductor manufacturers to decrease their manufacturing costs through increased density and yield improvements. As a measure of the increased bit density that the semiconductor manufacturers are achieving, consider Table 2.8.6-2: The 1K dynamic MOS RAM had an effective bit area of 20.0 $mils^2$ when it was introduced, while the 64K dynamic MOS RAM is expected to have an effective bit area of 0.75 $mils^2$. This represents a 27-fold increase in bit density between the 1K RAM of 1970 and the 64K RAM expected in 1979.

This continued progress toward higher densities is the result of two major trends: (1) design improvements, which have taken memory from the early days of three transistors per bit of storage to the present one transistor per bit; and (2) photolithography and processing improvements, which have permitted smaller dimensions on the chip. Currently, no designs exist that will enable the use of less than one transistor per cell. Major advances in density must now come from photolithography, and the 64K dynamic MOS RAM is now pushing the limits of conventional optical photolithography. Most semiconductor firms will probably use optical techniques on the 64K dynamic RAM, but the 256K RAM must be patterned with E-Beam techniques because of its smaller dimensions.

Definitions

Any discussion of semiconductor memory technology is laden with acronyms; therefore, we will present a clear set of definitions of those acronyms used throughout this section.

Metal Oxide Semiconductors (MOS)

Memory technology falls into two major technology segments— MOS and bipolar. Metal oxide semiconductors (MOS) are three-terminal devices in which current flow between source and drain is controlled by a voltage applied to the gate (or control) terminal. Current is conducted by either positive or negative carriers and current conduction occurs at the surface of the silicon.

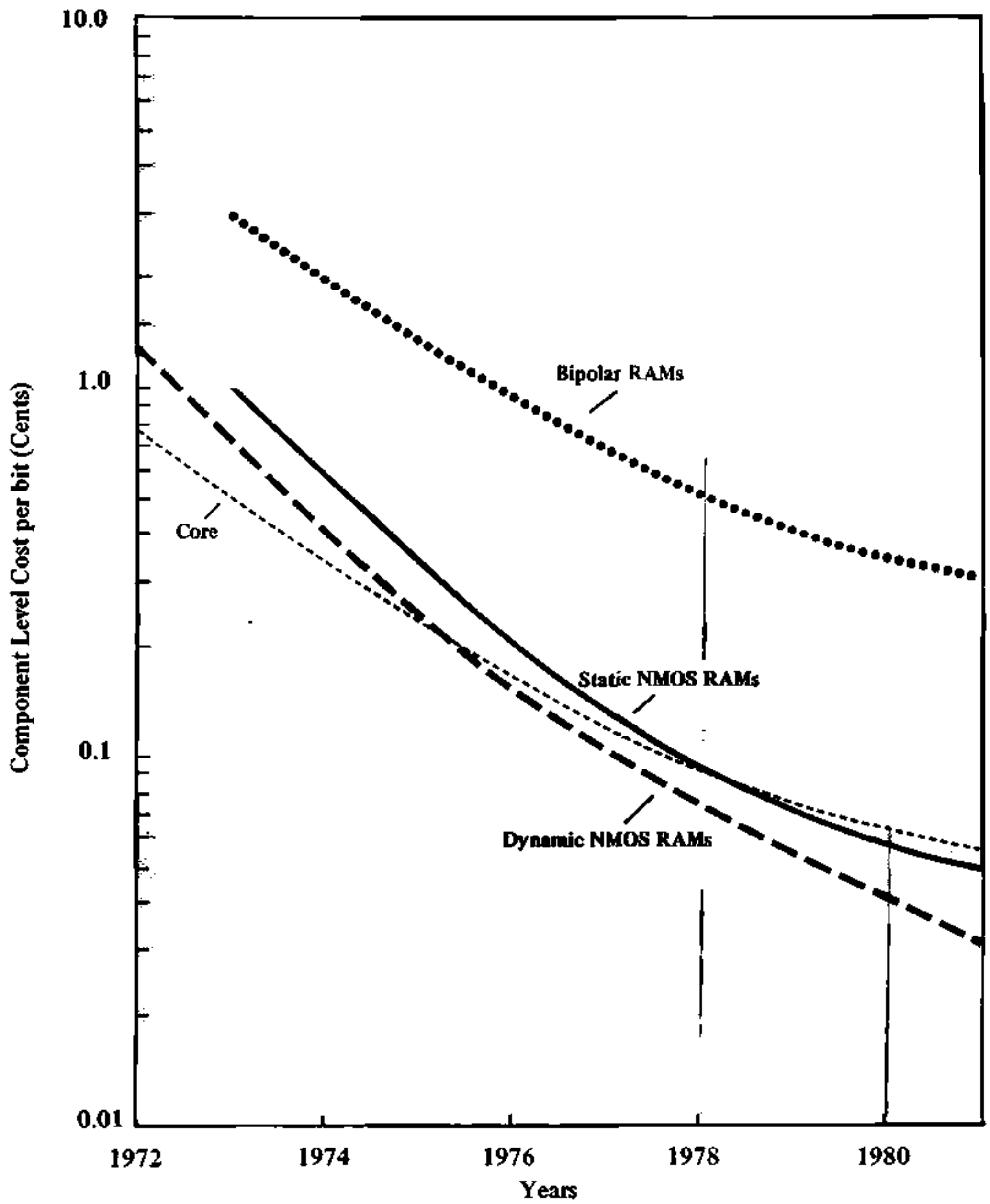
Bipolar Semiconductors

Bipolar devices are three-terminal devices in which current flow between emitter and collector is controlled by a current applied to the base terminal. Current flow is the sum of both negatively charged electrons and positively charged holes. The major flow of current in the bipolar device occurs within the bulk silicon substrate rather than on the silicon surface.

2.8.6 Semiconductor Memory Markets

Figure 2.8.6-1

COMPONENT LEVEL COSTS OF SEMICONDUCTOR AND CORE MEMORY



Source: DATAQUEST, Inc.

2.8.6 Semiconductor Memory Markets

Table 2.8.6-2
TYPICAL AREAS OF MOS RAMs

	Year	Chip Area (mils)^2	Effective Bit Area (mils)^2
1K	1970	20,000	20.00
4K	1975	15,000	3.75
16K	1977	25,000	1.56
64K	1979	48,000	0.75

Source: DATAQUEST, Inc.

Random Access Memory (RAM)

The random access memory (RAM) is a storage device in which each individual bit is addressable. It is a read/write device, which means that information may be read out or written in as often as desired. Semiconductor RAMS, however, are volatile devices, which means they lose their memory contents when the applied voltage is removed.

Dynamic RAM

Random access memories (RAMs) are either dynamic or static. Dynamic RAMs lose the charge that stores the information and must have their memory locations recharged about every two milliseconds by refresh circuits.

Static RAM

A static RAM does not lose the charge that stores the information as long as power is applied. Therefore, no refresh circuitry is required with static RAMs.

Read Only Memory (ROM)

A read only memory (ROM) is a storage device that has its contents programmed into it at the time of manufacture. The data are nonvolatile and cannot be changed. There is a mask charge of about $1,000 on orders of less than 1,000 units for each different ROM pattern, as well as a turnaround time of eight to sixteen weeks. Therefore, ROMs are only used in applications where significant production volume can be generated and the long turnaround time can be accepted.

Programmable Read Only Memory (PROM)

A programmable read only memory (PROM) is a memory device that is manufactured in an unprogrammed state. It is programmed in an electrical programmer and, once programmed, the PROM contents are nonvolatile and cannot be changed.

Erasable PROM (EPROM)

An erasable programmable read only memory (EPROM) is a memory device that is manufactured in an unprogrammed state. It is programmed in a programmer and each bit can be programmed only once between erasures. Once programmed, it can be returned to an unprogrammed state by the application of some nonelectrical energy (ultraviolet light, heat, etc.) for a period of generally 20 to 30 minutes. The data are nonvolatile for those devices programmed in a programmer.

Electrically Alterable Read Only Memory (EAROM)

An electrically alterable read only memory (EAROM) is a memory device that is manufactured in an unprogrammed state. Once programmed, it can be returned to the unprogrammed state by the application of electrical signals to its terminals. It can be programmed in-circuit or in a programmer box.

Volatile and Nonvolatile Memory

A volatile memory is one that loses its contents after power has been removed; a nonvolatile memory is one that retains the data bits even after power has been removed. The data in a nonvolatile memory are permanent and available for the expected life of the equipment in which it is used.

Charge Coupled Device (CCD)

A charge coupled device (CCD) is a volatile device that stores information by storing electronic charges in small packets. The manufacturing process used for the CCD is basically the same as that used for standard MOS devices; thus, it is generally considered to be a MOS device.

Magnetic Bubble Device (MBD)

The magnetic bubble device (MBD) is a memory device in which binary information is represented by the presence or absence of mobile cylindrical magnetic domains in a thin magnetic layer. The manufacture of MBDs is quite different from that of MOS and bipolar devices. The MBD is actually a magnetic device rather than a semiconductor device, but it is mentioned here because a discussion of semiconductor memories and their future outlook would not be complete without considering this important device.

THE MARKET

Market for MOS Memory

Market by Device Type

The estimated consumption of MOS semiconductor memory is shown in Table 2.8.6-3. We estimate that the market will grow from $558 million in 1977 to $1,007 million in 1981, which is a 15.9 percent compound annual growth rate. MOS RAMs constitute the major portion of the MOS memory market. In 1977, they represent approximately 61 percent of the total; in 1981, they are expected to represent 55 percent of the total MOS comsumption.

The compound annual growth rate for MOS RAM memory between 1977 and 1981 is expected to be 12.9 percent; dynamic RAMs will grow at an estimated 11.9 percent rate, and static RAMs will grow at an estimated 16.2 percent rate. ROMs have an estimated 14.2 percent average growth rate for the 1977 to 1981 period. EPROMs, EAROMs, and CCDs, with estimated compound annual growth rates of 18.9, 29.4, and 96.8 percent respectively, represent the high growth portion of the MOS memory market, but their high growth rate is somewhat due to their small base in 1977.

Dynamic MOS RAM Consumption

Table 2.8.6-4 is DATAQUEST's estimate of worldwide dynamic MOS RAM consumption for 1971 through 1981. Estimated consumption for 1971 to 1976 is shown to provide a historical perspective which has not been completely presented elsewhere. This table shows units and average selling prices as well as the dollar value of the MOS RAM markets. DATAQUEST estimates that the 4K dynamic RAM market will peak in 1978 in both units

2.8.6 Semiconductor Memory Markets

Table 2.8.6-3

ESTIMATED WORLDWIDE MOS SEMICONDUCTOR MEMORY CONSUMPTION
(Dollars in Millions)

	1970	1971	1972	1973	1974	1975	1976
RAM	$ 2	$13	$40	$ 68	$146	$152	$267
Dynamic	2	13	39	60	97	115	205
Static	0	0	1	8	49	37	62
ROM	8	20	30	50	67	73	88
EPROM	0	0	1	5	17	29	43
EAROM	0	0	0	0	0	0	2
CCD	0	0	0	0	0	1	3
Shift Register	10	20	26	34	50	40	41
Total MOS Memory	$20	$53	$97	$157	$280	$295	$444

	1977	1978	1979	1980	1981	Compound Annual Growth Rate 1977-1981
RAM	$343	$420	$446	$498	$558	12.9%
Dynamic	264	326	338	369	414	11.9%
Static	79	94	108	129	144	16.2%
ROM	103	121	135	160	175	14.2%
EPROM	61	90	96	104	122	18.9%
EAROM	5	8	9	11	14	29.4%
CCD	8	25	41	71	120	96.8%
Shift Register	38	32	25	22	18	(17.0%)
Total MOS Memory	$558	$696	$752	$866	$1,007	15.9%

Source: DATAQUEST, Inc.

and dollars while the 16K dynamic RAM market is gaining momentum. We estimate that the 64K RAM will be introduced in 1978 with small sample quantities, but production will not begin until 1979 with an estimated 800,000 units.

Note that the average selling price of the 1K dynamic RAM is expected to remain relatively flat between 1977 and 1981. This flatness is due to the fact that it is still used in many old designs, but there is no incentive for the few suppliers of this part to reduce prices on this dying part. The 4K, 16K, and 64K average selling prices are expected to decline 30 to 40 percent each year through 1981.

Static MOS RAM Consumption

Table 2.8.6-5 shows estimated worldwide static MOS RAM consumption for the years 1973 through 1981. Consumption estimates for the years 1973 to 1976 are shown for historical

Table 2.8.6-4

ESTIMATED WORLDWIDE DYNAMIC MOS RAM CONSUMPTION

	1971	1972	1973	1974	1975	1976
Value (Dollars in Millions)						
1K	$13	$39	$59	$83	$ 70	$ 42
4K	0	0	1	14	45	161
16K	0	0	0	0	0	2
64K	0	0	0	0	0	0
Total Dynamic RAMs	$13	$39	$60	$97	$115	$205
Units (Millions)						
1K	0.9	3.7	8.1	16.6	20.0	14.0
4K	0	0	0	0.7	5.0	28.0
16K	0	0	0	0	0	.05
64K	0	0	0	0	0	0
Average Selling Price						
1K	$15.00	$10.50	$7.25	$5.00	$3.50	$ 3.00
4K	N.A.	N.A.	N.A.	N.A.	$9.00	$ 5.75
16K	N.A.	N.A.	N.A.	N.A.	N.A.	$30.00
64K	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

	1977	1978	1979	1980	1981
Value (Dollars in Millions)					
1K	$ 28	$ 15	$ 10	$ 6	$ 2
4K	204	200	150	117	86
16K	32	110	150	182	182
64K	0	1	28	64	144
Total Dynamic RAMs	$264	$326	$338	$369	$414
Units (Millions)					
1K	11.0	7.0	5.0	3	1
4K	48.0	57.0	50.0	45	38
16K	1.7	10.0	20.0	35	48
64K	0	.02	.8	4	12
Average Selling Price					
1K	$ 2.50	$ 2.20	$ 2.00	$ 1.90	$ 1.80
4K	$ 4.25	$ 3.50	$ 3.00	$ 2.60	$ 2.25
16K	$19.00	$11.00	$ 7.50	$ 5.20	$ 3.80
64K	N.A.	$55.00	$35.00	$16.00	$12.00

N.A.: Indicates that product was not yet introduced.

Source: DATAQUEST, Inc.

significance. The total dollar value, units, and average selling prices are shown for the 1K, 4K, and 16K static RAMs. The year of 1977 is estimated to be the peak year (in both units and dollars) for 1K static RAMs, since the 4K statics are gaining production volume. We expect that the 4K static RAM will generate the most dollar value in the static MOS RAM market in 1978 to 1980. By 1981, we expect the 16K static RAM to be the leading dollar value product. We expect to see the first 16K static RAMS in late 1978, with production beginning in 1979.

MOS EPROM Consumption

Table 2.8.6-6 shows estimated MOS EPROM consumption for the period 1974 through 1981. Again, prior years are shown for their historical significance. We estimate that the 2K EPROM will peak out in unit volume in 1977; 8K EPROMs should peak out in 1978. We expect the 16K EPROM to be available only in small quantities in 1977, with production increasing in following years. By late 1979 or early 1980, we expect to see the first of the 32K EPROM devices. Average selling prices of EPROMs are falling rapidly in 1977 after the prices held relatively high levels through 1976 because of limited competition.

Table 2.8.6-5

ESTIMATED WORLDWIDE STATIC MOS RAM CONSUMPTION

	1973	1974	1975	1976	1977	1978	1979	1980	1981
Value (Dollars in Millions)									
1K	$8	$49	$35	$50	$52	$44	$ 38	$ 29	$ 20
4K	0	0	2	12	27	48	48	57	43
16K	0	0	0	0	0	2	22	43	81
Total Static RAMs	$8	$49	$37	$62	$79	$94	$108	$129	$144
Units (Millions)									
1K	0.9	9.6	12.7	25.1	27.1	24.2	23.0	18.0	13.0
4K	0	0	.06	.8	3.0	8.0	10.0	14.0	12.0
16K	0	0	0	0	0	.1	2.0	5.0	12.0
Average Selling Price									
1K	$8.80	$5.10	$ 2.75	$ 2.00	$1.92	$ 1.82	$ 1.65	$1.61	$1.54
4K	N.A.	N.A.	$30.00	$15.00	$9.00	$ 6.00	$ 4.80	$4.10	$3.60
16K	N.A.	N.A.	N.A.	N.A.	N.A.	$18.00	$11.00	$8.50	$6.75

N.A. Indicates that product was not yet introduced.

Source: DATAQUEST, Inc.

2.8.6 Semiconductor Memory Markets

Table 2.8.6-6

ESTIMATED WORLDWIDE MOS EPROM CONSUMPTION

	1974	1975	1976	1977	1978	1979	1980	1981
Value (Dollars in Millions)								
2K (1702 Type)	$17	$21	$12	$10	$ 4	$ 3	$ 1	$ 1
8K (2708 Type)	0	8	31	45	60	36	21	13
16K (2716 Type)	0	0	0	6	26	53	60	70
32K	0	0	0	0	0	4	22	38
Total	$17	$29	$43	$61	$90	$96	$104	$122
Units (Millions)								
2K	0.3	1.0	1.5	2.0	1.2	1.0	.5	.2
8K	0	.1	.6	3.0	6.0	4.5	3.0	2.0
16K	0	0	0	.1	1.2	3.5	5.0	7.0
32K	0	0	0	0	0	.1	.8	2.0
Average Selling Price								
2K	$57.00	$21.00	$ 8.00	$ 5.00	$ 3.50	$ 3.00	$ 2.80	$ 2.50
8K	N.A.	$80.00	$52.00	$15.00	$10.00	$ 8.00	$ 7.00	$ 6.50
16K	N.A.	N.A.	N.A.	$55.00	$22.00	$15.00	$12.00	$10.00
32K	N.A.	N.A.	N.A.	N.A.	N.A.	$40.00	$28.00	$19.00

N.A. Indicates that product was not yet introduced.

Source: DATAQUEST, Inc.

CCD Consumption

Table 2.8.6-7 shows estimated CCD consumption for 1976 through 1981. The 64K bit CCD was introduced in 1977; however, significant production quantities are not expected until 1978 and 1979. By 1979, we expect to see small quantities of a 256K bit CCD memory. The CCD average selling prices are expected to fall from the range of 50 millicents per bit in 1977 to nine millicents per bit by 1981, which represents a compound annual price decline of 35 percent.

Applications of MOS Memory

MOS memory finds its applications in four major areas; computers, industrial, government and military, and consumer.

Computer Memory Applications

The estimated end markets for MOS memories are shown in Table 2.8.6-8. The computer memory applications include mainframes, minicomputers, terminals, and peripherals. In 1977, we expect computers to represent 82 percent of the total MOS memory usage, falling off to an expected 57 percent of the total in 1982. Today, the main storage area of large mainframe

Table 2.8.6-7

ESTIMATED WORLDWIDE CCD CONSUMPTION

	1976	1977	1978	1979	1980	1981
Value (Dollars in Millions)						
16K	$3	$5	$ 5	$ 7	$ 2	$ 1
64K	0	3	20	24	32	57
256K	0	0	0	10	37	62
Total CCDs	$3	$8	$25	$41	$71	$120
Units (Millions)						
16K	.15	.6	1.0	2.0	1.0	.5
64K	0	.1	1.2	2.5	5.0	10.0
256K	0	0	0	.2	1.2	2.7
Average Selling Price						
16K	$20.00	$ 8.00	$ 4.80	$ 3.50	$ 2.20	$ 1.85
64K	N.A.	$30.00	$17.00	$ 9.60	$ 6.40	$ 5.75
256K	N.A.	N.A.	N.A.	$50.00	$31.00	$23.00

N.A. Indicates that product was not yet introduced.

Source: DATAQUEST, Inc.

computers ranges in size from two to eight megabytes with some going as high as 16 megabytes. An eight megabyte memory with error correction uses 18,000 to 20,000 4K RAMs. New memory designs are incorporating the 16K RAM to cut the device counts down by a factor of four. Smaller mainframes and minicomputers have main storage areas ranging in size from 8K bytes to one megabyte and use the 4K dynamic RAM. Their new memory designs are also rapidly incorporating the 16K RAM.

The 4K static RAMs, which were introduced in 1975, are finding very wide use in add on memories. The new fast 4K statics are in especially high demand by manufacturers of computers. These fast 4K statics are also finding wide acceptance in buffer and cache memory markets—a market previously dominated by bipolar RAMs. The competition between MOS and bipolar memory in the fast memory markets will be discussed in more detail later.

Terminals and peripherals range from general purpose intelligent terminals to dedicated point of sale terminals— as well as discs, tapes, and other peripherals that require memory in their controllers. In these applications, the 1K and 4K static MOS RAMs have become very popular because they require no refresh circuits and are thus easier to implement. The 4K and 16K dynamic RAMs are also used, as well as the 8K EPROMs. ROMs are widely used in terminals to store the microprocessor program code. The amount of ROM code per terminal varies widely from 4K bytes to 48K bytes and is increasing rapidly as more capability is constantly being added to terminals.

Industrial Applications

The industrial market includes communications, industrial controls, test instruments, and office equipment. Communications equipment is just beginning to switch over to exten-

Table 2.8.6-8

END MARKETS FOR MOS MEMORY
(Dollars in Millions)

	1977	1978	1979	1980	1981
Computers	$457	$522	$526	$546	$ 574
Mainframes					
Minicomputers					
Peripherals					
Terminals					
Industrial	84	125	150	199	262
Communications					
Control					
Instruments					
Office Equipment					
Government & Military	6	14	23	43	60
Aerospace					
Communications/Navigation					
Defense					
Consumer	11	35	53	78	111
Audio					
CB					
Calculators					
Games					
TV					
Watches					
Total	$558	$696	$752	$866	$1,007

Source: DATAQUEST, Inc.

sive use of semiconductor memory. Both on-site PABX equipment and local office electronic switching systems now incorporate 4K dynamic RAMs. The large number of PABXs and local exchanges makes a potentially very large market. Industrial controls use static and dynamic RAMs for work space as well as EPROMs and ROMs for program storage. Typically, more bits of ROM/EPROM are used than RAM bits. RAM storage requirements range from 1K to 4K bytes whereas ROM/EPROM requirements can range from 2K or 4K bytes up to 8K or 16K bytes.

Instruments also use both volatile RAM storage and nonvolatile ROM/EPROM storage. The amount of storage required varies with the instrument and application but are in the same ranges as those listed above for industrial controls. Both industrial controls and instruments are very good markets for memory because of the hundreds of thousands of units produced each year.

Office equipment includes all types of special banking, bookkeeping, and accounting equipment as well as word processing equipment. Word processing equipment typically uses 24K to 48K bytes of ROM program storage plus several K bytes of RAM storage. The other specialized office equipment uses both RAM and ROM storage in quantities per system that are similar to those for instruments and controls. Office equipment, especially word processing, offers a very attractive growth market for MOS memory.

Government and Military Applications

Government and military applications include aerospace, communications, and navigation, as well as defense requirements. Both the government and the military have used core memory and tape recorders almost exclusively until the last couple of years. They are now slowly switching over to the use of MOS memory in selected areas. Much of the new communications and navigation equipment for the FAA and other agencies is now using MOS memory. The military is now beginning to accept MOS RAM memory in some applications although they still depend heavily on core memory. Aerospace applications are also slowly converting to MOS memory. These markets range from 1 percent of the total MOS memory market in 1977 to 6 percent of the total in 1981.

Consumer Applications

The fourth application area for MOS memory is the consumer market which includes but is not limited to audio, CB, calculators, games, television, and watches. The major users of memory are the programmable video games and the new electronic board games, plus calculators—both hand-held and desk-top models. Although each application uses only a few K bytes of memory— generally ROM memory for program storage—the total number of units used runs into the millions.

MOS Market by Process Technology

There are four process technologies within the MOS memory market—NMOS, PMOS, CMOS, and SOS. Table 2.8.6-9 shows the MOS RAM market forecast by process technology. NMOS became the dominant technology in 1975 and is expected to maintain the major portion of the MOS RAM market. We do not expect the SOS technology to be widely used for memory applications because of its higher costs. There will be limited applications, however, where the use of SOS memory is worth the added cost. The use of CMOS technology for RAMs is increasing because of more demand for low power memories. The CMOS RAMs are used in battery powered applications (calculators, games, etc.) and in conjunction with CMOS microprocessor chips sets.

Market for Bipolar Memory

Market by Device Type

The estimated consumption of bipolar memory is shown in Table 2.8.6-10. Bipolar memory consumption is estimated to increase from $195 million in 1977 to $305 million by 1981, a compound annual growth rate of 11.8 percent. Bipolar RAMs are expected to grow at 14.3 percent annually; ROMs and PROMs are expected to grow at 9.8 percent annually. This somewhat slower growth for the total bipolar memory market compared to the MOS memory market is partially due to the fierce competition it is facing from dynamic and static MOS RAMs. This will be a key issue in the future and is addressed later in this section. It is also due to the higher average selling price that a

2.8.6 Semiconductor Memory Markets

Table 2.8.6-9

ESTIMATED WORLDWIDE MOS RAM CONSUMPTION BY PROCESS TECHNOLOGY
(Dollars in Millions)

	1977	1978	1979	1980	1981
NMOS	$291	$370	$395	$438	$481
PMOS	26	10	4	2	2
CMOS	22	34	40	48	60
SOS	4	6	7	10	15
Total MOS RAMs	$343	$420	$446	$498	$558

Source: DATAQUEST, Inc.

bit of bipolar memory commands over MOS memory because of its higher performance.

Applications for Bipolar Memory

Bipolar memory applications are segmented into four areas: computers, industrial, government and military, and consumer as

Table 2.8.6-10

ESTIMATED WORLDWIDE BIPOLAR MEMORY CONSUMPTION

	1970	1971	1972	1973	1974	1975	1976
Bipolar							
RAM	$ 9	$16	$28	$36	$ 48	$40	$ 55
ROM/PROM	4	7	11	38	64	58	80
Total Bipolar Memory	$13	$23	$39	$74	$112	$98	$135

	1977	1978	1979	1980	1981	Compound Annual Growth Rate 1977-1981
Bipolar						
RAM	$ 85	$110	$115	$125	$145	14.3%
ROM/PROM	110	120	125	140	160	9.8%
Total Bipolar Memory	$195	$230	$240	$265	$305	11.8%

Source: DATAQUEST, Inc.

shown in Table 2.8.6-11. Computers include mainframes, minicomputers, terminals, and peripherals, and consume 85 percent of the total bipolar market in 1977, falling to an estimated 74 percent in 1981. Bipolar devices are high speed devices and, as such, are used extensively in buffer and cache memories within mainframe CPUs; they are also used in some very high speed main memories for high performance mainframe and minicomputer systems, and in the input/output channel buffers associated with mainframes. These buffers require the high speed of bipolar RAMs but do not use large amounts of memory.

Terminals and peripherals represent a small portion of the computer category. Bipolar memory is used in those terminal and peripheral applications that require higher speeds; such as input/output buffers to high speed mainframes.

Industrial applications include communications equipment, industrial controls, test instruments, and office equipment. This segment uses an estimated 14 percent of the total bipolar memory market in 1977, growing to an estimated 20 percent in 1981. Bipolar memory is used in small quantities and only where its higher speed is required. This is primarily in the input/output channels and those areas requiring high speed computation, buffering, or refresh.

Government and military applications use an estimated 1 percent of the total in 1977, growing to an estimated 5 percent of the total in 1981. This market is not expected to be a significant market for bipolar memory.

The consumer markets for bipolar memory are not expected to exceed 1 percent of the total in 1981. Consumer applications do not need the higher speed and performance of bipolar memory.

Factors in the Marketplace

MOS versus Bipolar

MOS and bipolar have been and are expected to remain the major technologies in the semiconductor memory business. In 1977, MOS represents 74 percent of the estimated semiconductor memory market; this percentage is expected to increase to 77 percent by 1981 as shown in Table 2.8.6-12.

There will, however, be continuing competition between MOS and bipolar memory for commonly served markets. Intense competition is developing between high speed static MOS RAMs and bipolar RAMs.

The relatively lower power consumption of MOS devices, and especially CMOS devices, is an important factor in their favor. Some of the new static MOS RAMs have a standby mode that enables them to consume far less power than competing static RAMs. For example, the Mostek 4104 (4K static) dissipates 125 milliwatts maximum in the standby mode compared to 710 milliwatts for the standard 2114 device, which does not offer the standby mode. These considerations are quite important in power-limited applications such as portable terminals.

High Speed Memory

In 1976 and early 1977, significant advances were made in N-channel NMOS technology. Design and processing advances have enabled manufacturers to offer static and dynamic MOS RAMs whose access time is competitive with that of bipolar RAMs. For example, 120 nanosecond access times for 4K RAMs and 150 nanosecond access times for 16K RAMs are a production reality in mid-1977. By mid-1978 these access times are expected to drop to the range of 100 nanoseconds for both 4K and 16K RAMS. 4K static RAMs are now

Table 2.8.6-11

END MARKETS FOR BIPOLAR MEMORY
(Dollars in Millions)

	1977	1978	1979	1980	1981
Computers	$166	$191	$195	$204	$226
Mainframes					
Minicomputers					
Peripherals					
Terminals					
Industrial	27	35	38	48	61
Communications					
Control					
Instruments					
Office Equipment					
Government & Military	2	4	6	11	15
Aerospace					
Communications/Navigation					
Defense					
Consumer	0	0	1	2	3
Audio					
CB					
Calculators					
Games					
TV					
Watches					
Total	$195	$230	$240	$265	$305

Source: DATAQUEST, Inc.

available with access times of 50 to 70 nanoseconds. These access times are competing with bipolar RAMs whose access time is in the range of 5 to 50 nanoseconds. Since MOS devices consume less power than their bipolar counterparts, they are a very attractive alternative when speed and power are important parameters. Furthermore, N-channel MOS devices appear to have cost advantages over bipolar devices.

The primary competition in high speed MOS memories is coming from Intel, Intersil, Mostek, and several Japanese firms. We expect that other firms will be offering competing high speed products within the next year.

The technology used to achieve these higher speeds in MOS devices includes improved sensing circuitry, depletion enhancement, double poly, full ion implantation, smaller line widths, and thinner oxides. Each of these techniques is evolutionary rather than revolutionary. We expect that continued pro-

2.8.6 Semiconductor Memory Markets

Table 2.8.6-12

ESTIMATED WORLDWIDE SEMICONDUCTOR MEMORY CONSUMPTION

	Dollars in Millions					
	1970	1971	1972	1973	1974	1975
MOS Memory	$20	$53	$ 97	$157	$280	$295
Bipolar Memory	13	23	39	74	112	98
Total Semiconductor Memory	$33	$76	$136	$231	$392	$393
	Percent of Total					
MOS Memory	61%	70%	71%	68%	71%	75%
Bipolar Memory	39%	30%	29%	32%	29%	25%

	Dollars in Millions					
	1976	1977	1978	1979	1980	1981
MOS Memory	$444	$558	$696	$752	$ 866	$1,007
Bipolar Memory	135	195	230	240	265	305
Total Semiconductor Memory	$579	$753	$926	$992	$1,131	$1,312
	Percent of Total					
MOS Memory	77%	74%	75%	76%	77%	77%
Bipolar Memory	23%	26%	25%	24%	23%	23%

Source: DATAQUEST, Inc.

gress will be made on making MOS devices faster; consequently, by 1979, 50 nanosecond 4K RAMs should be available as well as 50 to 75 nanosecond 16K RAMs and 75 to 110 nanosecond 64K RAMs.

By 1978, static RAM access times are expected to be under 35 nanoseconds for 1K static devices and under 50 nanoseconds for 4K static devices. It it is conceivable that these speeds could be even faster. With this constant pressure from the MOS devices in terms of speed, power, and cost, bipolar devices will be pushing the one nanosecond barrier with increasing emphasis.

Static versus Dynamic Memory

Static and dynamic memory serve somewhat separate markets. Dynamic memory is used primarily in mainframe and minicomputer memory systems where speed, power, and cost are important considerations. Cost is usually the overriding factor in choosing dynamic memory because when large amounts of memory are used, a cost savings at the component level of 20 to 30 percent can be realized.

Static memory is used in terminals, calculators, instruments, and add on memories for use with large mainframe computers. Static memory requires no refreshing as does dynamic memory; thus, it is easier to use. Furthermore, clocked static memories have a standby mode that can considerably decrease the power consumption of the memory system.

Table 2.8.6-13 shows the total MOS RAM market as well as the share of market for dynamic and static RAMs expressed in millions of dollars and as a percent of the total. We believe the relative percentages will remain fairly constant through 1981, although such unsettling forces as greatly expanding static memory markets could change the mix.

Impact of Core Memory

In the 1960s, core memory was the dominant memory device. Other memory devices included plated wire and twistor memories. In the mid-1960s, the first semiconductor memory made its appearance. Until 1974, magnetic cores were supplying the majority of memory bits; then, in 1974, semiconductor memory took the lead away from core memory and the gap has been widening ever since. These trends are shown in Table 2.8.6-14, which provides estimated semiconductor and core bit consumption from 1970 to 1981. In 1970, core memory represented an estimated 96 percent of the total; in 1981, core memory is expected to represent only 3 percent of the estimated total. This drastic shift in a period of 11 years is the result of the continued price decline of semiconductor memory. The estimated component level price of core and semiconductor memory on a per bit basis is shown in Figure 2.8.6-1. It is this dra

Table 2.8.6-13

ESTIMATED WORLDWIDE DYNAMIC AND STATIC MOS RAM MEMORY CONSUMPTION

	Dollars in Millions					
	1976	**1977**	**1978**	**1979**	**1980**	**1981**
Dynamic MOS RAMs	$205	$264	$326	$338	$369	$414
Static MOS RAMs	62	79	94	108	129	144
Total MOS RAMs	$267	$343	$420	$446	$498	$558
	Percent of Total					
Dynamic MOS RAMs	77%	77%	78%	76%	74%	74%
Static MOS RAMs	23%	23%	22%	24%	26%	26%

Source: DATAQUEST, Inc.

matic change in price that has initiated the transition of the bulk of memory to semiconductor devices. Accompanying this price decline has been lower power per bit and higher packing density that results in savings at the system level.

Price

The estimated average selling price of MOS RAM and EPROM memories is shown in Table 2.8.6-15. It should be emphasized that these prices are average selling prices and that high volume quotes for a device fall below these numbers. The prices of EPROMS have been especially volatile in 1977; prices have decreased about $1 each month. The 8K EPROM in quantities of 1,000 began the year in the mid $20 range and is expected to be at $10 by year end 1977.

The price of semiconductor memory is on a predictable learning curve. Historically, memory prices have been falling 30 to 40 percent each year. We expect this trend to continue at least through 1981.

COMPETITION

Competitive Environment

Semiconductor memories have become one of the fastest growing and the most competitive segments of the semiconductor business. Intel pioneered this market and remains a market leader. Since the early 1970s, however, essentially every semiconductor company that manufactures integrated circuits has joined the memory race. Intel, Mostek, and Texas Instruments are acknowledged leaders in the MOS memory market; Fairchild and Signetics are the major leaders in the bipolar memory market.

In the past, the memory market was dominated by only a few products. If a company had one or two of these products, it could participate to a large degree in the memory market; however, this is no longer true. Now a company must have a very broad offering of products to participate actively in the memory market. Intel, Mostek, and Texas Instruments all have, or are working toward, a very broad product line. Several Japanese firms—including NEC, Hitachi, and Fujitsu—are also working toward this end. Currently, the share of the market enjoyed by the Japanese companies is relatively low when compared to that of the American firms. The Japanese government and the Japanese firms, however, are investing an estimated $250 million over the next three years in research and development directed at improving their Very Large Scale Integration (VLSI) capability. For this reason, they must be considered a potential major competitor in memory components.

Market Shares of Major Suppliers

MOS Market Shares

Table 2.8.6-16 shows our market share estimates for the major producers of MOS memory for the period 1973 through 1976. Intel had a 39 percent share of the 1974 RAM market and a 100 percent share of the 1974 EPROM market. After 1974, activity in the MOS memory market increased markedly as witnessed by the larger number of participants in 1975 and 1976. Table 2.8.6-17 shows market share estimates in the MOS memory market by percent of total market. In this table, the relative positions of the competitors are evident. Although Intel has lost market share (from 30 percent of the total MOS market in 1974 to 25 percent of the total in 1976), its dollar total has increased from an estimated $84 million in 1974 to an estimated $110 million in 1976.

In 1976 the leaders in the MOS memory

Table 2.8.6-14

ESTIMATED SEMICONDUCTOR AND CORE MEMORY BIT CONSUMPTION
(Bits in Billions)

	1970	1971	1972	1973	1974	1975
MOS Memory	1.3	4.2	10.5	34.2	77.4	122.1
RAMs	0.1	0.9	3.8	9.0	29.0	53.0
Dynamic	0.1	0.9	3.7	8.1	19.4	40.0
Static	N.A.	N.A.	0.1	0.9	9.6	13.0
ROMs	1.2	3.3	6.7	25.0	47.8	66.3
EPROMs	N.A.	N.A.	N.A.	0.2	0.6	2.8
Bipolar Memory	1.0	2.4	5.7	14.4	29.5	37.0
RAMs	0.5	1.5	3.7	5.8	10.7	13.8
ROM/PROM	0.5	0.9	2.0	8.6	18.8	23.2
Total Semiconductor Memory	2.3	6.6	16.2	48.6	106.9	159.1
Total Core Memory	50.0	53.0	60.0	65.0	72.0	68.0

	1976	1977	1978	1979	1980	1981
MOS Memory	267.7	482	848	1,292	2,284	3,926
RAMs	155.1	269	454	671	1,153	1,942
Dynamic	126.8	230	396	576	999	1,689
Static	28.3	39	58	95	154	253
ROMs	104.8	183	324	524	1,000	1,792
EPROMs	7.8	30	70	97	131	192
Bipolar Memory	82.2	161	260	405	600	1,050
RAMs	28.9	61	110	155	250	410
ROM/PROM	53.3	100	150	250	350	640
Total Semiconductor Memory	349.9	643	1,108	1,697	2,884	4,976
Total Core Memory	74.0	84.0	98	104	118	135

N.A. Indicates that product was not yet introduced.

Source: DATAQUEST, Inc.

Table 2.8.6-15

ESTIMATED AVERAGE SELLING PRICES OF MOS MEMORY
(Millicents per Bit)

	1975	1976	1977	1978	1979	1980	1981
MOS Dynamic RAMs							
1K	350	300	250	220	200	190	180
4K	225	144	106	88	75	65	56
16K	N.A.	188	119	75	47	33	24
64K	N.A.	N.A.	N.A.	85	55	25	19
MOS Static RAMs							
1K (weighted average)	275	200	192	182	165	161	154
4K	750	375	225	150	120	103	90
16K	N.A.	N.A.	N.A.	113	69	53	42
MOS ROMs							
4K	118	95	75	55	40	26	N.A.
8K	100	82	65	45	35	25	N.A.
16K	N.A.	80	40	30	22	16	14
32K	N.A.	N.A.	50	35	22	15	12
64K	N.A.	N.A.	70	50	28	14	10
128K	N.A.	N.A.	N.A.	60	36	18	9
MOS EPROMs							
2K	1,050	400	250	175	150	140	125
8K	1,000	650	188	125	100	88	81
16K	N.A.	N.A.	344	138	94	75	63
32K	N.A.	N.A.	N.A.	N.A.	125	88	59

N.A. Indicates product not available

Source: DATAQUEST, Inc.

market were Intel, Texas Instruments, and Mostek with an estimated 25, 11, and 8 percent share of the market respectively. Japanese firms collectively had an estimated 7 percent of the MOS market while European firms collectively had 3 percent. The interesting question for the future is which firm will have the dominant market share.

Bipolar Market Shares

Table 2.8.6-18 shows our market share estimates for the bipolar memory market in millions of dollars for the period 1974 to 1976. Table 2.8.6-19 shows bipolar memory market share estimates expressed as a percent of the total.

Fairchild is the dominant participant in this market, with a 25 percent share of the 1976 bipolar memory market. Signetics and

2.8.6 Semiconductor Memory Markets

Monolithic Memories followed with a 16 and 14 percent share of the total market in 1976. Within the bipolar RAM market, Fairchild had a very dominant 45 percent share of the market in 1976, followed by Signetics with 22 percent. In the 1976 ROM/PROM market, Monolithic Memories was the leader with 23 percent followed by Harris with 19 percent.

Future Competitive Factors

Several important factors will eventually affect the semiconductor memory market. These factors include the potential impact of Japanese semiconductor firms, competitive moves by IBM, and problems related to standardization.

Impact of Japanese Firms

The Japanese government has been funding basic research and development of VLSI (Very Large Scale Integration) for several years. Japanese firms are now entering the American market with high quality and high speed N-channel MOS random access memory. In 1977, they have made significant shipments of 4K RAMs to U.S. firms. We expect them to become a major factor in the worldwide memory markets over the next five years.

Impact of IBM

IBM computers still use the basic 2K bit static N-channel MOS memory chip, which was introduced by IBM in 1972. Four of these chips are packaged into a single 8K bit memory module. This memory module forms the memory for most of IBM's computer systems today. IBM is expected to make a change in its memory components soon to upgrade to the 16K or 64K chip. What IBM does will set some standards for semiconductor memory and have an impact on the memory market. The recent heavy demand for IBM computers is placing

Table 2.8.6-18

ESTIMATED MARKET SHARES OF BIPOLAR MEMORY PRODUCERS
(Dollars in Millions)

	Total			RAMs			ROMs/PROMs		
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Fairchild	$ 23	$21	$ 34	$18	$16	$25	$ 5	$ 5	$ 9
Harris	12	10	15	0	0	0	12	10	15
Intel	9	8	9	2	1	1	7	7	8
Intersil	13	8	10	8	5	4	5	3	6
MMI	21	17	19	3	1	1	18	16	18
Motorola	1	1	3	1	1	3	0	0	0
National	2	2	5	1	1	2	1	1	3
Signetics	10	8	22	5	4	12	5	4	10
TI	12	9	16	5	4	6	7	5	10
Others	9	14	2	5	7	1	4	7	1
Total	$112	$98	$135	$48	$40	$55	$64	$58	$80

Source: DATAQUEST, Inc.

2.8.6 Semiconductor Memory Markets

Table 2.8.6-19

ESTIMATED MARKET SHARES OF BIPOLAR MEMORY PRODUCERS
(Percent of Total)

	Total			RAMs			ROMs/PROMs		
	1974	1975	1976	1974	1975	1976	1974	1975	1976
Fairchild	21%	21%	25%	38%	40%	45%	8%	9%	11%
Harris	10	10	11	0	0	0	19	17%	19%
Intel	8	8	7	4	3	2	11	12%	10%
Intersil	12	8	7	17	12	7	8	5%	8%
MMI	19	18	14	7	3	2	28	28%	23%
Motorola	1	1	2	2	3	5	0	0%	0%
National	2	2	4	2	3	4	1	2%	4%
Signetics	9	8	16	10	10	22	8	7%	12%
TI	10	9	12	10	10	11	11	8%	12%
Others	8	15	2	10	16	2	6	12%	1%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: DATAQUEST, Inc.

extreme requirements on the IBM semiconductor facilities to produce the necessary memory modules and memory boards. The impact of this heavy demand will most likely precipitate an upgrade of the IBM memory module and thus have an impact on the add-on memory business.

Need for Standardization

Standards for memory components have been and will probably always continue to be a problem among semiconductor manufacturers. Although the 16-pin 4K NMOS memory package appears to be standard, it is not; several performance differences exist in the various 16-pin configurations. Therefore, there is a need for greater standardization, but it is expected that this need will be satisfied very slowly.

At present, Mostek has a competitive advantage because—in the 4K and 16K RAMs—its pin configuration and performance specifications have become the industry standards.

TECHNOLOGY FORECAST

MOS technology is expected to continue its record pace of development over the next five years. Major advances expected include an imaging and processing capability to enable the patterning of two-micron lines and gaps needed for the 64K dynamic RAM. Furthermore, processing and design enhancements are expected that will enable dynamic MOS RAMs to have sub-100 nanosecond access times by 1978 and static MOS RAMs to have sub-40 nanosecond access times by 1978. Additionally, E-Beam technology is expected to be available on a production basis by 1980 to enable the evolution to the 256K dynamic RAM.

In bipolar technology, major advances are expected in low-power Schottky and very fast ECL (less than one nanosecond access time). Bipolar technology is under pressure to offer speed advantages because NMOS technology is already approaching the access times available with TTL technology. Higher densities and faster speeds are the main advances expected in bipolar devices.

2.8.4 Add-On Computer Memory

SUMMARY

The add-on memory market consists of memory products added to computer systems after they are installed in the field. This need is created as new applications are added to the system, or as the volume of data being processed increases. The market is directly related to the installed base of computer CPUs and includes memory boards and systems added to the CPUs of IBM and the other large mainframe suppliers, as well as Data General, Digital Equipment Corporation (DEC), and other minicomputer manufacturers.

The market can be segmented into three submarkets. The first is the end-user-oriented market for adding memory to IBM 360, 370, and System 3 computers. In 1976, this market had an end-user equipment sales value of $140 million and an OEM value of $72 million; by 1981, it is projected to grow to $280 million end-user if-sold value and $135 million OEM. This market is primarily semiconductor memory systems for addition to IBM system 370 computers. The manufacture of 360/370 add-on memory is dominated by semiconductor suppliers such as Intel, Intersil (formerly Advanced Memory Systems), and National Semiconductor; marketing and leasing are handled by third parties such as Computer Investors Group (CIG), Control Data Corporation (CDC), Itel, Memorex, and Storage Technology Corporation (STC).

The second market segment is the add-on products for general purpose mini and microcomputers. These systems have well-defined card cage sizes and electrical interfaces that make possible "add-in" memories which fit inside the CPU enclosure and derive their power from the CPU power supply. The primary target in this market is the large installed base of DEC PDP-11 and PDP-8 processors. Add-on/add-in products are available for all popular minicomputers. This market is currently dominated by core suppliers, including the core systems manufactured by Data General and DEC. This predominantly OEM market had estimated sales of $52 million in 1976; the expected market size is $125 million by 1981.

The third market segment includes both custom and standard memory modules and systems manufactured for dedicated systems. This is the oldest and largest of the three segments, with an OEM market size in 1976 of $120 million that should grow to $290 million by 1981. Like the minicomputer market, this segment is served by over 30 manufacturers that offer over 100 standard memory boards, modules, and systems employing both core and semiconductor technologies. The latter is rapidly increasing market share. Market share is not highly concentrated.

The total add-on memory market is estimated at $244 million in 1976; it should grow at about an 18 percent compound annual rate to an estimated $550 million in 1981. The number of bits of memory shipped is expected to grow even faster—from 41 billion bits in 1976 to 202 billion bits in 1981. This represents a 37 percent compound annual growth rate in bits shipped over the forecast period. The add-on memory market is summarized in Table 2.8.4-1.

As the market shifts from core to semiconductor due to the falling prices of semiconductor devices, the dollar volume of semiconductor OEM memory systems is expected to grow from $120 million in 1976 to $450 million in 1981. This is about a 30 percent growth rate and an expansion from 49 percent of the OEM dollar market to 82 percent of the market by 1981.

The potential market for semiconductor memory devices in add-on products is expected to increase from $24 million in 1976 to just under $77 million in 1981, which represents a 26 percent growth rate. In semiconductor memory systems, the cost of the memory devices currently averages close to 20 percent of the OEM

2.8.4 Add-On Computer Memory

Table 2.8.4-1

SUMMARY OF ESTIMATED ADD-ON MEMORY MARKET 1976-1981 (Dollars in Millions)

	1976	1981	Compound Annual Growth Rate
Total OEM Add-on Memory	$244	$550	17.7%
Core Add-on	124	100	-4.2%
Semiconductor Add-on	120	450	30.3%
Semiconductor Devices	24	77	26.3%
Devices as Percent of OEM System Dollars	20%	17%	-

Source: DATAQUEST, Inc.

sales price. Due to the increase in memory sizes and the decreasing costs of semiconductors relative to other system components, this is expected to decrease to 17 percent by 1981. The semiconductor memory content of add-on systems is primarily MOS devices, with some limited use of bipolar RAM in higher performance cache memory systems.

Toward the end of the forecast period, more intelligent memory systems will be introduced that provide full management of large memory systems under the control of a local processor. Moreover, systems and boards utilizing CCD and bubble memory devices should be common by 1981.

INTRODUCTION AND BACKGROUND

Overview

Add-on memory refers to memory modules or subsystems added to a computer system after it is in the field. Memory may be added to large mainframes such as the IBM 360 and 370 series, as well as standard minicomputers and microcomputers such as those manufactured by Data General and DEC. The term "add-on" generally is used to describe a stand-alone subsystem attached to the host system as a replacement for, or in addition to, the original system main memory. A similar term—"add-in" memory—refers to circuit cards containing additional memory inserted in the card slots in the CPU. This latter type of memory usually draws its electrical power from the power supply in the host. Add-on and add-in memory products are supplied by the computer system manufacturers as well as a number of independent suppliers of memory systems.

The add-on memory market is a direct function of the installed base of computer systems as opposed to the market for main memory for use with new system shipments. Add-on memory must be electrically, and in the case of add-in memory, physically compatible with the memory originally shipped with the system.

Each computer manufacturer has developed policies for handling maintenance and service of its CPUs with "foreign" memory attachments. In the case of large IBM-oriented systems, the memory system can be made transparent to the CPU by software; therefore, it is not attached to the system during maintenance operations. Many smaller systems are under third-party maintenance agreements, and the computer manufacturer is no longer responsible for the system operation or reliability.

Market Segmentation

The add-on memory market is divided into three segments for this analysis and forecast. The first segment is the large mainframe add-on memories for systems such as the IBM 360 and 370. Add-on memory is also available for mainframes of other manufacturers and the IBM System 3. The second segment is the market for memory systems and modules for use with general purpose minicomputers and microcomputers. Such products must be bus-compatible with the host mini or micro; for add-in products, they must also fit the card rack inside the CPU. The third segment includes custom memory modules and systems, as well as standard products that do not meet any general CPU interface standard.

Market Development

The large mainframe market evolved in response to the need for memory extension to the aging 360 series computers during the time of the introduction of the 370 series. During this time (in the early 1970s), the non-IBM owners of 360s (e.g., users who had purchased systems and the third-party leasing firms with extensive 360 portfolios) wanted to extend the life of their 360s because they could avoid the need to upgrade to a 370 (which, in the case of the leasing firms, would protect their lease portfolios). A number of core memory systems were developed for all sizes of 360 systems, which were quite successful in extending the life of that product family.

The minicomputer add-on memory market started at about the same time. Independent firms began to offer memory boards based on core technology for use by systems houses and system users as a lower cost alternative when memory expansion was necessary. As the installed bases of the leading minicomputer manufacturers grew, more firms entered the market and new and improved products were made available.

The custom and standard systems market has always existed to provide memory boards and subsystems for special or low-volume systems and higher volume dedicated systems such as industrial control and intelligent terminals. Many of the current minicomputer add-on memory suppliers began by supplying custom core and semiconductor memory products. In this segment are also memory systems that use other than RAM techniques, such as cache memory systems and CCD-based memory boards and subsystems.

Add-On Memory Products

Products in the add-on memory market range from complete subsystems containing power supply, storage, interface, diagnostics, and error correction (such as that supplied for use with a system 370) down to small core memory modules or circuit boards used in programmable calculators. The minicomputer and microcomputer products are generally circuit boards with the proper dimension and connector to fit the card slot of the host CPU. These add-on memory boards and subsystems may use either semiconductor or core technology. Prices range from over $200,000 for a 2-megabyte 370 add-on to $6,000 for a 16K word minicomputer memory and further down to a $500 core memory card used with 8080 based microcomputer systems.

End User and OEM Markets

Memory products may take a variety of paths to reach the end-user computer site. In the case of the large IBM-oriented systems, sales are directed to the system owner or renter who contracts for the additional memory for his system. The system may be either sold or leased, with service contracts for system maintenance. The primary end-user marketing organizations are the leasing companies such as Itel and the plug-compatible peripheral suppliers with established marketing, leasing, and service capabilities such as CDC, Memorex, and STC.

The OEM market refers to sales of systems to systems houses that combine the CPU, memory, peripherals, software, and applications expertise to provide a complete system to the end user. In this case, the sale or lease of the system is by an independent system integrator who must ensure that the system performs as required. Both minicomputer add-on and the custom/standard memory products are primarily OEM markets. A small percentage of the small computer add-on memory is sold to the computer owner, but usually these owners are universities or laboratories that have put the system together and provide their own programming and maintenance.

In the past, computer CPU manufacturers such as IBM have been forced to make policy decisions regarding maintenance of their equipment with independent add-on memory. IBM has consented to continue maintenance contracts for systems containing add-on memory not manufactured by IBM after a "certification" of the product to ensure that it meets all IBM specifications, and can be electrically removed from the system for IBM maintenance of the CPU and other equipment. Since only a small percentage of the minicomputers built by, for example, DEC are maintained by DEC, a serious problem does not exist. Most computer manufacturers make available the specification for the bus interface to their systems to aid systems houses in using the equipment. This facilitates the design of add-on memory, particularly for minicomputers and microcomputers.

Advantages of Independent Add-On Memory

All computer manufacturers provide add-on memory boards or systems for use with their computers. Why then does a market exist for independents to supply equivalent memory products to computer users and systems houses? The primary consideration is cost; until recently, the minicomputer manufacturers and the large mainframe manufacturers were charging premium prices for add-on memory since it was a sole source item. As competition developed, prices have decreased rapidly for both the computer suppliers and the independent memory producers. The price differential is generally in the 20 to 40 percent range, which is enough to attract all but the most conservative of computer users.

Another major reason for the independent market is increased performance. The IBM 360 series, like all IBM computers, was limited concerning the amount of main memory that could be attached to each model. These limits were structured so that the user would switch to a larger CPU when memory sizes beyond the limits were needed. The 360 add-on products offered memory extension beyond the IBM limits and increased system performance due to faster memory and CPU cycle times. The 370 series computers are not as memory limited as the 360 series, but the independents are prepared to offer memory performance and options not available from IBM when the need arises.

In the OEM market, alternate sources of compatible memory products are available, which makes possible multiple sources and competitive bidding for large OEM quantities of memories. The competitive nature of the independent memory market also provides alternative technologies such as core or semiconductor to suit the particular application. Some enhanced products—such as multiport memories—are available for minicomputers that make them well-suited to multiprocessor environments. Similar products can be expected for the larger computers in the future.

MARKETS AND COMPETITION

Overview

The add-on memory market for independents was relatively small in 1970, when it had

2.8.4 Add-On Computer Memory

grown to include only custom and standard products built for dedicated computer systems. In recent years, both the IBM compatible and general purpose minicomputer compatible markets have grown rapidly. In 1976, the total add-on memory market worldwide was estimated at $244 million, with a total of 41 billion bits shipped in modules and systems. By 1981, this market is expected to grow to $550 million, with a total of 202 billion bits shipped. Dollar volume is forecasted to grow at a 17.7 percent annual rate; annual bits shipped should grow at a 37.4 percent annual rate. The difference in growth rates is directly related to decreases in memory cost and the highly elastic nature of the market.

In the past five years, the cost of main memory has declined to the point where it is now feasible to trade off memory cost for other system costs or problems. One method is to use complex software operating systems that use large amounts of main memory but keep the system more efficient by allocating and scheduling resources more effectively than programmers. A second method, even in smaller systems, is to trade off more memory for increased programmer productivity by using high-level languages. The use of language interpreters increases memory size and reduces processor performance for a given job; however, lower hardware costs make it possible to compensate for these problems. A third method of recent innovation that contributes to the increase in memory is the use of memory management or virtual memory techniques. This allows the CPU to address considerably more memory than would be practical or economical in older systems. Virtual memory is a derivative of the memory paging techniques developed for use with time-sharing systems. Finally, another contribution is the unspoken truth of Parkinson's laws applied to computer memory: data expands to fill the memory available and memory expands to fill the budget available. As memory costs decrease, users find it possible to add ever larger increments of memory to their computer systems.

Table 2.8.4-2 summarizes the three segments of the add-on memory market. To avoid confusion, care should be taken in this and subsequent tables to differentiate between OEM and retail values and bits and bytes. The end-user price or market is approximately twice the OEM levels. Prices for 360/370 add-on products at the end-user level are on an if-sold basis, although most of these products are leased to end users under various types of agreements.

The add-on market for the large mainframes is served by only a few companies; the other two market segments each have between 20 and 30 suppliers, depending upon the specific product. As these markets change from core to semiconductor for primary technology, the semiconductor manufacturers such as Intel, Intersil, and National should increase their share of the market. Table 2.8.4-3 illustrates the shift in market dollars and bits among the three segments during the forecast period. As can be seen, we expect the 360/370 add-on market to decline in its share of dollars and bits, while the other segments gain in dollar share. The custom/standard module and system segment looks attractive; however, this market is comprised of a number of fragmented submarkets with a relatively large number of small suppliers competing with a few large memory manufacturers.

Add-On Memory Suppliers

The manufacturers of add-on memories include the core memory suppliers, several semiconductor companies, and a large number of assemblers. Upwards of 50 companies supply some type of add-on memory product for use with both general purpose and dedicated computer systems. Intense competition exists between the suppliers of CPUs and the indepen-

2.8.4 Add-On Computer Memory

Table 2.8.4-2

SUMMARY OF ESTIMATED INDEPENDENT ADD-ON MEMORY MARKET

	1976	1977	1979	1981	Annual Growth Rate (1976-81)
360/370 Add-on OEM Market (Millions of Dollars)	$ 72	$ 79	$ 110	$ 135	13.4%
Average Price Per Bit (Cents)	1.10¢	0.90¢	0.73¢	0.60¢	-11.4%
Market Size (Millions of Bits)	6,550	8,800	15,000	22,500	28 %
Minicomputer Add-on OEM Market (Millions of Dollars)	$ 52	$ 66	$ 98	$ 125	19.2%
Average Price Per Bit (Cents)	0.40¢	0.35¢	0.25¢	0.15¢	-17.8%
Market Size (Millions of Bits)	12,900	18,700	39,550	82,500	45 %
Custom and Other Memory OEM Market (Millions of Dollars)	$ 120	$ 143	$ 205	$ 290	19.3%
Average Price Per Bit (Cents)	0.55¢	0.50¢	0.40¢	0.30¢	-11.4%
Market Size (Millions of Bits)	21,800	28,600	51,000	97,000	35 %
Total Add-on Market OEM Market (Millions of Dollars)	$ 244	$ 288	$ 413	$ 550	17.7%
Average Price Per Bit (Cents)	0.59¢	0.57¢	0.39¢	0.27¢	-14.5%
Market Size (Millions of Bits)	41,250	56,100	105,550	202,000	37.4%

Source: DATAQUEST, Inc.

2.8.4 Add-On Computer Memory

Table 2.8.4-3

ESTIMATED PERCENT SHARE OF TOTAL ADD-ON MEMORY MARKET BY SEGMENT - 1976 To 1981

	1976	1981
360/370 Add-on		
Percent of Total Dollars	29.5%	24.6%
Percent of Total Bits	15.9	11.1
Minicomputer		
Percent of Total Dollars	21.3%	22.7%
Percent of Total Bits	31.3	40.9
Custom/Standard		
Percent of Total Dollars	49.2%	52.7%
Percent of Total Bits	52.8	48.0

Source: DATAQUEST, Inc.

dent add-on memory suppliers. Major independent suppliers are Ampex, Cambridge Memories, Electronic Memories & Magnetics (EM&M), Fabri-tek, Intel, Intersil, Lockheed, Monolithic Systems, National, Plessey Memories, and Standard Memories. A complete listing of the suppliers of core and semiconductor add-on memory is given at the end of this subsection. Table 2.8.4-4 shows the participation in various market segments by the major independent suppliers.

The independent market for semiconductor add-on memories has been increasingly dominated by semiconductor manufacturers. In 1976, Intel, Intersil, and National Semiconductor were all major producers, each with revenues close to $30 million. Of this, the three companies produced an estimated $63 million of IBM add-on memories, with Intersil having the largest share. As other semiconductor companies become more firmly established in these markets, however, market shares may show major changes.

Large Mainframe Market

This segment of the add-on memory market is directly related to the installed base of IBM 360, 370, and System 3 computers (see Table 2.8.4-5). Although the installed base of 360s is now declining, it has been a strong market for independently supplied add-on memory. In 1976, the 360 segment accounted for about one-third of dollar sales of add-on memory. The System 3 market has seen only limited sales and competition and is a very small part of the total market.

The IBM-compatible market was started in the early 1970s when the new IBM 370 was a substantial competitive threat to the non-IBM owned 360 installed base. These machines were owned primarily by third-party leasing companies that were leasing them in direct competition to IBM, but at lower monthly rates. The lower rates were made possible by depreciating the equipment over an eight- to ten-year period instead of the usual five years. As a result, a considerable need developed to keep the 360s on rent despite the introduction of the new and attractive 370 line.

A number of enhancements were developed for the 360s including better software, attachment of 370 peripherals, and the addition of larger, faster main memory. These main memory products were primarily core since the 360 was a core machine and semiconductor technology was not price-competitive at that time. As the 360 portfolio began to be phased out in 1975 and 1976, the attention of the third-party leasing companies turned to enhancements for the growing number of 370s they were placing on lease. By 1974, the 370 memory interface was sufficiently defined to permit wide-scale attachment of memory to the 155 and 165 models that IBM had introduced and then abandoned in favor of the virtual

Table 2.8.4-4

MARKET PARTICIPATION OF MAJOR INDEPENDENT MEMORY SYSTEM MANUFACTURERS

	Technology		Markets		
Company	Core	Semi	360/370	Mini/Micro	Custom
Ampex	x			x	x
Cambridge Memories	x	x	x	x	x
Control Data	x			x	x
Dataproducts	x			x	x
Dataram	x		x	x	x
EM&M	x	x	x	x	x
Fabri-tek	x		x	x	x
Fairchild		x		x	x
Harris (Datacraft)	x			x	x
Intel		x	x	x	x
Intersil (AMS)		x	x	x	x
Lockheed	x			x	x
Monolithic Systems		x		x	x
Motorola		x		x	x
National Semiconductor		x	x	x	x
Plessey	x			x	x
Standard Memories	x			x	x

Source: DATAQUEST, Inc.

Table 2.8.4-5

ESTIMATED WORLDWIDE INSTALLED BASE OF IBM COMPUTER SYSTEMS (Thousands of Units)

	1976	1978	1981
System/370	32	38	45
System/360	10	7	5
System/3	37	41	45
Total	79	86	95

Source: DATAQUEST, Inc.

memory versions called the 158 and 168. These computers are the upper end of the 370 line; they are the CPUs that need memory expansion the most due to the substantial software overhead of the complex operating systems used in their large installations.

With the IBM VS 370 introductions came the widespread use of MOS semiconductor memory in the 370 line. With this IBM blessing of semiconductor memory, the add-on suppliers introduced semiconductor-based memory systems for the 158 and 168. The 158 and 168 users were sophisticated users accustomed to dealing with independent vendors for memory and peripherals. At prices that saved the user up to 40 percent of normal monthly rental, many users quickly accepted the independent 158 and 168 memory. During 1976 and 1977, the new models pursued by the add-on suppliers are the 145 and 148, and the 135 and 125 small systems.

The market for IBM add-on memory is shown in Tables 2.8.4-6 and 2.8.4-7. To date, the independents have been able to capture approximately 20 percent of the sites in the IBM installed base for a given processor; consequently, they predict this same rate of success with the other models. Although it is unlikely that IBM would complicate the attachment of foreign memory systems any more than was done in the design of the 370, some system changes could decrease the effectiveness of the independent memory. Perhaps the most effective potential competitive edge IBM has is price; during 1976, the company reduced the prices of many memory products by as much as 35 percent. It can be expected that the product introductions will see further decreasing prices for 370 memory products.

The current IBM product lines—the 360, 370 and System 3—represent different stages in the product maturity cycle; however, all three are now mature products. It is relatively apparent that IBM will not introduce a major new series of computers in the near future. Instead, the company is expected to introduce evolutionary changes in the 370 series directed at conversion to virtual storage and distributed processing. This provides a stable 370 market in terms of technology and one in which the independents who manufacture their own semiconductors can expect to remain quite competitive.

Despite the large number of System 3 computers installed worldwide, little attention has been given to this market. The reasons are the relatively low prices for these smaller products (typically, 32K to 64K words) and the high marketing expenses. A few of the smaller firms have introduced products for this market; however, fewer than 1,000 systems have been installed to date, whereas close to 3,000 360/370 add-on systems have been installed by independents worldwide. Firms supplying System 3 add-on memory include CFI Memories, Fabri-tek, and Business Systems Technology; all of these suppliers use core memory.

Table 2.8.4-6

ESTIMATED 1976 WORLDWIDE IBM ADD-ON MEMORY MARKET (360, 370 and System 3 At If-Sold Market Value)

	Independents	IBM	Total
Units Shipped	1,200	3,715	4,915
Average Size (Megabytes)	0.5	0.4	0.44
Total Memory Shipped (Megabytes)	655	1,485	2,140
Average Price/Byte (Cents per Byte)	21¢	30¢	27¢
End User Market (Millions of Dollars)	$140	$445	$585
OEM Market (Millions of Dollars)	$ 72	-	-

Source: DATAQUEST, Inc.

Of the original ten suppliers of 360 add-on memory, few are active in the 370 market. With the exception of EM&M, none of the other core suppliers have developed a semiconductor capability. EM&M, Fabri-tek, and Lockheed remain the primary suppliers of core for 360 sites. The 360 market currently accounts for about 30 percent of sales; however, this is expected to decrease rapidly as the 360 and 370/155 and 370/165 markets saturate.

During the past three years, the semiconductor companies that participated in the add-on memory market have come to dominate it. The top three are Intel, Intersil, and National; combined, these companies have over 80 per-

2.8.4 Add-On Computer Memory

Table 2.8.4-7

ESTIMATED IBM ADD-ON MEMORY MARKET
SERVED BY INDEPENDENTS
1976-1981

	1976	1977	1979	1981	Annual Growth Rate
Total Market (Millions of Dollars)	$585	$650	$825	$1,125	14.0%
End User Price (Cents per Byte)	27¢	24¢	18¢	16¢	- 9.9%
Total Memory Shipped (Millions of Bytes)	2,140	2,700	4,500	7,025	26.8%
Independent Market (Millions of Dollars)	$140	$160	$220	$280	14.9%
Independent Market Share	24%	25%	27%	25%	-
Independent Units Shipped	1,200	1,350	2,500	4,500	30.3%
Independent Memory Shipped (Millions of Bytes)	655	880	1,500	2,250	28.0%
Average System Size (Megabytes)	0.55	0.65	0.60	0.50	-

Source: DATAQUEST, Inc.

cent of the 360/370 add-on memory market at the OEM level. The core memory suppliers that were active in the 360 market have redirected their efforts into the minicomputer and custom markets where core is still a major factor.

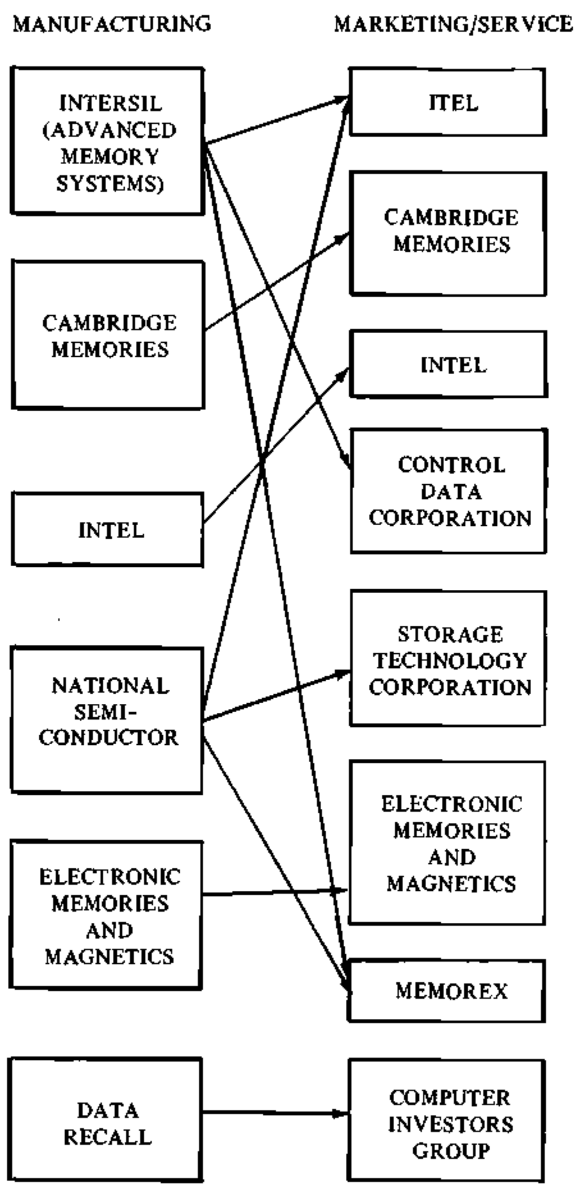
Over 90 percent of the large add-on memory systems are marketed by organizations other than those that build the products. Market outlets for large add-on memory systems include third-party leasing companies such as CIG (a part of General Electric), Itel, and established IBM plug-compatible products suppliers such as CDC, Memorex, and STC (see Figure 2.8.4-1). Moreover, Intel and EM&M have end-user marketing groups. Figure 2.8.4-1 depicts the manufacturing/marketing relationships existing in the IBM-compatible add-on memory market.

A number of consolidations and acquisitions have occurred in this market in recent years. In 1974, CDC bought Memory Technology and its installed base; in the same year, Fabri-tek bought Data Recall and established CIG as the sole end-user marketing outlet for the Data Recall products. In late 1976, EM&M bought the installed base of 360 and 370 memory systems from Cambridge Memories, which gave EM&M the largest installed base in the industry. Cambridge Memories was one of the early suppliers of both core and semiconductor based add-on products. The firm successfully integrated into the manufacture of semiconduc-

2.8.4 Add-On Computer Memory

Figure 2.8.4-1

MANUFACTURING MARKETING RELATIONSHIPS IN THE 360/370 ADD-ON MEMORY MARKET



Source: DATAQUEST, Inc.

tor devices; however, this cash drain, along with the financing of a rental installed base, brought the firm to Chapter XI. It was at this time that EM&M purchased the Cambridge Memories installed base.

It appears that the shakeout in the IBM add-on market has reduced the number of viable suppliers to four or five, with a two-tier market for manufacturing and marketing. The marketing organizations generally also provide the maintenance and service for the memories. It appears that the 370 add-on market at the OEM level belongs to the semiconductor manufacturers and the one or two memory suppliers who have vertically integrated. The semiconductor suppliers are expected to continue dominating the manufacturing of add-on memory systems, with the primary market access being OEM sales to marketing organizations with service and leasing capabilities.

Minicomputer/Microcomputer Market

The minicomputer/microcomputer add-on memory segment contains products designed to be plug- or bus-compatible with the general purpose minicomputer and microcomputer products. The independents compete directly with the mainframe or CPU suppliers for this market. The total market—including sales by CPU manufacturers and independents—will be presented and analyzed.

The 1976 market for add-in memories is estimated at 12.9 billion bits and $52 million, as shown in Table 2.8.4-8. By 1981, this market is expected to grow to 82.5 billion bits and $125 million, which represents a dollar growth rate of 19 percent and a bit growth rate of 45 percent. During this time, the installed base of minicomputers worldwide is expected to grow from 285 thousand units to 1.2 million units, a 33 percent annual rate of increase.

Add-on minicomputer memory is primarily single board memory modules ranging from 1K words to 128K words; this translates to a range of 32K bits to 5 million bits per module. These products plug into the standard connectors in the computer chassis and obtain their power directly from the system power supply. A small portion of the market is complete memory systems for use with minicomputers. Approximately 10 percent of the market is considered to be end user, which means that products are sold directly to the computer owner/user.

Minicomputer products include add-in memories for most popular minicomputers such as the DEC PDP-11 series, PDP-8, and LSI-11, the Data General Nova Series, Hewlett-Packard, Interdata, Microdata, and Varian CPUs. DEC claims to have over 50,000 computers installed. The independent suppliers have apparently sold memories to only about 1 percent of the DEC installed base.

Products are sold to OEMs who incorporate the memory devices in a minicomputer-based system such as a remote batch terminal or machine tool controller. Additional units go to systems houses that assemble hardware and then write applications programs for specialized applications. As indicated earlier, an estimated 10 percent of the shipments go directly to computer owner/users.

The minicomputer add-on market is extremely competitive with some 30 suppliers offering over 100 different products using both core and semiconductor technologies. Recent entry into the market has been announced by Fairchild, Mostek, and Motorola.

In addition to the suppliers of minicomputers, major suppliers of small computer add-on memory are Ampex, Cambridge Memories, Dataproducts, Dataram, EM&M, Fabri-tek, Harris (Datacraft), Intel, Monolithic Systems, Plessey Memories, and Standard Memories.

The core versus semiconductor competition is intensifying in this market, with prices in the 0.2 cent to 0.4 cent per bit range for most single board products. The CPU manufacturers

Table 2.8.4-8

GENERAL PURPOSE MINICOMPUTER ADD-ON MEMORY MARKET

	1976	1977	1979	1981	Annual Growth Rate
Worldwide Minicomputer Installed Base (Units in Thousands)	285	395	680	1,200	33%
Minicomputer Add-On (Megabits)	12,900	18,700	39,550	82,500	45%
Average Price per Bit (Cents)	0.40¢	0.35¢	0.25¢	0.15¢	-18%
Market Size (Dollars in Millions)	$ 52	$ 66	$ 98	$ 125	19%

Source: DATAQUEST, Inc.

have become quite competitive in the last two years in an attempt to retain their share of the market.

In the microcomputer market, the Altair (MITS) and IMSAI computers have standard bus configurations that lend themselves to add-in memory products. These systems currently have a relatively small (under 10,000 units) non-consumer installed base.

Custom and Standard Memory Products

The custom and standard memory market segment includes memory products of both the custom and standard type that are not designed to interface with the popular minicomputers or microcomputers. This is the oldest and largest of the markets, and although it is not in the true sense an add-on market, it is of importance since it is a related market in which most of the suppliers in the other segments are active; furthermore, it is one of the fastest growing of the memory markets. Products included in this market go into new systems as well as for add-on. In most cases, these systems are dedicated, such as in the case of programmable calculators or intelligent terminals.

This market segment accounted for an estimated 21.8 billion bits, with an OEM market value of about $120 million in 1976, as shown in Table 2.8.4-9. By 1981, this market is expected to grow to 96.7 billion bits and $290 million in sales, which represents a 19 percent growth rate for dollars and a 35 percent rate for bits. Approximately $50 million, or 42 percent of the 1976 market, was custom products; this percentage is expected to remain relatively constant throughout the forecast period.
Included in this segment are memory products other than RAM. Some products have already been introduced using devices and this trend—particularly CCD and bubble memories—is expected to continue. Suppliers are basically the same as in the minicomputer segment, with the addition of Intersil, Lockheed, and National.

MEMORY TECHNOLOGY AND COSTS

Semiconductor Versus Core

The primary competing technologies in the add-on memory market are magnetic core and MOS semiconductor. Despite forecasts of the demise of core due to semiconductor memory, core is still a major factor in the memory market; it continues to make incremental improvements in product cost. Moreover, core relies on its advantages of familiarity and non-volatility if price is the same. In general, semiconductor memory is more cost-effective in small memories, and core memories have better cost in large memories; this crossover is currently in the 16K to 32K word range. Below that level, semiconductor memories using 4K MOS RAMs are clearly less expensive. Above that, core shows a cost advantage but not a performance advantage. Thus, in large high-performance memories such as those used on the system 370s, IBM and the independents are exclusively using semiconductor memory devices.

Overall, core still accounts for close to 60 percent of the total add-on memory market. This share is expected to decrease rapidly to 20 percent by 1981, but core should not be completely eliminated from the market in the near future. In fact, in some applications where non-volatility and noise immunity are critical, core is expected to continue to be the predominant memory technology. The larger, business-oriented systems with disk memory can make effective use of large quantities of semiconductor main memory since the disk is a non-volatile back-up store. This type of application should dominate the computer market in the next five years, and create a substantially increased use of semiconductor memory in both large and minicomputer systems.

Table 2.8.4-9

ESTIMATED CUSTOM/STANDARD MEMORY MODULE MARKET

	1976	1977	1979	1981	Annual Growth Rate (1976-81)
Number of Bits (Megabits)	21,800	28,600	51,000	96,700	34.7%
Average Price Per Bit (Cents)	0.55¢	0.50¢	0.40¢	0.30¢	-11.4%
Market Size (Dollars in Millions)	$ 120	$ 143	$ 205	$ 290	19.3%

Source: DATAQUEST, Inc.

Memory Costs

The minicomputer memory market provides an effective example of rapid decrease in the cost of semiconductor memory. A 32K by 16-bit memory built in 1976 using 2K RAMs sells for $4,500 at the OEM board level; to obtain a 64K memory, two of these boards at a total cost of $9,000 would be required. During 1977, a single board 64K by 16-bit memory built using 4K RAMs will sell for approximately $3,000. A direct cost breakdown is shown in Table 2.8.4-10. Since the 1K, 4K, and 16K MOS RAMs will all use a 16- or 18-pin package, they are interchangeable from a space standpoint. The number of packages, circuit boards, and assembly cost remain the same; the major differences are the cost of the chips and the chip density at any given time. This permits the cost of semiconductor memory to drop in direct proportion to the declining chip cost.

Table 2.8.4-10

TYPICAL COST ANALYSIS – MINICOMPUTER MEMORY BOARD
Size: 64K x 16 Bits, Semiconductor
(One Million Bits)

256 4K RAMS @ $4.00	$1,024
Miscellaneous TTL Logic	26
Circuit Board, Hardware	50
Total Materials Cost	$1,100
Assembly, Test, Rework	50
Total Direct Cost	$1,150
Quantity OEM Selling Price	$3,000
Cost Per Bit	0.3¢
Semiconductor Percent of Selling Price	35%

Source: DATAQUEST, Inc.

Core memory, on the other hand, is fabricated in mats of cores strung together by fine wires. The larger the total number of bits and the wider the data word, the more economical core can be. Current price levels for large core boards are under 0.2 cent per bit; smaller memories in small OEM quantities are in the 0.4 cent per bit range area.

A recent advertisement for a PDP-8 add-in memory with 8K by 12 bits had a quantity one OEM price of $695 or 0.72 cents per bit. A product of this type with a large quantity OEM discount would sell for about $425 or 0.44 cents per bit.

With semiconductor memory, the modular nature of the technology makes the cost per bit more a function of the bits per chip than the size of the memory system; as a result, major cost decreases come with each new generation of devices. Conversely, core memory is more economical with larger numbers of bits, since they are all strung at the same time. This permits the semiconductor technology to continually push at the core market from the smaller size modules and keep increasing the memory size at which the core/semiconductor costs are the same. With the introduction of the 16K RAM, the crossover will likely be raised to at least 256K words.

The same type of boards or modules that are used in minicomputer add-on memory are combined in a cabinet with a power supply and control electronics to form an add-on system for a large computer. Therefore, with the cabinet and power supply as a fixed overhead, the increase in bits per chip allows more bits in the same physical space; this brings greater economies to the large computer add-on market. A typical cost breakdown is shown in Table 2.8.4-11. The competition with IBM in this market forces the use of the latest MOS devices for both economy and performance. Prices of 370 add-on memory are approximately $0.32 per byte at the end-user level; this translates into an OEM price of approximately $0.16 per byte, which is the price for the complete system with power supply cabinet, error detection and correction, diagnostics, and IBM interface. The equivalent IBM end-user price is approximately $0.60 per byte.

Technology Trends

The primary concern at the memory system level is reliability and errors. The introduction of single bit error detection and correction by IBM in the 370 computer's semiconductor memory has provided a clear trend that the independents have followed. The memory supplied by Data General for the Eclipse Computers also uses this technique. Using a method known as a Hamming Code, the output of the memory plus some additional bits are run through an error checking algorithm to detect and correct single bit per word errors and to detect and flag multiple bit errors, which in-

Table 2.8.4-11

TYPICAL COST ANALYSIS - 370 ADD-ON MEMORY SYSTEM

Size: One Megabyte, Semiconductor

2600 4K RAMS @ $4.00	$10,400
Miscellaneous TTL Logic	600
Power Supplies, Cabinets, Circuit Boards, etc.	3,000
Total Materials Cost	$14,000
Assembly, Test, Rework	3,000
Total Direct Cost	$17,000
Typical OEM Selling Price	$50,000
Cost Per Byte	5¢
Semiconductor Percent of Selling Price	21%

Source: DATAQUEST, Inc.

volves additional bits in the memory. Earlier, large memories stored one additional parity bit for each 8-bit byte of data stored, which required 18 bits for the storage of a 16-bit word. With the newer method, a total of 20 bits are required—the 16-bit data word plus 4 bits for the Hamming code. This increases the cost per bit slightly and slows down the memory due to the time necessary to check the output before passing it on to the CPU. However, in large semiconductor memory systems, this type of error protection is considered essential for reliable operation.

Another technique that has been developed by the 370 add-on market is self-diagnostics in the memory. This permits the CPU in conjunction with the memory to make controllable, routine status checks on each memory subsystem to ascertain its error rate and the source of the errors. Maintenance is facilitated by the diagnostics informing the serviceman which memory card contains the chip with the error-producing bit so that it can be replaced. Similar features are available on large memory subsystems for use with minicomputers.

Other technology trends are the use of multiple port memories that allow multiple CPUs to access the same main memory concurrently; this is an attractive feature for multiprocessor systems of all sizes. It is expected that the upper end of the IBM 370 line will evolve to tightly coupled multiprocessors with up to 32 megabytes of multiport or shared main memory. The upper end of the minicomputer market is following the same trend.

Additional technology innovations revolve around extensions of the concept of the main memory system as a functional subsystem in the overall computer system. Such a system acts on commands from the CPU or CPUs and handles its own memory management, including paging or virtual memory control. These intelligent memory subsystems can be expected to be introduced for use with minicomputers; they would operate in conjunction with large disk files in business-oriented systems.

Low cost and relatively slow bulk RAM using either semiconductor or core technology is making some progress as a replacement for fast-fixed head disk memory in large memory management applications. Up to 10 megabytes of this bulk RAM can be placed between the slow disk memory and the smaller, faster main memory to form a very efficient hierarchial memory system. Software development and system compatibility with existing large computer operating systems are the current problems with this approach; however, it is expected that the growing need for this type of memory will produce solutions to these limitations by 1979 or 1980.

Future Memory Systems and Products

Some general long-term trends exist in the memory market that apply to all of the market segments being discussed here. A few of these trends relate to the use of memory systems using a mixture of technologies to implement hierarchial memory architectures for computers of all sizes. These systems would start with high-speed cache memory that attaches directly to the CPU. The core or semiconductor main memory systems would connect to the cache memory and provide access to bulk RAM or rotating magnetic memory. Currently, the file storage would have to be rotating disk; however, the potential exists for the use of bubble domain technology as a solid state replacement for the rotating memory. This type of memory system would be processor-controlled and function as a complete subsystem in a distributed processor system configuration.

The semiconductor companies appear to be in the best position to exploit these technologies early with their memory systems operations. For example, Intel has introduced a board level product using the 16K CCD device introduced in 1975.

Where software permits, complex systems of this type will be added to existing 360 and 370 series computers. Moreover, the large minicomputers such as the DEC 11/70 and System 20 are a market for such systems.

MARKET FOR SEMICONDUCTOR MEMORY DEVICES

The growth of the semiconductor memory market has been shown in the add-on memory market analysis of this report. During the 1976 to 1981 period, semiconductor memory is expected to grow from 49 percent of the market to 82 percent.

In relation to OEM system selling price, the semiconductor device cost represents from 10 to 35 percent of the system price. Large 370 add-on systems with power supplies, control electronics, fans, and cabinets have a semiconductor content of about 10 percent, which increases to a high of 35 to 40 percent for a simple one-board memory module containing under 100K bits of storage.

Current semiconductor technology is based on the 4K dynamic RAM with production of 16K RAMs in early 1977. The 16K devices are expected to reduce the chip level cost of RAM to under 0.03 cents per bit by 1978. Prices using the current 4K devices are in the 0.1 cent per bit area and expected to drop to 0.05 cents by 1980. Current trends are to offer both dynamic and static versions of popular memory products. Static parts have about a 25 percent price premium.

Table 2.8.4-12 provides the derivation of the market potential for semiconductor memory devices in add-on memory products. The number of bits is forecasted to grow at a 58 percent rate from 16.5 billion bits in 1976 to 160 billion bits by 1981. The average cost per bit for the memory devices in this broad range of products is expected to decline from 0.15 cents per bit in 1976 to 0.05 cents in 1981. These averages reflect the expected mix of MOS and bipolar devices.

The dollar market potential for semiconductor devices in add-on memory is forecasted to grow from $24 million in 1976 to $77 million in 1981, which is a 26 percent growth rate. During the same period, the OEM market value of semiconductor add-on memory boards and systems is expected to grow from $120 million to $450 million, which is a 30 percent growth rate. The difference in the system and device growth rates reflects the fact that semiconductor device prices are expected to be falling faster than the other components in the system. During this time, the average semiconductor device value as a percent of OEM system value should decrease from 20 percent in 1976 to an estimated 17 percent in 1981. This decline reflects the expected increase in memory size and the fact that device prices will be falling faster than system prices. During the next five years, the growth rate for the semiconductor-based memory systems market will be nearly twice the growth rate for the total add-on memory market.

2.8.4 Add-On Computer Memory

Table 2.8.4-12

ESTIMATED MARKET FOR SEMICONDUCTOR DEVICES IN ADD-ON MEMORY SYSTEMS

	1976	1977	1979	1981	Annual Growth Rate (1976-81)
360/370 Bits	6,550	8,800	15,000	22,500	28.0%
% Semiconductor	76%	83%	91%	95%	-
Semiconductor Bits	4,975	7,325	13,695	21,300	34.0%
Minicomputer Bits	12,900	18,700	39,550	82,500	45.0%
% Semiconductor	30%	40%	60%	80%	-
Semiconductor Bits	3,870	7,480	23,730	66,000	76.0%
Custom/Standard Bits	21,800	28,600	51,000	97,000	35.0%
% Semiconductor	35%	40%	55%	75%	-
Semiconductor Bits	7,630	11,440	28,050	72,750	57.0%
Total Semiconductor Bits (Megabits)	16,475	26,245	65,475	160,050	57.6%
Average Price Per Bit (Cents)	0.145¢	0.10¢	0.065¢	0.048¢	-19.8%
Semiconductor Market Potential (Millions of Dollars)	$ 24	$ 26	$ 43	$ 77	26.3%

Source: DATAQUEST, Inc.

2.8.4 Add-On Computer Memory

ADD-ON MEMORY MANUFACTURERS

Core Memory

Ampex Corporation
Memory Products Division
200 N. Nash St.
El Segundo, CA 90245
(213) 640-0150

Applied Magnetics Corp.
Standard Memories, Inc.
2221 South Anne St.
Santa Ana, CA 92704
(714) 540-3605

Business Systems Technology, Inc.
3015 Daimler St.
Irvine, CA 92705
(714) 549-9961

CFI Memories, Inc.
Subsidiary of Lencor Co.
305 Crescent Way
Anaheim, CA 92803
(714) 776-8571

Dataproducts Corporation
Woodland Hills Division
6219 DeSoto Ave.
Woodland Hills, CA 91365
(213) 887-8451

Dataram Corporation
Princeton-Hightstown Rd.
Cranbury, NJ 08512
(609) 799-0071

Fabri-tek Incorporated
Computer Systems Division
5901 South County Road 18
Minneapolis, MN 55436
(612) 935-8811

Harris Corporation (Datacraft)
1200 Gateway Drive
Fort Lauderdale, FL 33309
(305) 974-1700

Lockheed Electronics Company, Inc.
Data Products Division
6201 East Randolph St.
Los Angeles, CA 90040
(213) 722-6810

The Plessey Company Limited
Plessey Memories, Inc.
1674 McGaw Ave.
Santa Ana, CA 92705
(714) 540-9945

Core and Semiconductor Memory

Cambridge Memories, Inc.
12 Crosby Drive
Bedford, MA 01730
(617) 271-6300

Electronic Memories and Magnetics Corp.
EMM—West Coast Division
Computer Products
3216 West El Segundo Blvd.
Hawthorne, CA 90250
(213) 644-9881

Semiconductor Memory

Fairchild Camera and Instrument Corp.
Systems Technology Division
1725 Technology Drive
San Jose, CA 95110
(408) 998-0123

Intel Corp.
Memory Systems Division
1302 North Mathilda Ave.

2.8.4 Add-On Computer Memory

Sunnyvale, CA 94036
(408) 734-8102

Intersil, Inc.
1275 Hammerwood Ave.
Sunnyvale, CA 94036
(408) 734-4330

Monolithic Systems Corp.
14 Inverness Drive East
Englewood, CO 80110
(303) 770-7400

Motorola, Inc.
Motorola Semiconductor Products, Inc.
5005 East McDowell Rd.
Phoenix, AZ 85008
(602) 273-6900

National Semiconductor Corp.
Systems Division
2921 Copper Rd.
Santa Clara, CA 95051
(408) 737-5515

Add-On Memory Marketing and Leasing

Computer Investors Group, Inc.
1351 Washington Blvd.
Stamford, CN 06902
(203) 359-2100

Control Data Corp.
8100 34th Avenue South
Minneapolis, MN 55420
(612) 853-8100

Itel Corp.
Computer Products Division
One Embarcadero Center
San Francisco, CA 94111
(415) 989-4220

Memorex Corp.
San Tomas at Central Expressway
Santa Clara, CA 95052
(408) 987-1000

Storage Technology Corp.
2270 South 88th St.
Louisville, CO 80027
(303) 666-6581

Memory Modules

SUMMARY

The semiconductor industry's recent advances in VLSI have prompted a surge of interest in semiconductor packaging. As semiconductor end users demand more function per chip size, packaging has become a very important issue for semiconductor manufacturers.

One approach in semiconductor packaging has been to assemble prepackaged memory chips onto a second substrate to create a memory module. This solution answers the needs of many end users but is not without drawbacks.

OVERVIEW

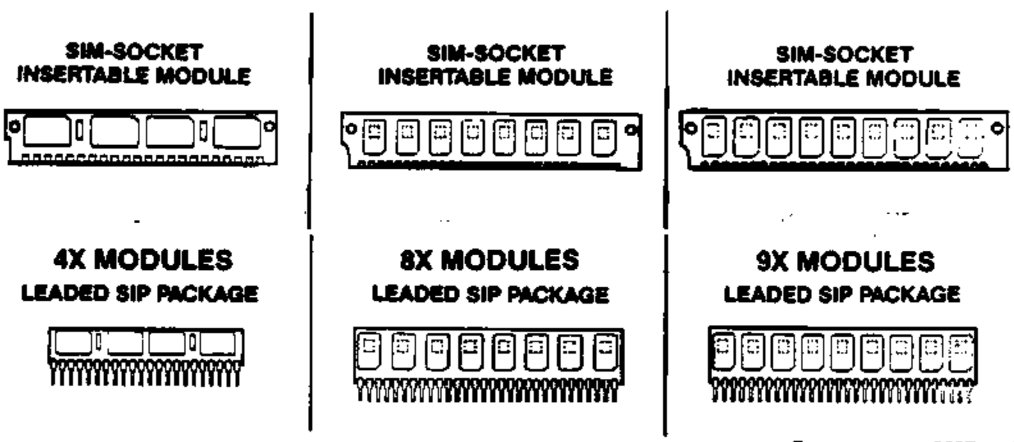
Several different types of modules are available in the semiconductor memory market. The two main types of modules are SIP assemblies and DIP configured modules.

Single-in-Line Memory Modules

One of the most frequently seen module types is a single-in-line memory module. Some manufacturers refer to this type as a SIP (single-in-line package), while others call the same part a SIMM (single-in-line memory module). DATAQUEST makes the distinction that a SIP module is insertion (through-hole) mounted, and a SIMM module has no pins and requires a socket (Figure 1).

Figure 1

SINGLE-IN-LINE MEMORY MODULES



Source: AWI, Inc.

SIPs (and SIMMs) are typically composed of individual plastic leaded chip carriers (PLCC) or leadless ceramic chip carriers (LCC), and decoupling capacitors surface-mounted onto either one or both sides of the single-in-line substrate.

The single-in-line memory module was originally designed by James Clayton in July 1983 for Wang Laboratories, Inc. Wang issued no licenses for this technology. Wang's intention was to benefit from lower memory prices when other module manufacturers entered volume production.

The first SIPs were composed of nine 64K DRAMs with associated decoupling capacitors on a ceramic substrate. Eight of the chips served as usable memory while the ninth provided parity bits for error detection. The resulting SIP was 3.0 inches long, 0.185 inches wide, 0.75 inches high, and had 30 pins. The individual chips used were 18-pin plastic leaded chip carriers. Wang provided the design for these modules, Texas Instruments supplied the DRAM chips, and Zenith Microcircuits Corporation manufactured the ceramic module and mounted the chips. The module was designed to be upgradable to nine 256K DRAMs.

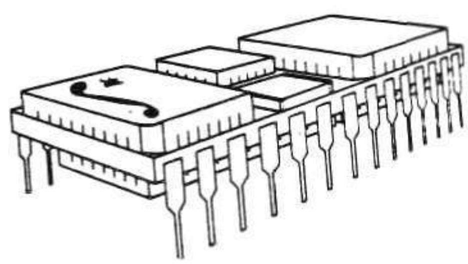
Wang's SIP could be mounted on the surface of a board or plugged into a socket. This module initially sold for $200. In comparison, nine 64K DRAMs sold for around $35.

Dual-in-Line Memory Modules

Several companies are offering modules composed of LCCs surface-mounted on top of, or on both sides of, a dual-in-line package (DIP). DIP modules are available with up to 18 individual LCCs. These modules are being used predominantly in the military market (Figure 2).

Figure 2

DUAL-IN-LINE MEMORY MODULE



Source: Integrated Device Technology

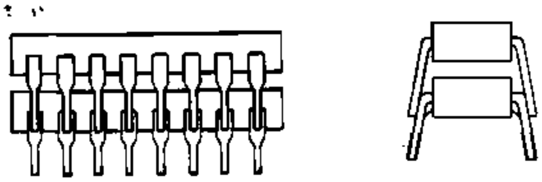
Memory Modules

Piggy-Back or Stack Pack Modules

A two-chip module called a piggy-back or stack is being offered by other companies. This is typically one DIP package connected to the top of a second DIP package. The pins from the top DIP are physically connected to the pins on the bottom DIP. For this organization to be connected, chips with one or two unused pins are required for the purpose of the interconnect (Figure 3). There are also stacks composed of two chip carriers instead of two DIPs.

Figure 3

PIGGY-BACK OR STACK PACK



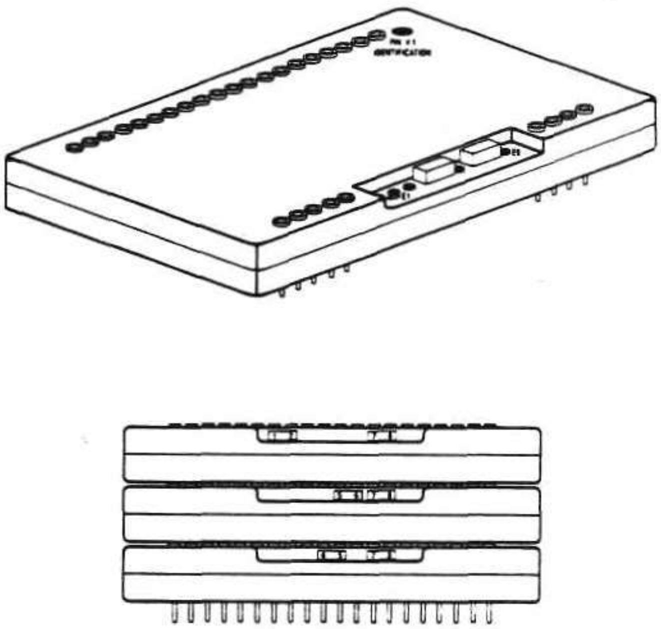
Source: Micron Technology, Inc.

Stackable DIP Modules

National Semiconductor offers stackable DIP modules. These modules have a top surface that is essentially a socket for another module. Up to eight modules can be stacked in this fashion (Figure 4).

Figure 4

STACKABLE DIP MODULE



Source: National Semiconductor

ISSUES

Memory modules offer tremendous advantages over monolithic chips. Modules are not, however, a good choice for all applications. End users must weigh the pros and cons of using modules in their particular applications before sound business decisions can be made.

Memory Modules

Advantages

Modules offer many benefits. The examples given are listed in approximate order of importance.

- Space savings--The main motivation for using modules is the saving of space. Modules can increase memory density by nearly a factor of six (Table 1). The use of smaller components can reduce the size of the end product. This is especially important in handheld or portable equipment. It can also lower the overall system cost by reducing the number or size of the boards within the system. This can result in a substantial cost savings that can eliminate the added cost of the module itself. Modules can also allow, for example, a personal computer manufacturer to free up board space to accommodate additional add-on features, such as modems or networking connections.

- Bypass surface-mount upgrade--Memory modules allow manufacturers not yet geared to surface-mount technology (SMT) to utilize the advantages of surface-mount chips. By using modules, a company would not have to modify its present soldering apparatus or invest in surface-mount assembly equipment. However, as SMT becomes more widespread in the industry, this will become less of an advantage.

- Fewer PC board layers--Having the various interconnects and decoupling capacitors already in the module simplifies board layout compared to the DIP. Modules allow the use of double layer PC boards as opposed to multilayer boards. This reduces system costs substantially.

- Reduced assembly costs--With fewer components, assembly costs are reduced for the module user. Related to this is the benefit of easier inventory control. Though probably not a justification for purchasing modules, the decreased number of individual components in inventory simplifies inventory control.

- Improved reliability--Reliability is a major issue in the military market. Memory modules are sold as fully tested products. The individual chips, decoupling capacitors, and interconnect mechanisms are all fully functional. Module manufacturers that sell to the military market stress reliability as a strong motivation for using modules.

- Stability under thermal stress--A ceramic module can be more stable than direct surface mounting of LCCs. When an LCC is mounted directly to a polyimide PC board, there is a difference in the thermal coefficients of expansion (TCE) of the chip and the board. This can cause the solder joints between the ceramic chip carrier and the PC board to stress or break. This problem can be avoided by using a module where the LCCs are mounted onto a ceramic DIP or SIP. The pins of the module can accommodate any heat induced expansion or contractions of the different substrates.

- Ease of upgradability to the next density--Memory modules can design in future upgradability much more easily than can monolithic chips. A module composed of X number of monolithic chips can be replaced by a new module with X number of next-generation chips. This allows the equipment manufacturer to upgrade his end product without having to do major design changes. It also allows the end user to stay at least one step ahead of semiconductor chip evolution.

- Faster speed mix over monolithic chips--As generations of monolithic chips mature, faster speed mixes become available. This allows end users to obtain modules with access times faster than the corresponding monolithic chips. Modules composed of four to eight 16K SRAMs are currently available with access times of 25ns, while 64K SRAMs typically reach only 45 to 55ns. This advantage decreases in impact as the new chip generation matures and matches the access time of the previous generation.

- Easy repair of socketed modules--When modules are socketed, they are easily removed. As previously mentioned, this is an advantage for upgradability, but is also a benefit for field repair of equipment.

- Improved heat dissipation--Memory modules typically have more surface area exposed than do surface-mounted chips. (This is true of modules with chips mounted on one side of the substrate.) Cooling is improved with the increased potential for air circulation.

- Improved performance--The interconnect distance in modules is shorter than on conventional PC boards. This improves performance in some systems. In highly speed-dependent systems such as large computers, this can be very beneficial.

Table 1

BOARD DENSITY COMPARISON
Monolithic Chips Versus Modules

Packaging	Relative to 16-Pin DIP	Relative to 28-Pin DIP	Height (Inches)
Monolithic Chips			
DIP:			
16-pin	1.0	1.9	0.18
28-pin	0.6	1.0	0.18
PLCC:			
One side of board	1.4	2.4	0.13
Both sides of board	2.8	4.8	0.26
ZIP*	1.6	2.7	0.33
Modules			
SIP Modules:			
One-sided 4 chip	1.9	3.4	0.33
One-sided 8 chip	2.7	4.8	0.65
One-sided 9 chip	3.3	5.8	0.65
Two-sided 8 chip	2.7	4.8	0.33
Two-sided 9 chip	2.8	4.9	0.65
DIP Modules:			
One-sided 4 chip	1.5	2.6	0.25
Two-sided 4 chip	2.4	4.2	0.27
Two-sided 8 chip	2.9	5.1	0.30
Two sided 16 chip	3.1	5.4	0.26

*ZIP (zig-zag-in-line package) is a monolithic DIP with all of its pins on one edge. The ZIP is mounted on its longest edge.

Source: DATAQUEST

Memory Modules

Disadvantages

Modules also have the following disadvantages:

- Cost premiums--The most obvious drawback of memory modules is the cost. A module will always cost more than the individual chips. A SIP module usually costs from 1.3 to 5 times the cost of individual chips. The premium for a DIP module can be even higher, possibly even 2 to 10 times the cost of individual chips. However, this price differential will decrease as the module market expands. If the increased cost of the module is not offset either by a substantially improved end product, or by a resulting decrease in system cost (due to lower assembly costs or fewer boards required), then a module is not a good solution.

- Instability--Some end users, especially the military, feel that SIP modules are not rugged. Because they rest on one row of pins, they can be brittle from the weight of the module. Thus, the military often prefers DIP modules.

- Lack of second sources--A lack of second sources for many modules is cited by some as a disadvantage. This will become less of a concern as the market develops.

- Lack of standards--A lack of standards is seen by others as a drawback. The Joint Electronic Devices Engineering Council (JEDEC) has not published standards for memory modules. However, as the market develops and more than one manufacturer pushes for acceptance of standards, this disadvantage will be eliminated.

- Module height exceeds monolithic chip height--Another disadvantage of modules can be their height. SIP modules are 2 to 3-1/2 times as tall as DIPs, and 2-1/2 to 5 times as tall as PLCCs (Table 1). This problem can be reduced by inserting the SIP modules at a 30 degree angle. General Micro Systems has produced a single VMEbus board containing two megabytes of dual-ported RAM using this method. This reduced the height to 0.503 times the height of the SIPs inserted vertically. To accommodate this height reduction, board spacing of the SIPs had to be increased from 0.2 inches to 0.3 inches.

Memory Modules

APPLICATIONS

Memory modules are being used for a variety of applications. These include:

- Military equipment
  - Aerospace industry
  - Defense equipment
- Data processing equipment
  - Computers
    - Cache memory
    - Writable stores for medium and large computers
    - CAE workstations
  - Graphics terminals
  - Point-of-sale terminals
  - Industrial equipment
  - Process control instruments
  - Portable medical equipment
  - Remote instrumentation

Modules are used in all areas for prototyping new equipment ahead of the next-generation chip availability.

Essentially any applications where size, efficiency, or reliability are vital concerns, are potential markets for memory modules.

MARKET POTENTIAL

The memory module market is still in its infancy. Because of the newness of the market and the broad base of its potential applications, market size projections are difficult to predict. If the user community becomes familiar and comfortable with memory modules, the market could expand substantially.

Memory Modules

End-user opinions on memory modules vary dramatically. Some end users see the module market as only a transitory vehicle between chip generations. They define the market as a bridge between 256K DRAMs and 1 megabit DRAMs. Other end users are very enthusiastic about the benefits provided by modules. Some very large semiconductor end users have no current plans for using memory modules. Other large end users claim nearly all of their new designs will incorporate modules.

DATAQUEST estimates that the current size of the memory module market (excluding stacks) is $200 million. This represents roughly 7 percent of all MOS DRAM and SRAM units packaged as modules. In addition, a very small percentage of EPROM units are packaged as modules. The size of the stack market is an additional $70 million per year. If modules continue to receive an increasingly positive reception from the end-user market segments, the percentage of units packaged as modules could increase dramatically. Some major suppliers predict that 40 to 50 percent of all MOS DRAM and SRAM units will be sold as modules by 1989. A more realistic estimate may be closer to 20 percent.

At present, SIP modules account for about 80 percent of the module market in units, but DIP modules may be responsible for nearly half of the dollars. This is due to the high average selling price of modules sold to the military market. Currently, around 20 percent of all 256K DRAM units are packaged as modules. One major supplier predicts that next year nearly half of all 1Mb DRAMs may be in modules.

AVAILABILITY

Memory modules are available now from at least a dozen semiconductor companies. In addition, there are a large number of repackaging houses buying DIPs or chip carriers and assembling them into modules. Many of these repackagers have standard products and most will do custom orders. The vast majority of memory modules are being produced by the semiconductor companies. Repackaging houses appear to have less than 10 percent of the memory module packaging market.

Semiconductor companies have a definite advantage over chip repackagers, especially in the military market. When chip traceability is an issue, buying a module from a supplier who has made the chip as well as the module is an advantage. Some semiconductor manufacturers believe that the module market is too small at present to merit the time and commitment of their resources. If the market continues to grow, they could have a change of heart.

Memory Modules

COMPANY PROFILES

Semiconductor Companies

The addresses and telephone numbers of the current memory module suppliers are provided in Table 2 at the end of this section.

AT&T Technologies

AT&T makes its own SIP modules for internal consumption. It does not sell them on the merchant market. AT&T's main motivation for using modules is space savings and the ability to be one generation ahead of monolithic chips. Probably about 15 percent of the 256K DRAMs used by AT&T are in SIP modules. DATAQUEST estimates that this equates to around 1 million DRAMs in SIP units per year. This number could decrease as 1Mb chips become available and as direct surface mounting of chip carriers increases.

Fujitsu Ltd.

Fujitsu has two 22-pin SIP modules composed of four 64K DRAMs. One is organized 64Kx4 and the other is 256Kx1. The company also has a SIP module composed of eight 64K DRAMs.

Harris Semiconductor

Harris offers a line of military-grade DIP modules. SRAM modules are available in densities of 64K to 256K. Harris has a 1-megabit SRAM module scheduled for availability at the end of 1985.

Hitachi Ltd.

Hitachi makes a DIP module with two 64K SRAMs on the top surface and two 64Ks on the underside of a 30-pin DIP. This results in a 32Kx8 SRAM module with access from 150ns to 200ns.

Integrated Device Technology (IDT)

IDT offers a broad range of DIP modules. SRAM modules are available with densities of 64K to 1 megabit. IDT has a 256K CMOS SRAM module with an access time of 55ns commercial and 65ns military. The module is customer configurable to 16Kx16, 32Kx8, and 64Kx4. The company's 1 megabit module is composed of 16 64Kx1 SRAMs with access times of 60ns commercial and 70ns military. IDT also offers dual port RAM modules at 8Kx8 and 16Kx8, and FIFO modules at 2Kx9 and 4Kx9.

Memory Modules

The majority of IDT's business is the military end market. As its production capacity expands, IDT's participation in the commercial market will probably increase.

Micron Technology, Inc.

Micron Technology has SIP modules composed of eight or nine 64K DRAMs. It plans to introduce 256Kx4, x8, and x9 modules soon. Micron offers error correction as an on-chip feature. ZIP modules are available in 256Kx1 and 64Kx4 versions.

Micron also offers a stack pack of two 64K DRAMs. This 128Kx1 module has access times of 120ns, 150ns, or 200ns.

Micron also offers another dense packaging alternative, the "cluster" DRAM. (This is not technically a "module" but actually wafer-scale integration.) To produce this cluster, the scribe lines on a wafer are eliminated from the ten 64K DRAMs. This gives a cluster of two rows of five die each. The cluster is then tested for eight to nine functional die. It is then packaged in a 68-pin LCC. Thirty-six of the pins are active connections. The part measures about one square inch. Organizations of 512Kx1, 64Kx8, and 64Kx9 are available. Pricing is in the $30 range per cluster.

Mitsubishi Electric

Mitsubishi has modules composed of four or eight 64K DRAMs, and one composed of nine 256K DRAMs. Its 256Kx9 module is a 30-pin SIMM with an access time of 150ns.

Mitsubishi has been showing more interest in the zig-zag in-line package (ZIP) than in modules. The ZIP is essentially a DIP on its side with the pins on one edge in a zig-zag formation. The ZIP provides nearly a 2:1 space savings over a DIP for the same price.

National Semiconductor

National has 16Kx8 CMOS SRAM modules with access times of 250ns. These modules are stackable DIP modules. A version with a lithium battery as a power supply backup is also available. Pricing for this module is around $120 each in quantities of 100. This module is intended for low-power instrumentation or for handheld, battery-powered applications, such as portable data acquisition equipment, field test equipment, point-of-sale equipment, remote instrumentation, real-time process controllers, and microcomputer memory.

Memory Modules

Oki Semiconductor

Oki has a 128K NMOS DRAM stack composed of two 64K chips. This module is packaged in 16-pin DIPs with access of 150ns to 200ns. Stacks are being used in PC/AT-compatible computers.

In addition to the stack, Oki has released a preliminary data sheet on a 256Kx9 SIMM. This module has 30 pins and access time of 120ns or 150ns.

Texas Instruments (TI)

Texas Instruments was among the first participants in the SIMM market. It has a large variety of modules available. TI offers 64Kx4, x5, x8, and x9 SIMMs, as well as 256Kx4, x8, and x9 SIMMs. TI is not using any of these modules internally, but may do so in the future.

Toshiba America, Inc.

Toshiba has SIP modules composed of nine 256K chips. This module has 150ns access and 30 pins. Toshiba also has a 512Kx4 module composed of eight 256K DRAMs. This 24-pin SIP has access of 150ns.

Repackagers

Advanced Electronic Packaging

Advanced Electronic Packaging offers SRAM and DRAM SIP modules. Most of its modules have eight or nine chips on each side of the module. Currently, the company supplies 32Kx8, 64Kx8, and 128Kx8 SRAM organizations, and 256Kx9 DRAM modules.

Advanced Surface Mount Devices (ASMD)

ASMD has a standard line of memory modules including 64Kx4, x5, x8, and x9 SIMMS as well as 256Kx4, x5, x7, and x9 SIMMs. It also does custom configurations.

AWI, Inc.

AWI offers SIP and SIMM modules composed of 64K or 256K DRAMs in x4, x8, or x9 configurations. The x4 module has 22 pins and the x8 and x9 modules have 30 pins. AWI also does custom packaging.

Memory Modules

Dense-Pac Development, Inc.

Dense-Pac offers a very broad line of standard memory modules. Both SIP and DIP modules are composed of DRAMs, SRAMs, EPROMs, and EEPROMs. Module densities reach 1Mb for EEPROMs and 4Mb DRAMs. The company offers a 16Kx8 SRAM module with access time of 25ns. Dense-Pac will also do custom configurations.

Electronic Designs Inc. (EDI)

EDI was formed in 1980 as one of the first companies to specialize in the design and manufacture of high-density modules. It produces both SIP and DIP modules. Currently, about half of EDI's business is in DRAMs and modules, but the proportion of SRAM modules is increasing. The company also offers UV EPROMs, organized 16Kx8 an 32Kx8, and EEPROMs organized 32Kx8, 24Kx16, and 64Kx16.

EDI combines SRAM and EPROM on a single module called a COMBO. COMBOs satisfy the need for external data memory and program memory, making the device ideal for microprocessor-based systems.

Custom modules are available for all memory products as well as microprocessors, gate arrays, and random logic devices.

Hy-Pac Technology

Hy-Pac is a subsidiary of Stanford Applied Engineering. Currently, it only produces DIP modules. SRAM modules are available organized 32Kx8, as well as DRAM modules organized 64Kx8 and x9, and 256Kx8 and x9. Custom products are available for both commercial and military applications.

Integrated Circuits, Inc.

Static RAM DIP modules are available from Integrated Circuits, Inc. Prices for a 64K CMOS SRAM module are around $100 for a commercial 100ns version, and $150 for the military version. The 256K module is about $250 for commercial and $300 for the military.

Micro Industries

Micro Industries offers DRAM and SRAM SIP modules. DRAM modules composed of 64K or 256K chips are organized x4, x8, or x9. DRAM modules composed of eight or nine 1Mb chips will also be available. Micro's SRAM modules composed of 64K chips are organized 32Kx8 or 128Kx8.

T.L. Industries, Inc.

T.L. Industries offers a very large pseudostatic RAM DIP module composed of 16 DRAMs and a controller. To mount this 2 x 3.5-inch module requires two SIP sockets. The price is $395 for a 64Kx16 module and $1,395 for a 512Kx16. The module covers 7 square inches of PC board. This is the point at which one begins to wonder whether to call the product a module or a small PC board.

Zenith Electronics Corporation

Zenith has byte-wide DRAM modules. Using nine 64K DRAMs, this DIP has 30 pins and column access time of 100ns. Zenith also does custom designs.

Table 2

MEMORY MODULE SUPPLIERS

Advanced Electronic Packaging
2159 Bay Street
Los Angeles, CA 90021
(213) 622-9042

Advanced Surface Mount Devices
11180-G Roselle Street
San Diego, CA 92121
(619) 453-8111

AT&T Technologies
555 Union Blvd.
Allentown, PA 18103
(215) 770-2200

AWI, Inc.
558 Oakmead Parkway
Sunnyvale, CA 94086
(408) 720-8860

Dense-Pac Development, Inc.
1588-A S. Anaheim Blvd.
Anaheim, CA 92805
(714) 898-0007

Electronic Designs, Inc.
Hopkington Industrial Park
35 South Street
Hopkington, MA 01748
(617) 435-9077

Fujitsu Ltd.
3320 Scott Blvd.
Santa Clara, CA 95051
(408) 727-1700

Harris Semiconductor
CMOS Digital Products Division
P.O. Box 883
Melbourne, Florida 32901
(305) 727-9100

Hitachi Ltd.
2210 O'Toole Avenue
San Jose, CA 95131
(408) 942-1500

Hy-Pac Technology
760 Aleso
Sunnyvale, CA 94086
(408) 745-0950

Integrated Circuits, Inc.
10301 Willows Road
Redmond, WA 98052
(206) 882-3100

Integrated Device Technology
3236 Scott Blvd.
Santa Clara, CA 95051
(408) 727-6116

Micro Industries
691 Greencrest Drive
Westerville, Ohio 43081
(614) 895-0404

Micron Technology, Inc.
2805 E. Columbia Road
Boise, Idaho 83706
(208) 386-3900

Mitsubishi Electric
1050 East Arques Avenue
Sunnyvale, CA 94086
(408) 730-5900

Oki Semiconductor
650 N. Mary Avenue
Sunnyvale, CA 94086
(408) 720-1900

(Continued)

Table 2

MEMORY MODULE SUPPLIERS

National Semiconductor
2900 Semiconductor Drive
Santa Clara, CA 95051
(408) 721-5000

T. L. Industries, Inc.
2541 Tracy Road
Toledo, Ohio 43619
(419) 666-8144

Texas Instruments
P.O. Box 225012
Dallas, Texas 75265
(214) 995-2011

Toshiba America, Inc.
2441 Michele Drive
Tustin, CA 92680
(714) 730-5000

Zenith Electronics Corporation
1000 Milwaukee Avenue
Glenview, IL 60025
(312) 391-7000

Source: DATAQUEST

MOS Memory--Forecast

MOS MEMORY TOTAL WORLDWIDE FORECAST

The Dataquest MOS memory forecast is presented in Tables 1 through 7. Revenue, unit shipments, average selling price, bit shipments, and average price per bit are forecast for each of the major MOS memory product areas for the years 1987 to 1991. These product areas are dynamic RAMs (DRAMs), static RAMs (SRAMs), EPROMs, mask-programmable ROMs, and EEPROMs. Historical data from 1984 to 1986 are also provided for your reference. Tables contained in this forecast are as follows:

Table 1--Worldwide MOS Memory Market--Revenue

Table 2--Worldwide MOS Memory Market--Revenue Trends

Table 3--Worldwide MOS Memory Market--Unit Shipments

Table 4--Worldwide MOS Memory Market--Unit Shipment Trends

Table 5--Worldwide MOS Memory Market--Average Selling Prices

Table 6--Worldwide MOS Memory Market--Bit Shipments

Table 7--Worldwide MOS Memory Market--Average Selling Price per Bit

For more detailed forecasts of each product family, refer to the appropriate product section.

Comparison to Earlier Forecasts

The last Dataquest MOS memory forecast was published in September 1986. Although actual 1986 MOS memory revenue is the same as that of the previous forecast, unit shipments are higher and the average selling price (ASP) is lower. Despite the U.S.-Japan Semiconductor Trade Arrangement and the accompanying foreign market values (FMVs), DRAM prices dropped considerably in the last quarter of 1986 after a brief increase in the third quarter. Prices of MOS memories in Europe and the Asia Pacific region were consistently and markedly lower than in the United States.

The projected growth in 1987 has been revised to 21 percent, compared to 40 percent in the September forecast. Although U.S. book-to-bill ratios have crossed unity, European ratios have not shown the same strength and Japan's economy is hurting because of the depreciating dollar. Yet, 21 percent is a healthy growth, a welcome relief after the soft market conditions of 1985 and 1986.

MOS Memory--Forecast

Tempered optimism characterizes the 1988 to 1991 outlook in this forecast. The MOS memory market is expected to grow at a compound annual growth rate (CAGR) of 14.7 percent, compared to 22.0 percent in the previous forecast. New product introduction schedules (4Mb DRAM, 1Mb SRAM, and others) have been adjusted. Conservatism in capital spending for production equipment for new products is prevalent after the severe financial losses incurred in 1985 and 1986.

For Japanese companies, this problem is compounded by the strong yen and an expected weak domestic consumption. Japanese government intervention in pricing and production of MOS memories is expected to continue.

Highlights of the MOS Memory Forecast

We expect the following to occur in the MOS memory market:

- The market achieved $4.4 billion in revenue in 1986 and is expected to grow to $5.3 billion in 1987 and $8.8 billion by 1991.
- The market will grow at 14.7 percent CAGR from 1986 to 1991, compared to a 16.7 percent CAGR from 1981 to 1986.
- The fastest-growing product families are the fast SRAM and EEPROM.
    - Fast SRAMs and EEPROMs will grow at 17 percent and 36 percent CAGRs, respectively.
    - DRAM revenue will have an above-average 16 percent CAGR in this period.
- Average selling prices are expected to improve beginning in 1987, as the industry improves and newer products increasingly are produced.
- The market is expected to experience narrower swings in annual growth rates, similar to those of the latter years of the last decade.
    - There is no apparent application like the personal computer that will cause the wild swings of recent years.
    - We believe that the industry will be better prepared for the next downturn.

MOS Memory--Forecast

- The year 1989 is projected to be a soft year for the whole semiconductor industry, based on projections of the industry's cycles. However, Dataquest expects a milder downturn in 1989 than that of 1985.

- MOS memory bits are expected to grow at a 63 percent CAGR from 1986 to 1991, versus a 92 percent CAGR from 1981 to 1986.

MARKET OUTLOOK

The Short-Term Outlook

The book-to-bill ratio of U.S. suppliers and the general increased purchasing activity in the early months of 1987 are positive market signs that are expected to fuel the 21 percent growth in 1987. Market opportunities abound. Personal computer manufacturers such as IBM and Apple have announced new products with denser and faster memories. Furthermore, several mainframe and minicomputer companies are performing well, boosting static RAM sales, and the 256K EEPROM is being designed into several military applications. More companies are expected to slowly return to profitability. In the United States, lead times for certain DRAMs and EPROMs have stretched out and are expected to remain so through the third quarter.

Nevertheless, negative factors exist as well. Japanese consumption is expected to be weak in 1987 because of the strong yen. Investments in new, expensive lines for new densities and packages are being constrained by the low level of profitability in the industry, increasing the potential for 1Mb DRAM shortages. The U.S.-Japan trade war is escalating with the semiconductor industry as the more visible battlefield. Consequently, Japanese producers have implemented production cuts that could lead to severe 256K DRAM shortages.

The Long-Term Outlook

Dataquest believes that the following factors will lend to the anticipated 14.7 percent CAGR for MOS memories through 1991:

- The traditional growth of new, higher-density memories

- The penetration of the bipolar market by high-speed MOS memories

- The expansion of the market into nontraditional memory uses

MOS Memory--Forecast

- The emergence of new applications in graphics, speech, and digital television

- Consumption growth in the Asia Pacific countries other than Japan

We believe that higher-density memories will dominate the market. We expect 1Mb and 4Mb DRAMs, for example, to account for 93 percent of the total DRAM market in 1991, compared to only 8 percent in 1986.

The MOS memory market promises to reach out beyond its traditional boundaries. Submicron processes have given birth to CMOS SRAMs and EPROMs that approximate bipolar speeds. These products are expected to take a slice out of the bipolar memory market. With additional on-chip logic, memories are being used in applications that perform interface and processing-related functions, a departure from conventional storage tasks. Classified as specialty memories, they include FIFOs, dual-port RAMs, video RAMs, and cache tag RAMs. Dataquest expects the specialty memory market segment to grow significantly in the next years.

New applications in graphics, speech, IC cards, digital television, and other areas are projected to pick up in activity, although real expansion in these markets is not expected until after the turn of the decade. Faster, high-density memories are being developed to meet future needs of 32-bit microprocessor-based systems.

The anticipated consumption growth in the Asia Pacific region will also contribute to the growth in MOS memory revenue. MOS memory revenue in this region is expected to reach $880 million by 1991.

MOS Memory--Forecast

Table 1

WORLDWIDE MOS MEMORY MARKET REVENUE
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	$4,850	$2,473	$2,905	$3,463	$4,438	$4,056	$4,743	$5,999
Dynamic RAM	$3,540	$1,592	$2,102	$2,467	$3,371	$3,110	$3,478	$4,360
NMOS	3,523	1,560	1,896	1,746	1,416	860	401	288
CMOS	17	32	206	721	1,955	2,250	3,077	4,072
Static RAM	$1,310	$ 881	$ 803	$ 996	$1,067	$ 946	$1,265	$1,639
Fast SRAM	323	339	353	446	520	524	677	763
Slow SRAM	987	542	450	550	547	422	588	876
NMOS	481	315	198	128	84	47	28	15
CMOS	830	569	606	869	982	898	1,236	1,623
Read-Only Memory	$1,774	$1,406	$1,467	$1,826	$2,085	$2,147	$2,555	$2,696
EPROM	$1,185	$ 876	$ 910	$1,052	$1,176	$1,225	$1,497	$1,616
UV EPROM	1,164	856	861	989	1,055	1,097	1,346	1,428
OTP	21	20	49	63	121	128	151	188
NMOS	1,071	791	720	725	681	560	594	593
CMOS	114	85	190	326	495	665	902	1,023
ROM	$ 434	$ 388	$ 418	$ 543	$ 564	$ 493	$ 453	$ 442
NMOS	321	255	243	283	256	160	112	81
CMOS	113	133	175	260	308	333	341	361
EEPROM	$ 155	$ 142	$ 139	$ 231	$ 345	$ 429	$ 605	$ 638
NMOS	145	130	117	158	208	185	268	282
CMOS	10	12	22	73	137	244	337	356
Other MOS Memory	$ 50	$ 45	$ 55	$ 65	$ 75	$ 80	$ 100	$ 100
Total MOS Memory	$6,674	$3,924	$4,427	$5,354	$6,598	$6,283	$7,398	$8,795
Percent Change from Previous Year	63.0%	(41.2%)	12.8%	20.9%	23.2%	(4.8%)	17.7%	18.9%

Source: Dataquest
April 1987

Table 2

WORLDWIDE MOS MEMORY MARKET--REVENUE TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	73%	64%	72%	71%	76%	77%	73%	73%
Percent SRAM	27	36	28	29	24	23	27	27
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	67%	62%	62%	58%	56%	57%	59%	60%
Percent Mask ROM	24	28	28	30	27	23	18	16
Percent EEPROM	9	10	9	13	17	20	24	24
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	73%	63%	66%	65%	67%	65%	64%	68%
Percent Read Only Memory	27	36	33	34	32	34	35	31
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	84%	79%	73%	57%	41%	29%	19%	14%
Percent CMOS	16	21	27	43	59	71	81	86
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	25%	38%	44%	45%	49%	55%	54%	47%
Percent Slow SRAM	75	62	56	55	51	45	46	53
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	2%	4%	5%	7%	7%	7%	8%
Percent Reprogrammable	98%	98%	96%	95%	93%	93%	93%	92%
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

MOS Memory--Forecast

Table 5

WORLDWIDE MOS MEMORY MARKET--AVERAGE SELLING PRICES
(Dollars per Unit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	$3.50	$2.03	$1.98	$2.17	$2.74	$2.37	$2.57	$3.00
Static RAM	$4.50	$2.97	$2.64	$3.18	$3.35	$2.84	$3.32	$3.86
Fast SRAM	$5.41	$5.00	$4.47	$4.76	$5.13	$4.70	$4.72	$4.60
Slow SRAM	$4.26	$2.36	$2.00	$2.51	$2.52	$1.91	$2.47	$3.39
EPROM	$5.37	$3.57	$3.41	$3.66	$3.78	$3.81	$4.29	$4.53
UV EPROM	$5.40	$3.62	$3.45	$3.75	$3.76	$3.85	$4.36	$4.69
OTP	$4.10	$2.40	$2.84	$2.69	$3.98	$3.49	$3.76	$3.57
ROM	$3.28	$2.83	$2.72	$3.42	$3.54	$3.37	$3.37	$3.15
EEPROM	$3.58	$3.15	$2.86	$4.17	$5.13	$5.85	$7.05	$6.09
Other MOS Memory	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
Overall MOS Memory	$3.90	$2.59	$2.40	$2.73	$3.14	$2.86	$3.18	$3.52
Percent Change from Previous Year	19.9%	(33.7%)	(7.2%)	13.7%	15.0%	(9.1%)	11.5%	10.6%

Source: Dataquest
April 1987

MOS Memory--Forecast

Table 6

WORLDWIDE MOS MEMORY MARKET--BIT SHIPMENTS
(Billions of Bits)

	1984	1985	1986	1987
Dynamic RAM	68,162	98,184	196,182	295,585
Static RAM	5,197	7,257	11,134	21,774
Fast SRAM	618	885	1,436	2,695
Slow SRAM	4,580	6,371	9,698	19,078
EPROM	12,933	21,827	36,445	58,123
UV EPROM	12,720	21,231	33,474	52,396
OTP	213	596	2,971	5,727
ROM	13,649	23,032	41,701	75,579
EEPROM	126	188	290	598
Overall MOS Memory	100,067	150,488	285,752	451,659
Percent Change from Previous Year	95.0%	50.4%	89.9%	58.1%

	1988	1989	1990	1991
Dynamic RAM	572,680	887,279	1,353,967	2,538,471
Static RAM	34,750	51,947	99,590	198,468
Fast SRAM	5,285	8,955	18,357	34,005
Slow SRAM	29,465	42,992	81,234	164,463
EPROM	90,006	133,829	201,282	259,797
UV EPROM	77,526	112,932	168,677	204,584
OTP	12,480	20,897	32,605	55,213
ROM	112,853	132,710	175,112	261,554
EEPROM	1,668	3,360	8,428	15,931
Overall MOS Memory	811,957	1,209,125	1,838,379	3,274,221
Percent Change from Previous Year	79.8%	48.9%	52.0%	78.1%

Source: Dataquest
April 1987

MOS Memory—Forecast

Table 7

WORLDWIDE MOS MEMORY MARKET—AVERAGE SELLING PRICE PER BIT
(Millicents per Bit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	5.2	1.6	1.1	0.8	0.6	0.4	0.3	0.2
Static RAM	25.2	12.2	7.2	4.6	3.1	1.8	1.3	0.8
Fast SRAM	52.3	38.3	24.6	16.6	9.8	5.9	3.7	2.2
Slow SRAM	21.5	8.5	4.6	2.9	1.9	1.0	0.7	0.5
EPROM	18.8	7.3	4.3	3.0	2.4	1.6	1.3	1.0
UV EPROM	9.2	4.0	2.6	1.9	1.4	1.0	0.8	0.7
OTP	9.6	3.3	1.7	1.1	1.0	0.6	0.5	0.3
ROM	3.2	1.7	1.0	0.7	0.5	0.4	0.3	0.2
EEPROM	122.6	75.5	48.2	38.6	20.7	12.8	7.2	4.0
Overall MOS Memory	6.6	2.6	1.5	1.2	0.8	0.5	0.4	0.3
Percent Change from Previous Year	(18.0%)	(61.1%)	(40.6%)	(23.5%)	(31.4%)	(36.1%)	(22.6%)	(33.1%)

Source: Dataquest
April 1987

MOS Memory—Forecast

Table 1

WORLDWIDE MOS MEMORY MARKET REVENUE
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	$4,850	$2,473	$2,905	$3,463	$4,438	$4,056	$4,743	$5,999
Dynamic RAM	$3,540	$1,592	$2,102	$2,467	$3,371	$3,110	$3,478	$4,360
NMOS	3,523	1,560	1,896	1,746	1,416	860	401	288
CMOS	17	32	206	721	1,955	2,250	3,077	4,072
Static RAM	$1,310	$ 881	$ 803	$ 996	$1,067	$ 946	$1,265	$1,639
Fast SRAM	323	339	353	446	520	524	677	763
Slow SRAM	987	542	450	550	547	422	588	876
NMOS	481	315	198	128	84	47	28	15
CMOS	830	569	606	869	982	898	1,236	1,623
Read-Only Memory	$1,774	$1,406	$1,467	$1,826	$2,085	$2,147	$2,555	$2,696
EPROM	$1,185	$ 876	$ 910	$1,052	$1,176	$1,225	$1,497	$1,616
UV EPROM	1,164	856	861	989	1,055	1,097	1,346	1,428
OTP	21	20	49	63	121	128	151	188
NMOS	1,071	791	720	725	681	560	594	593
CMOS	114	85	190	326	495	665	902	1,023
ROM	$ 434	$ 388	$ 418	$ 543	$ 564	$ 493	$ 453	$ 442
NMOS	321	255	243	283	256	160	112	81
CMOS	113	133	175	260	308	333	341	361
EEPROM	$ 155	$ 142	$ 139	$ 231	$ 345	$ 429	$ 605	$ 638
NMOS	145	130	117	158	208	185	268	282
CMOS	10	12	22	73	137	244	337	356
Other MOS Memory	$ 50	$ 45	$ 55	$ 65	$ 75	$ 80	$ 100	$ 100
Total MOS Memory	$6,674	$3,924	$4,427	$5,354	$6,598	$6,283	$7,398	$8,795
Percent Change from Previous Year	63.0%	(41.2%)	12.8%	20.9%	23.2%	(4.8%)	17.7%	18.9%

Source: Dataquest
April 1987

MOS Memory--Forecast

Table 2

WORLDWIDE MOS MEMORY MARKET--REVENUE TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	73%	64%	72%	71%	76%	77%	73%	73%
Percent SRAM	27	36	28	29	24	23	27	27
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	67%	62%	62%	58%	56%	57%	59%	60%
Percent Mask ROM	24	28	28	30	27	23	18	16
Percent EEPROM	9	10	9	13	17	20	24	24
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	73%	63%	66%	65%	67%	65%	64%	68%
Percent Read Only Memory	27	36	33	34	32	34	35	31
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	84%	79%	73%	57%	41%	29%	19%	14%
Percent CMOS	16	21	27	43	59	71	81	86
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	25%	38%	44%	45%	49%	55%	54%	47%
Percent Slow SRAM	75	62	56	55	51	45	46	53
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	2%	4%	5%	7%	7%	7%	8%
Percent Reprogrammable	98%	98%	96%	95%	93%	93%	93%	92%
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

Table 3

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENTS
(Millions of Units)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	1,304	1,080	1,363	1,448	1,549	1,643	1,736	1,878
Dynamic RAM	1,012	782	1,060	1,135	1,230	1,311	1,355	1,454
NMOS	1,010	777	1,043	1,060	870	622	326	240
CMOS	3	5	17	75	361	689	1,029	1,214
Static RAM	291	298	304	313	318	333	381	424
Fast SRAM	60	68	79	94	101	112	143	166
Slow SRAM	232	230	225	219	217	221	238	258
NMOS	138	121	89	47	31	20	12	6
CMOS	154	177	214	266	287	313	369	418
Read-Only Memory	396	427	470	501	538	541	569	602
EPROM	221	245	267	287	311	322	349	357
UV EPROM	216	237	250	264	281	285	308	304
OTP	5	8	17	23	30	37	40	53
NMOS	208	228	227	228	218	183	173	160
CMOS	13	17	40	60	93	139	176	197
ROM	132	137	154	159	160	146	135	140
NMOS	110	106	108	103	86	55	41	32
CMOS	22	31	46	55	74	91	94	108
EEPROM	43	45	49	55	67	73	86	105
NMOS	42	42	41	44	44	39	38	49
CMOS	1	4	7	12	24	35	48	56
Other MOS Memory	10	9	11	13	15	16	20	20
Total MOS Memory	1,710	1,516	1,844	1,962	2,102	2,200	2,325	2,500
Percent Change from Previous Year	33.0%	(11.3%)	21.6%	6.4%	7.1%	4.7%	5.6%	7.5%

Source: Dataquest
April 1987

MOS Memory--Forecast

Table 4

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENT TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	78%	72%	78%	78%	79%	80%	78%	77%
Percent SRAM	22	28	22	22	21	20	22	23
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	56%	57%	57%	57%	58%	59%	61%	59%
Percent Mask ROM	33	32	33	32	30	27	24	23
Percent EEPROM	11	11	10	11	13	14	15	17
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	76%	71%	74%	74%	74%	75%	75%	75%
Percent Read Only Memory	23	28	25	26	26	25	24	24
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	89%	84%	82%	76%	60%	42%	26%	20%
Percent CMOS	11	16	18	24	40	58	74	80
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	20%	23%	26%	30%	32%	34%	38%	39%
Percent Slow SRAM	80	77	74	70	68	66	62	61
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	3%	5%	6%	7%	8%	8%	10%
Percent Reprogrammable	98	97	95	94	93	92	92	90
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

MOS Memory Market Forecast

MOS MEMORY TOTAL WORLDWIDE FORECAST

The Dataquest MOS memory forecast is presented in Tables 1 through 7. Revenue, unit shipments, average selling price, bit shipments, and average price per bit are forecast for each of the major MOS memory product areas for the years 1987 to 1991. These product areas are dynamic RAMs (DRAMs), static RAMs (SRAMs), EPROMs, mask-programmable ROMs, and EEPROMs. Historical data from 1984 to 1986 are also provided for your reference. Tables contained in this forecast are as follows:

Table 1--Worldwide MOS Memory Market--Revenue

Table 2--Worldwide MOS Memory Market--Revenue Trends

Table 3--Worldwide MOS Memory Market--Unit Shipments

Table 4--Worldwide MOS Memory Market--Unit Shipment Trends

Table 5--Worldwide MOS Memory Market--Average Selling Prices

Table 6--Worldwide MOS Memory Market--Bit Shipments

Table 7--Worldwide MOS Memory Market--Average Selling Price per Bit

For more detailed forecasts of each product family, refer to the appropriate product section.

Comparison to Earlier Forecasts

The last Dataquest MOS memory forecast was published in September 1986. Although actual 1986 MOS memory revenue is the same as that of the previous forecast, unit shipments are higher and the average selling price (ASP) is lower. Despite the U.S.-Japan Semiconductor Trade Arrangement and the accompanying foreign market values (FMVs), DRAM prices dropped considerably in the last quarter of 1986 after a brief increase in the third quarter. Prices of MOS memories in Europe and the Asia Pacific region were consistently and markedly lower than in the United States.

The projected growth in 1987 has been revised to 21 percent, compared to 40 percent in the September forecast. Although U.S. book-to-bill ratios have crossed unity, European ratios have not shown the same strength and Japan's economy is hurting because of the depreciating dollar. Yet, 21 percent is a healthy growth, a welcome relief after the soft market conditions of 1985 and 1986.

MOS Memory Market Forecast

Tempered optimism characterizes the 1988 to 1991 outlook in this forecast. The MOS memory market is expected to grow at a compound annual growth rate (CAGR) of 14.7 percent, compared to 22.0 percent in the previous forecast. New product introduction schedules (4Mb DRAM, 1Mb SRAM, and others) have been adjusted. Conservatism in capital spending for production equipment for new products is prevalent after the severe financial losses incurred in 1985 and 1986.

For Japanese companies, this problem is compounded by the strong yen and an expected weak domestic consumption. Japanese government intervention in pricing and production of MOS memories is expected to continue.

Highlights of the MOS Memory Forecast

We expect the following to occur in the MOS memory market:

- The market achieved $4.4 billion in revenue in 1986 and is expected to grow to $5.3 billion in 1987 and $8.8 billion by 1991.
- The market will grow at 14.7 percent CAGR from 1986 to 1991, compared to a 16.7 percent CAGR from 1981 to 1986.
- The fastest-growing product families are the fast SRAM and EEPROM.
  - Fast SRAMs and EEPROMs will grow at 17 percent and 36 percent CAGRs, respectively.
  - DRAM revenue will have an above-average 16 percent CAGR in this period.
- Average selling prices are expected to improve beginning in 1987, as the industry improves and newer products increasingly are produced.
- The market is expected to experience narrower swings in annual growth rates, similar to those of the latter years of the last decade.
  - There is no apparent application like the personal computer that will cause the wild swings of recent years.
  - We believe that the industry will be better prepared for the next downturn.

MOS Memory Market Forecast

- The year 1989 is projected to be a soft year for the whole semiconductor industry, based on projections of the industry's cycles. However, Dataquest expects a milder downturn in 1989 than that of 1985.

- MOS memory bits are expected to grow at a 63 percent CAGR from 1986 to 1991, versus a 92 percent CAGR from 1981 to 1986.

MARKET OUTLOOK

The Short-Term Outlook

The book-to-bill ratio of U.S. suppliers and the general increased purchasing activity in the early months of 1987 are positive market signs that are expected to fuel the 21 percent growth in 1987. Market opportunities abound. Personal computer manufacturers such as IBM and Apple have announced new products with denser and faster memories. Furthermore, several mainframe and minicomputer companies are performing well, boosting static RAM sales, and the 256K EEPROM is being designed into several military applications. More companies are expected to slowly return to profitability. In the United States, lead times for certain DRAMs and EPROMs have stretched out and are expected to remain so through the third quarter.

Nevertheless, negative factors exist as well. Japanese consumption is expected to be weak in 1987 because of the strong yen. Investments in new, expensive lines for new densities and packages are being constrained by the low level of profitability in the industry, increasing the potential for 1Mb DRAM shortages. The U.S.-Japan trade war is escalating with the semiconductor industry as the more visible battlefield. Consequently, Japanese producers have implemented production cuts that could lead to severe 256K DRAM shortages.

The Long-Term Outlook

Dataquest believes that the following factors will lend to the anticipated 14.7 percent CAGR for MOS memories through 1991:

- The traditional growth of new, higher-density memories

- The penetration of the bipolar market by high-speed MOS memories

- The expansion of the market into nontraditional memory uses

MOS Memory Market Forecast

- The emergence of new applications in graphics, speech, and digital television

- Consumption growth in the Asia Pacific countries other than Japan

We believe that higher-density memories will dominate the market. We expect 1Mb and 4Mb DRAMs, for example, to account for 93 percent of the total DRAM market in 1991, compared to only 8 percent in 1986.

The MOS memory market promises to reach out beyond its traditional boundaries. Submicron processes have given birth to CMOS SRAMs and EPROMs that approximate bipolar speeds. These products are expected to take a slice out of the bipolar memory market. With additional on-chip logic, memories are being used in applications that perform interface and processing-related functions, a departure from conventional storage tasks. Classified as specialty memories, they include FIFOs, dual-port RAMs, video RAMs, and cache tag RAMs. Dataquest expects the specialty memory market segment to grow significantly in the next years.

New applications in graphics, speech, IC cards, digital television, and other areas are projected to pick up in activity, although real expansion in these markets is not expected until after the turn of the decade. Faster, high-density memories are being developed to meet future needs of 32-bit microprocessor-based systems.

The anticipated consumption growth in the Asia Pacific region will also contribute to the growth in MOS memory revenue. MOS memory revenue in this region is expected to reach $880 million by 1991.

MOS Memory Market Forecast

Table 1

WORLDWIDE MOS MEMORY MARKET REVENUE
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	$4,850	$2,473	$2,905	$3,463	$4,438	$4,056	$4,743	$5,999
Dynamic RAM	$3,540	$1,592	$2,102	$2,467	$3,371	$3,110	$3,478	$4,360
NMOS	3,523	1,560	1,896	1,746	1,416	860	401	288
CMOS	17	32	206	721	1,955	2,250	3,077	4,072
Static RAM	$1,310	$ 881	$ 803	$ 996	$1,067	$ 946	$1,265	$1,639
Fast SRAM	323	339	353	446	520	524	677	763
Slow SRAM	987	542	450	550	547	422	588	876
NMOS	481	315	198	128	84	47	28	15
CMOS	830	569	606	869	982	898	1,236	1,623
Read-Only Memory	$1,774	$1,406	$1,467	$1,826	$2,085	$2,147	$2,555	$2,696
EPROM	$1,185	$ 876	$ 910	$1,052	$1,176	$1,225	$1,497	$1,616
UV EPROM	1,164	856	861	989	1,055	1,097	1,346	1,428
OTP	21	20	49	63	121	128	151	188
NMOS	1,071	791	720	725	681	560	594	593
CMOS	114	85	190	326	495	665	902	1,023
ROM	$ 434	$ 388	$ 418	$ 543	$ 564	$ 493	$ 453	$ 442
NMOS	321	255	243	283	256	160	112	81
CMOS	113	133	175	260	308	333	341	361
EEPROM	$ 155	$ 142	$ 139	$ 231	$ 345	$ 429	$ 605	$ 638
NMOS	145	130	117	158	208	185	268	282
CMOS	10	12	22	73	137	244	337	356
Other MOS Memory	$ 50	$ 45	$ 55	$ 65	$ 75	$ 80	$ 100	$ 100
Total MOS Memory	$6,674	$3,924	$4,427	$5,354	$6,598	$6,283	$7,398	$8,795
Percent Change from Previous Year	63.0%	(41.2%)	12.8%	20.9%	23.2%	(4.8%)	17.7%	18.9%

Source: Dataquest
April 1987

MOS Memory Market Forecast

Table 2

WORLDWIDE MOS MEMORY MARKET--REVENUE TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	73%	64%	72%	71%	76%	77%	73%	73%
Percent SRAM	27	36	28	29	24	23	27	27
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	67%	62%	62%	58%	56%	57%	59%	60%
Percent Mask ROM	24	28	28	30	27	23	18	16
Percent EEPROM	9	10	9	13	17	20	24	24
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	73%	63%	66%	65%	67%	65%	64%	68%
Percent Read Only Memory	27	36	33	34	32	34	35	31
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	84%	79%	73%	57%	41%	29%	19%	14%
Percent CMOS	16	21	27	43	59	71	81	86
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	25%	38%	44%	45%	49%	55%	54%	47%
Percent Slow SRAM	75	62	56	55	51	45	46	53
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	2%	4%	5%	7%	7%	7%	8%
Percent Reprogrammable	98%	98%	96%	95%	93%	93%	93%	92%
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

Table 3

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENTS
(Millions of Units)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	1,304	1,080	1,363	1,448	1,549	1,643	1,736	1,878
Dynamic RAM	1,012	782	1,060	1,135	1,230	1,311	1,355	1,454
NMOS	1,010	777	1,043	1,060	870	622	326	240
CMOS	3	5	17	75	361	689	1,029	1,214
Static RAM	291	298	304	313	318	333	381	424
Fast SRAM	60	68	79	94	101	112	143	166
Slow SRAM	232	230	225	219	217	221	238	258
NMOS	138	121	89	47	31	20	12	6
CMOS	154	177	214	266	287	313	369	418
Read-Only Memory	396	427	470	501	538	541	569	602
EPROM	221	245	267	287	311	322	349	357
UV EPROM	216	237	250	264	281	285	308	304
OTP	5	8	17	23	30	37	40	53
NMOS	208	228	227	228	218	183	173	160
CMOS	13	17	40	60	93	139	176	197
ROM	132	137	154	159	160	146	135	140
NMOS	110	106	108	103	86	55	41	32
CMOS	22	31	46	55	74	91	94	108
EEPROM	43	45	49	55	67	73	86	105
NMOS	42	42	41	44	44	39	38	49
CMOS	1	4	7	12	24	35	48	56
Other MOS Memory	10	9	11	13	15	16	20	20
Total MOS Memory	1,710	1,516	1,844	1,962	2,102	2,200	2,325	2,500
Percent Change from Previous Year	33.0%	(11.3%)	21.6%	6.4%	7.1%	4.7%	5.6%	7.5%

Source: Dataquest
April 1987

Table 4

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENT TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	78%	72%	78%	78%	79%	80%	78%	77%
Percent SRAM	22	28	22	22	21	20	22	23
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	56%	57%	57%	57%	58%	59%	61%	59%
Percent Mask ROM	33	32	33	32	30	27	24	23
Percent EEPROM	11	11	10	11	13	14	15	17
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	76%	71%	74%	74%	74%	75%	75%	75%
Percent Read Only Memory	23	28	25	26	26	25	24	24
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	89%	84%	82%	76%	60%	42%	26%	20%
Percent CMOS	11	16	18	24	40	58	74	80
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	20%	23%	26%	30%	32%	34%	38%	39%
Percent Slow SRAM	80	77	74	70	68	66	62	61
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	3%	5%	6%	7%	8%	8%	10%
Percent Reprogrammable	98	97	95	94	93	92	92	90
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

Table 5

WORLDWIDE MOS MEMORY MARKET--AVERAGE SELLING PRICES
(Dollars per Unit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	$3.50	$2.03	$1.98	$2.17	$2.74	$2.37	$2.57	$3.00
Static RAM	$4.50	$2.97	$2.64	$3.18	$3.35	$2.84	$3.32	$3.86
Fast SRAM	$5.41	$5.00	$4.47	$4.76	$5.13	$4.70	$4.72	$4.60
Slow SRAM	$4.26	$2.36	$2.00	$2.51	$2.52	$1.91	$2.47	$3.39
EPROM	$5.37	$3.57	$3.41	$3.66	$3.78	$3.81	$4.29	$4.53
UV EPROM	$5.40	$3.62	$3.45	$3.75	$3.76	$3.85	$4.36	$4.69
OTP	$4.10	$2.40	$2.84	$2.69	$3.98	$3.49	$3.76	$3.57
ROM	$3.28	$2.83	$2.72	$3.42	$3.54	$3.37	$3.37	$3.15
EEPROM	$3.58	$3.15	$2.86	$4.17	$5.13	$5.85	$7.05	$6.09
Other MOS Memory	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
Overall MOS Memory	$3.90	$2.59	$2.40	$2.73	$3.14	$2.86	$3.18	$3.52
Percent Change from Previous Year	19.9%	(33.7%)	(7.2%)	13.7%	15.0%	(9.1%)	11.5%	10.6%

Source: Dataquest
April 1987

Table 6

WORLDWIDE MOS MEMORY MARKET--BIT SHIPMENTS
(Billions of Bits)

	1984	1985	1986	1987
Dynamic RAM	68,162	98,184	196,182	295,585
Static RAM	5,197	7,257	11,134	21,774
Fast SRAM	618	885	1,436	2,695
Slow SRAM	4,580	6,371	9,698	19,078
EPROM	12,933	21,827	36,445	58,123
UV EPROM	12,720	21,231	33,474	52,396
OTP	213	596	2,971	5,727
ROM	13,649	23,032	41,701	75,579
EEPROM	126	188	290	598
Overall MOS Memory	100,067	150,488	285,752	451,659
Percent Change from Previous Year	95.0%	50.4%	89.9%	58.1%

	1988	1989	1990	1991
Dynamic RAM	572,680	887,279	1,353,967	2,538,471
Static RAM	34,750	51,947	99,590	198,468
Fast SRAM	5,285	8,955	18,357	34,005
Slow SRAM	29,465	42,992	81,234	164,463
EPROM	90,006	133,829	201,282	259,797
UV EPROM	77,526	112,932	168,677	204,584
OTP	12,480	20,897	32,605	55,213
ROM	112,853	132,710	175,112	261,554
EEPROM	1,668	3,360	8,428	15,931
Overall MOS Memory	811,957	1,209,125	1,838,379	3,274,221
Percent Change from Previous Year	79.8%	48.9%	52.0%	78.1%

Source: Dataquest
April 1987

Table 7

WORLDWIDE MOS MEMORY MARKET--AVERAGE SELLING PRICE PER BIT
(Millicents per Bit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	5.2	1.6	1.1	0.8	0.6	0.4	0.3	0.2
Static RAM	25.2	12.2	7.2	4.6	3.1	1.8	1.3	0.8
Fast SRAM	52.3	38.3	24.6	16.6	9.8	5.9	3.7	2.2
Slow SRAM	21.5	8.5	4.6	2.9	1.9	1.0	0.7	0.5
EPROM	18.8	7.3	4.3	3.0	2.4	1.6	1.3	1.0
UV EPROM	9.2	4.0	2.6	1.9	1.4	1.0	0.8	0.7
OTP	9.6	3.3	1.7	1.1	1.0	0.6	0.5	0.3
ROM	3.2	1.7	1.0	0.7	0.5	0.4	0.3	0.2
EEPROM	122.6	75.5	48.2	38.6	20.7	12.8	7.2	4.0
Overall MOS Memory	6.6	2.6	1.5	1.2	0.8	0.5	0.4	0.3
Percent Change from Previous Year	(18.0%)	(61.1%)	(40.6%)	(23.5%)	(31.4%)	(36.1%)	(22.6%)	(33.1%)

Source: Dataquest
April 1987

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MOS Memory Market Forecast

SUMMARY

The worldwide market for MOS memory has exhibited steady growth since its inception, except for 1981, when declining unit prices and stagnant demand combined to reduce the market size by 17 percent from 1980. Table 1, below, summarizes market size estimates for 1982 and forecasts market size for 1983 through 1988. During the 1983-88 period, aggregate memory growth is expected to average 31 percent annually. The extreme market strength of 1982 through 1985, with growth averaging 45 percent per year with growing margins, is expected to moderate markedly during 1986 through 1988 to a more modest 20 percent per year. Bit growth and rates of decline of prices per bit are anticipated to be slightly greater than the 1977-82 period, and again, the 1982-85 period is expected to be qualitatively different from the 1986-88 period.

Table 1

ESTIMATED WORLDWIDE MOS MEMORY MARKET
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987	1988
Dynamic RAM	$ 952	$1,818	$3,372	$4,960	$ 5,807	$ 6,142	$ 8,175
Static RAM	539	772	1,094	1,435	1,809	2,105	2,287
EPROM	528	709	946	1,383	1,459	1,675	2,167
ROM	718	559	655	850	966	1,285	1,726
EEPROM	49	103	190	373	583	787	1,029
Other	55	60	65	70	75	85	100
Total	$2,841	$4,020	$6,323	$9,071	$10,700	$12,079	$15,483

Source: DATAQUEST
December 1983

FORECAST DESCRIPTION

The MOS memory forecast is built bottom up by multiplying estimates of unit shipments and estimated average selling prices (ASPs) for a wide variety of memory products. From this detail can be generated total product revenues, total market revenues, total bits and total units shipped, and average prices per bit. As such, this forecast contains a considerable amount of detail as well as capturing the broader market size, market growth, and technology shifts that are evident in the summaries. The List of Tables at the bottom of page 3 provides capsule descriptions of the 18 tables included in this report. Tables 2-5 summarize, respectively, revenues, bits, prices, and unit shipment data from the detailed data of Tables 6-14. The forecast methodology is described on pages 30-31.

MOS Memory Market Forecast

MOS MEMORY MARKET TRENDS

We have incorporated the principal trends in the MOS memory market into this forecast, and have built it around the historical data base established by DATAQUEST over the past six years as published in the DATAQUEST quarterly newsletter series, "MOS Memory Shipments." While parts of this data base have been published in past DATAQUEST newsletters, the comprehensive picture presented here has not been formally published before.

On the following two pages, we will discuss major trends affecting the MOS memory market as a whole, which trends have been quantified in the tables following. Further detail is contained in the discussion of the summary tables (2-5), as well as in the individual product tables (6-14).

Long-Term Trend--Short-Term Trend

In this forecast, we have tried to maintain what we feel will be the long-term growth trends of the market, as well as to include what we feel will be the regular oscillations about the trend line based on issues of supply or demand excess, as well as changes in the macroeconomic picture. In short, we see a strong market with good unit growth and slow price declines during 1983 and 1984, a weakening market in 1985, and increasing margin pressure and more rapidly declining prices per bit during 1986 through 1988.

The Role of Prices

Closely tied with the shortage/excess scenario is the issue of prices. The long-term historical trend line, which has driven down prices an average of more than 30 percent per year since 1972 (and 50 percent per year for 1981 and 1982), has been interrupted--temporarily--with the strong market of 1983.

Needless to say, prices will play an extremely important role in the growth of the market during 1983 and 1984. Between 1980 and 1982, MOS memory prices per bit dropped an average of 70.7 percent. Historically, prices have tended to drop 56.4 percent every two years (34 percent per year). Between 1982 and 1984, prices per bit are expected to drop a total of only 42.6 percent. In a sense, the slower than normal decline in price per bit between 1982 and 1984 will account for more than 40 percent of the revenue growth expected during that same period.

MOS Memory Market Forecast

The Trend to CMOS

There is a general trend throughout the industry to shift manufacturing to a variety of CMOS technologies. This is true within the family of MOS memory products as well. Static RAMs were, for a variety of reasons, the first memory market where CMOS devices appeared in volume. It is almost certain that in 1983, CMOS static RAMs will generate more revenue than NMOS devices. In addition, emerging markets exist for CMOS ROMs and EPROMs. CMOS dynamic RAMs and EEPROMs are beginning to be seen, but do not yet have the broad constituency that any of the other major memory groups do. Estimates of CMOS market penetration in 1982 and 1988 are as follows:

Year	DRAM	SRAM	ROM	EPROM	EEPROM
1982	0%	46%	8%	3%	2%
1988	54%	90%	89%	77%	75%

Because CMOS is expected to play an increasingly important role in the future development of the MOS memory market, it is broken out specifically in Tables 8, 10, and 13 (SRAMs, EPROMs, and ROMs) but not in Tables 6 and 14 (DRAMs and EEPROMs), where it still plays an extremely small role.

LIST OF TABLES

MOS Memory Market Forecast

MOS MEMORY REVENUES

Table 2b breaks down total MOS memory revenues into major subcategories as shown in the List of Tables. In addition, calculations in lines 19-34 track several key measures of market composition: CMOS vs. P or NMOS; read-write memory vs. read-only memory; DRAM share of total RAM market; and reprogrammable memory share of the total read-only memory market. Most entries in lines 19-34 can be calculated directly from entries in lines 1-16, except where the detail has not been worked out in the specific product tables (Tables 6-14). In these cases, an aggregate estimate was made directly and combined for the entry listed (e.g., forward estimates for CMOS share of the dynamic RAM and EEPROM markets, while not identified exactly in Tables 6 and 14, respectively, are included in a share of line 22, CMOS Percent of Total MOS Memory.)

The "Other" category (lines 15 and 33) contains a miscellany of small MOS memory product lines--some of which are mature, some of which are active and growing. Included in the "Other" category are, for example, CCDS, shift registers, FIFOS, and unclassifiable custom memories.

Historical revenues for various product groups for the years 1977-82 are shown in Table 2a.

Table 2a

ESTIMATED WORLDWIDE MOS MEMORY REVENUES
(Millions of Dollars)

	1977	1978	1979	1980	1981	1982	CAGR 1977-1982
DRAM	$268	$ 408	$ 652	$1,031	$ 635	$ 952	28.9%
SRAM	112	210	374	491	471	539	36.9%
EPROM	109	176	405	539	412	528	37.1%
ROM	135	170	220	322	436	718	39.7%
Other	41	50	67	76	87	104	20.5%
Total	$665	$1,014	$1,718	$2,458	$2,042	$2,841	31.6%

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

Table 2b

MOS MEMORY REVENUES

		1980	1981	1982	1983	1984	1985	1986	1987	1988	CMPD-GR 1982-87	CMPD-GR 1983-88
1	Read/Write Memory	1522	1107	1491	2589	4466	6395	7616	8247	10462	41	32
2	Dynamic RAM	1031	635	952	1818	3372	4960	5807	6142	8175	45	35
3	Static RAM	491	471	539	772	1094	1435	1809	2105	2287	31	24
4	NMOS	307	293	291	357	399	393	381	315	237	2	(8)
5	CMOS	184	178	248	414	695	1042	1429	1790	2050	48	38
6	Read-Only Memory	891	886	1295	1371	1791	2606	3009	3747	4922	24	29
7	EPROM	539	412	528	709	946	1383	1459	1675	2167	26	25
8	NMOS	535	399	510	655	633	513	318	177	115	(19)	(29)
9	CMOS	4	12	18	46	134	256	282	323	437	79	57
10	OTP	0	0	0	8	180	614	859	1176	1616	(100)	191
11	ROM	322	436	718	559	655	850	966	1285	1726	12	25
12	NMOS	302	410	661	457	421	435	340	314	188	(14)	(16)
13	CMOS	19	26	58	102	234	415	626	971	1538	76	72
14	EE/EAROM	'31	37	49	103	190	373	583	787	1029	74	58
15	Other MOS Memory	45	50	55	60	65	70	75	85	100	9	11
16	Total MOS Memory	2458	2042	2841	4020	6323	9071	10700	12079	15483	34	31
17	Percent Change From											
18	Previous Year	41	(17)	39	41	57	43	18	13	28		
19	Percent DRAM	68	57	64	70	76	78	76	74	78		
20	Percent SRAM	32	43	36	30	24	22	24	26	22		
21	Total RAM	100	100	100	100	100	100	100	100	100		
22	Percent CMOS	10	12	11	14	18	24	36	54	67		
23	Percent P or NMOS	90	88	89	86	82	76	64	46	33		
24	Total MOS Memory	100	100	100	100	100	100	100	100	100		
25	Once-Programmable	36	49	55	41	47	56	61	66	68		
26	Reprogrammable	64	51	45	59	53	44	39	34	32		
27	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
28	Factory Programmable	36	49	55	41	37	33	32	34	35		
29	User Programmable	64	51	45	59	63	67	68	66	65		
30	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
31	Read/Write Memory	62	54	52	64	71	70	71	68	68		
32	Read-Only Memory	36	43	46	34	28	29	28	31	32		
33	Other MOS Memory	2	2	2	1	1	1	1	1	1		
34	Total MOS Memory	100	100	100	100	100	100	100	100	100		

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

MOS MEMORY BITS

Table 3b breaks down total shipments of MOS memory bits into the major subcategories shown in the List of Tables. Bit growth for the period 1977-82, shown in Table 3a, has been about 100 percent per year in most categories of MOS memory products and is expected to continue to do so for the 1983-88 period.

The discontinuity caused by the extraordinary growth in the MOS ROMs market in 1981-83 has been followed by a similar exceptional explosion in dynamic RAM during 1982 to 1984, brought by sales into small systems. Both of these phenomena caused departures from the steadily evolving ratio of read-write memory bits to read-only memory bits. The magnitude of these events has been remarkable: Video games absorbed as many ROM bits as all markets that had come before it, combined. Personal and home computers are expected to absorb as many dynamic RAM bits in 1982 to 1984 as all other sources of dynamic RAM demand up to that time as well.

Table 3a

ESTIMATED WORLDWIDE MOS MEMORY BITS SHIPPED
(Gigabits)

	1977	1978	1979	1980	1981	1982	CAGR 1977-1982
DRAM	275	659	1,488	3,390	4,812	11,384	110.6%
SRAM	53	118	224	357	588	1,210	86.9%
EPROM	40	125	376	715	1,425	3,237	140.8%
ROM	369	548	1,129	2,002	4,005	9,800	92.7%
Other	12	16	20	19	28	47	31.4%
Total	749	1,466	3,237	6,483	10,859	25,679	102.8%

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

Table 3b

MOS MEMORY BITS

		1980	1981	1982	1983	1984	1985	1986	1987	1988	CMPD-GR 1982-87	CMPD-GR 1983-88
1	Read/Write Memory	3747	5400	12594	30968	64696	140113	282521	505053	859996	109	94
2	Dynamic RAM	3390	4812	11384	28535	60101	132078	267715	475849	806093	111	95
3	Static RAM	357	588	1210	2433	4596	8035	14806	29204	53903	89	86
4	NMOS	288	402	681	1109	1524	1765	1982	2130	1966	26	12
5	CMOS	69	186	530	1324	3072	6270	12825	27075	51937	120	108
6	Read-Only Memory	2728	5448	13070	19300	34077	79710	161822	341009	755152	92	108
7	EPROM	715	1425	3237	6652	13278	36281	72316	133104	246383	110	106
8	NMOS	713	1419	3182	6368	8903	11770	12727	12141	11076	31	12
9	CMOS	2	6	55	202	999	4162	9617	18874	41976	221	191
10	OTP	0	0	0	82	3375	20349	49971	102089	193331	(100)	373
11	ROM	2002	4005	9800	12565	20455	41732	83923	196674	483918	82	108
12	NMOS	1974	3931	9526	11238	14930	23085	29753	41353	27329	34	19
13	CMOS	28	74	274	1327	5525	18647	54170	155320	456589	255	222
14	EE/EAROM	12	18	32	83	344	1698	5583	11232	24852	223	213
15	Other MOS Memory	7	10	15	25	35	45	70	100	150	46	43
16	Total MOS Memory	6483	10859	25679	50293	98808	219868	444413	846162	1615298	101	100
17	Percent Change From											
18	Previous Year	99	67	136	96	96	123	102	90	91		
19	Percent DRAM	90	89	90	92	93	94	95	94	94		
20	Percent SRAM	10	11	10	8	7	6	5	6	6		
21	Total RAM	100	100	100	100	100	100	100	100	100		
22	Percent CMOS	2	2	3	6	10	17	30	50	69		
23	Percent P or NMOS	98	98	97	94	90	83	70	50	31		
24	Total MOS Memory	100	100	100	100	100	100	100	100	100		
25	Once-Programmable	73	74	75	66	70	78	83	88	90		
26	Reprogrammable	27	26	25	34	30	22	17	12	10		
27	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
28	Factory Programmable	73	74	75	65	60	52	52	58	64		
29	User Programmable	27	26	25	35	40	48	48	42	36		
30	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
31	Read/Write Memory	58	50	49	62	65	64	64	60	53		
32	Read-Only Memory	42	50	51	38	34	36	36	40	47		
33	Other MOS Memory	0	0	0	0	0	0	0	0	0		
34	Total MOS Memory	100	100	100	100	100	100	100	100	100		

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

MOS MEMORY AVERAGE SELLING PRICES

Aggregate average selling prices (ASPs) for MOS memory are shown in Table 4b. These data are transferred directly from the appropriate line in Tables 6-14, and, as such, are weighted averages of ASPs for all products in that group, i.e., total revenue dollars generated divided by total bits shipped.

Historical average selling price estimates are given in Table 4a. The average decline of all products of 34.6% per year has been exceeded by a wide margin by EPROMs, at 43.0% per year. The coming of one-time programmable (OTP) EPROMs (see Table 11) will have the effect of pushing this ASP down considerably in the coming five years.

Table 4a

HISTORICAL AVERAGE SELLING PRICES
(Millicents per Bit)

	1977	1978	1979	1980	1981	1982	CAGR 1977-1982
DRAM	97.5	61.9	43.8	30.4	13.2	8.4	(39.8%)
SRAM	212.0	177.2	167.2	137.3	80.2	44.6	(26.8%)
EPROM	270.4	140.2	107.8	75.4	28.9	16.3	(43.0%)
ROM	47.5	27.7	21.7	16.1	10.9	7.3	(31.2%)
Overall	91.7	66.9	53.4	37.7	18.7	11.0	(34.6%)

Source: DATAQUEST
December 1983

Caveats

ASPs provided here are composites of a large number of individual products. Variables may include lot size, speed mix (especially for static RAMs), package type, and military or Radiation Hard devices.

Forecast changes in price per bit are estimated to be in line with historical rates of roughly 30 percent each year. However, temporary market conditions may result in rates of price decline greater than this rate (capacity excess, 1981-82) or less than this rate (supply constraints, 1983-84).

MOS Memory Market Forecast

Table 4b

AVERAGE SELLING PRICES
MOS MEMORY

		1980	1981	1982	1983	1984	1985	1986	1987	1988	CMPD-GR 1982-87	CMPD-GR 1983-88
1	Read/Write Memory	40.6	20.5	11.8	8.6	7.0	4.6	2.7	1.6	1.2	(32.7)	(32.3)
2	Dynamic RAM	30.4	13.2	8.4	6.4	5.6	3.8	2.2	1.3	1.0	(31.2)	(30.8)
3	Static RAM	137.3	80.2	44.6	36.7	24.9	18.3	12.3	7.2	4.2	(30.5)	(35.0)
4	NMOS	106.5	73.0	42.8	32.2	26.2	22.2	19.2	14.8	12.0	(19.1)	(17.9)
5	CMOS	265.9	95.6	46.8	31.3	22.6	16.6	11.1	6.6	3.9	(32.4)	(33.9)
6	Read-Only Memory	32.7	16.3	9.9	7.1	5.1	3.3	1.8	1.0	0.6	(36.3)	(39.0)
7	EPROM	75.4	28.9	16.3	10.7	7.1	3.8	1.9	1.1	0.7	(41.6)	(41.7)
8	NMOS	75.1	28.2	16.0	10.3	7.1	4.4	2.5	1.5	1.0	(38.1)	(36.8)
9	CMOS	183.1	203.5	32.0	22.9	13.4	6.2	2.9	1.7	1.0	(44.3)	(46.1)
10	OTP	0.0	0.0	0.0	9.5	5.3	3.0	1.7	1.2	0.8	(100.0)	(38.5)
11	ROM	16.1	10.9	7.3	4.4	3.2	2.0	1.2	0.7	0.4	(38.3)	(39.6)
12	NMOS	15.3	10.4	6.9	4.1	2.8	1.9	1.1	0.8	0.7	(35.8)	(29.9)
13	CMOS	68.9	35.8	21.0	7.7	4.2	2.2	1.2	0.6	0.3	(50.5)	(46.5)
14	EE/EAROM	261.3	204.7	151.2	124.8	55.1	22.0	10.4	7.0	4.1	(45.9)	(49.4)
15	Other MOS Memory	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0
16	Total MOS Memory	37.7	18.7	11.0	8.0	6.3	4.1	2.4	1.4	0.9	(34.0)	(35.2)
17	Percent Change From											
18	Previous Year	(29.4)	(50.3)	(41.0)	(27.5)	(20.8)	(34.6)	(42.6)	(41.8)	(33.9)		

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

MOS MEMORY UNIT SHIPMENTS

Table 5b summarizes unit shipments of MOS memory for the period 1980-88, broken down into the major categories shown in the List of Tables.

Historical MOS memory unit shipments for the period 1977-82 are shown in Table 5a, below. Dynamic RAMs have always constituted at least 40 percent of total units shipped, thus their importance as a "process technology driver." For comparison, about 3.7 billion units of all TTL devices combined were shipped in 1982, and, among LSI devices, all microprocessors and microcontrollers totaled about 264 million devices in 1982.

While most MOS memory products are now shipped in 16- to 28-pin DIPs, a small number are shipped in chip carriers or flatpacks. In addition, there have been other notable exceptions, including the famous "piggy-back" and "camel-back" 32K dynamic RAMs (two 16K die packaged as a single 32K unit) purchased in large quantity by IBM and others. Another important exception is the chip-on-board (COB) device, which took a significant fraction of the ROM market going into video games. As a result, total die shipped has exceeded the unit totals shown here; the number of DIPs shipped will be somewhat less than these totals.

Table 5a

ESTIMATED MOS MEMORY UNIT SHIPMENTS
(Millions)

	1977	1978	1979	1980	1981	1982	CAGR 1977-1982
DRAM	67	104	147	229	258	357	39.7%
SRAM	37	54	79	107	132	174	36.3%
EPROM	7	15	35	50	71	107	72.5%
ROM	31	37	63	92	154	256	52.5%
Other	8	10	13	17	20	25	25.6%
Total	150	220	337	485	635	919	43.7%

Source: DATAQUEST
December 1983

Table 5b

MOS MEMORY UNIT SHIPMENTS

		1980	1981	1982	1983	1984	1985	1986	1987	1988	CMPD-GR 1982-87	CMPD-GR 1983-88
1	Read/Write Memory	335	390	531	835	1239	1782	2351	3123	3929	43	36
2	Dynamic RAM	229	258	357	616	959	1450	1964	2614	3300	49	40
3	Static RAM	107	132	174	220	280	332	387	509	629	24	23
4	NMOS	86	97	113	123	129	117	112	100	84	(2)	(7)
5	CMOS	21	35	60	97	151	215	275	409	545	47	41
6	Read-Only Memory	153	235	377	390	414	589	749	1034	1471	22	30
7	EPROM	50	71	107	145	197	303	372	454	657	34	35
8	NMOS	49	70	105	138	135	99	50	30	21	(22)	(31)
9	CMOS	1	1	2	6	15	37	47	56	76	[illegible]	68
10	OTP	0	0	0	2	47	167	275	369	560	(100)	227
11	ROM	95	154	256	220	177	216	254	400	552	9	20
12	NMOS	92	149	245	200	135	132	116	135	102	(11)	(13)
13	CMOS	3	5	11	19	42	84	138	265	450	90	88
14	EE/EAROM	8	10	14	25	40	70	123	180	263	66	60
15	Other MOS Memory	9	10	11	12	13	14	15	17	20	9	11
16	Total MOS Memory	497	635	919	1237	1667	2385	3115	4173	5420	35	34
17	Percent Change From											
18	Previous Year	34	28	45	35	35	43	31	34	30		
19	Percent DRAM	68	66	67	74	77	81	84	84	84		
20	Percent SRAM	32	34	33	26	23	19	16	16	16		
21	Total RAM	100	100	100	100	100	100	100	100	100		
22	Percent CMOS	5	6	8	9	13	16	24	38	50		
23	Percent P or NMOS	95	94	92	91	87	84	76	62	50		
24	Total MOS Memory	100	100	100	100	100	100	100	100	100		
25	Once-Programmable	62	66	68	57	54	65	71	74	76		
26	Reprogrammable	38	34	32	43	46	35	29	26	24		
27	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
28	Factory Programmable	62	66	68	56	43	37	34	39	38		
29	User Programmable	38	34	32	44	57	63	66	61	62		
30	Total Programmable Memory	100	100	100	100	100	100	100	100	100		
31	Read/Write Memory	67	61	58	68	74	75	75	75	72		
32	Read-Only Memory	31	37	41	32	25	25	24	25	27		
33	Other MOS Memory	2	2	1	1	1	1	0	0	0		
34	Total MOS Memory	100	100	100	100	100	100	100	100	100		

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

DYNAMIC RAMs

Table 6 shows the detailed breakdown of the dynamic RAM market for the years 1980-88. After a brief pause in 1981, as demand stagnated and prices dropped nearly 60 percent, the dynamic RAM market has bounced back strongly.

Assumptions

- The strength of 16Ks, witnessed through mid-1983, has been eroded by the uncertainties in the home computer business and other small systems with relatively short product life cycles. We expect 1984 to see a sharp decline in 16K shipments as 64Ks continue to become more available.
- We expect a significant relaxation in upward price pressure on 64Ks, beginning about mid-1984, as capacity comes on line. In 1984, the second-half ASP is expected to be at least 50 cents lower than the first-half ASP for most vendors.
- Market penetration by 256Ks in 1984 will be moderated by price (about $25 ASP) and by the strength of the 64K market.
- The units and ASP data shown are aggregate over an increasingly wide variety of devices with often widely divergent prices: CMOS and NMOS; x1, x4, x8 devices; and speeds ranging from sub-75 ns to 300 ns.
- One-megabit devices are expected to appear as engineering samples in late 1985.
- We believe that forward DRAM prices shown here (1987-88 256K prices, for example) are quite achievable in light of improved lithographic capabilities and production economics established during 1982-83.

Uncertainties

Not shown here separately are CMOS dynamic RAMs, which are expected to be a significant portion of the 256K market by 1987-88. Attractive both in serving the highest growth rate markets for dynamic RAMs (small systems) and displacing SRAMs on a price-per-bit basis, these parts are just beginning to become available.

Pseudostatic or integrated RAMs, incorporating the dynamic RAM storage cell with clock and refresh circuitry on board, have begun to reappear and may further attract some applications that had formerly used SRAMs.

MOS Memory Market Forecast

Table 6

DYNAMIC RAMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
1K	8	9	0	0	0	0	0	0	0
4K	67	27	12	8	4	0	0	0	0
16K (3 Power Supply)	884	346	224	201	112	38	11	4	0
16K (5-Volt Only)	9	23	52	81	56	30	8	3	0
32K (2 Chip Package)	48	84	139	72	38	18	0	0	0
64K	15	145	524	1405	2714	2460	2188	1760	1050
256K	0	0	1	50	450	2400	3500	4125	5625
1M	0	0	0	0	0	15	100	250	1500
Total Dollars	1031	635	952	1818	3372	4960	5807	6142	8175
Percent Change From Previous Year	58	(38)	50	91	86	47	17	6	33
Units (Millions)									
1K	4.0	4.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	31.2	13.0	4.6	2.5	1.0	N/A	N/A	N/A	N/A
16K (3 Power Supply)	188.0	210.0	195.0	175.0	80.0	25.0	7.0	2.0	N/A
16K (5-Volt Only)	1.1	5.8	23.7	54.0	40.0	20.0	5.0	1.5	N/A
32K (2 Chip Package)	4.0	12.0	30.0	18.0	10.0	5.0	N/A	N/A	N/A
64K	0.4	12.6	103.7	365.0	810.0	1200.0	1250.0	1100.0	700.0
256K	N/A	N/A	0.0	1.0	18.0	200.0	700.0	1500.0	2500.0
1M	N/A	N/A	N/A	N/A	N/A	0.1	2.0	10.0	100.0
Total Units	228.7	257.9	357.0	615.5	959.0	1450.1	1964.0	2613.5	3300.0
Average Selling Price									
1K	2.00	2.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	2.15	2.10	2.50	3.25	3.50	N/A	N/A	N/A	N/A
16K (3 Power Supply)	4.70	1.65	1.15	1.15	1.40	1.50	1.60	2.00	N/A
16K (5-Volt Only)	8.00	4.00	2.20	1.50	1.40	1.50	1.65	2.00	N/A
32K (2 Chip Package)	12.00	7.00	4.65	4.00	3.75	3.50	N/A	N/A	N/A
64K	35.00	11.50	5.05	3.85	3.35	2.05	1.75	1.60	1.50
256K	N/A	N/A	100.00	50.00	25.00	12.00	5.00	2.75	2.25
1M	N/A	N/A	N/A	N/A	N/A	150.00	50.00	25.00	15.00
Bits (Billions)									
1K	4	5	0	0	0	0	0	0	0
4K	128	53	19	10	4	0	0	0	0
16K (3 Power Supply)	3080	3441	3195	2867	1311	410	115	33	0
16K (5-Volt Only)	18	95	388	885	655	328	82	25	0
32K (2 Chip Package)	131	393	983	590	328	164	0	0	0
64K	29	826	6796	23921	53084	78643	81920	72090	45875
256K	0	0	3	262	4719	52429	183501	393216	655360
1M	0	0	0	0	0	105	2097	10486	104858
Total Bits	3390	4812	11384	28535	60101	132078	267715	475849	806093
Percent Change From Previous Year	128	42	137	151	111	120	103	78	69
Price Per Bit									
(Millicents/Bit)									
1K	195.3	205.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	52.5	51.3	61.0	79.3	85.4	N/A	N/A	N/A	N/A
16K (3 Power Supply)	28.7	10.1	7.0	7.0	8.5	9.2	9.8	12.2	N/A
16K (5-Volt Only)	48.8	24.4	13.4	9.2	8.5	9.2	10.1	12.2	N/A
32K (2 Chip Package)	36.6	21.4	14.2	12.2	11.4	10.7	N/A	N/A	N/A
64K	53.4	17.5	7.7	5.9	5.1	3.1	2.7	2.4	2.3
256K	N/A	N/A	38.1	19.1	9.5	4.6	1.9	1.0	0.9
1M	N/A	N/A	N/A	N/A	N/A	14.3	4.8	2.4	1.4
Avg Price Per Bit	30.4	13.2	8.4	6.4	5.6	3.8	2.2	1.3	1.0
Percent Change From Previous Year	(31)	(57)	(37)	(24)	(12)	(33)	(42)	(40)	(21)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

NMOS STATIC RAMs

Table 7 shows details of expected shipments and prices for NMOS static RAMs for the period 1980-88. The table is divided into several speed ranges and types of organization. These devices characteristically serve two distinct markets: slower byte-wide devices for MPU-based systems, fast x1 or x4 devices for high-speed cache, or buffer memories for larger, faster systems.

Prices per bit for NMOS SRAMs are not expected to drop as fast as those of other MOS memory categories as the mix becomes richer in high-speed/higher-priced drives (i.e., slower byte-wide NMOS SRAMs are losing ground to CMOS faster than high-speed NMOS SRAMs).

The market for NMOS SRAMs has always been larger than that for CMOS. However, the rapid growth of 16K CMOS devices has finally resulted, in 1983, in a CMOS SRAM market that is about 15 percent larger than the NMOS SRAM market.

Assumptions

- We expect that all fast SRAMs (NMOS and CMOS) will continue to gain ground on ECL devices, thus gaining new markets.
- The emerging fast byte-wide SRAM market will, in the long run, be the largest segment of the high-speed SRAM market, surpassing both x1 and x4 devices.
- NMOS will likely remain most competitive with CMOS 64K in high speed, but will continue to give ground in the slow byte-wide areas where CMOS's power advantage is greatest.
- All static RAMs tend to be designed into long-lived applications or other MPU applications that economically resist redesign or replacement by higher density devices. Therefore, product life cycles tend to be prolonged compared to dynamic RAMs.

Major Uncertainties

Fast static RAMs have been dominated by NMOS devices since Intel's 4K 2147 became available in 1977-78. At 16K, NMOS retained dominance, with more than 85 percent of fast 16K SRAM unit shipments through mid-1983 being NMOS. However, the success of fast NMOS 64Ks remains to be seen, as even some of the more dedicated fast NMOS SRAM suppliers are moving to CMOS.

MOS Memory Market Forecast

Table 7

NMOS STATIC RAMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
1K (All Types)	29	21	17	9	8	4	0	0	0
4K (Slow, 1Kx4)	131	126	87	60	45	18	9	0	0
4K (Slow, 4Kx1)	57	31	9	3	4	0	0	0	0
4K (Fast, 1Kx4)	7	7	9	13	11	0	3	0	0
4K (Fast, 4Kx1)	62	41	27	33	24	16	8	0	0
8K (All Types)	14	21	17	11	10	0	0	0	0
16K (Sub-100ns, 2Kx8)	0	4	5	15	36	64	56	33	14
16K (Slow, 2Kx8)	4	29	60	114	138	113	68	30	16
16K (4Kx4)	0	1	13	33	54	80	105	105	96
16K (16Kx1)	2	13	40	60	63	71	100	98	69
64K (All Types)	0	0	0	0	7	20	33	50	42
Total Dollars	307	293	291	357	399	393	381	315	237
Percent Change From Previous Year	15	(5)	(1)	23	12	(2)	(3)	(17)	(25)
Units (Millions)									
1K (All Types)	23.5	19.0	11.0	5.0	3.0	1.5	N/A	N/A	N/A
4K (Slow, 1Kx4)	37.5	50.4	62.4	50.0	30.0	12.0	5.0	N/A	N/A
4K (Slow, 4Kx1)	14.9	10.6	5.4	2.0	2.0	N/A	N/A	N/A	N/A
4K (Fast, 1Kx4)	0.6	1.4	2.5	3.5	3.5	2.0	0.8	N/A	N/A
4K (Fast, 4Kx1)	7.8	9.1	9.1	10.0	7.5	4.5	2.0	N/A	N/A
8K (All Types)	1.6	3.1	4.0	3.0	2.5	N/A	N/A	N/A	N/A
16K (Sub-100ns, 2Kx8)	N/A	0.1	0.4	2.5	8.0	15.0	14.0	10.0	5.0
16K (Slow, 2Kx8)	0.1	3.4	15.0	35.0	50.0	45.0	30.0	15.0	7.0
16K (4Kx4)	N/A	0.0	1.1	5.0	12.0	20.0	30.0	35.0	35.0
16K (16Kx1)	0.0	0.4	2.5	7.0	10.0	15.0	25.0	30.0	25.0
64K (All Types)	N/A	N/A	N/A	N/A	0.2	2.0	5.0	10.0	12.0
Total Units	86.0	97.5	113.4	123.0	128.7	117.0	111.8	100.0	84.0
Average Selling Price									
1K (All Types)	1.25	1.10	1.50	1.75	2.50	2.50	N/A	N/A	N/A
4K (Slow, 1Kx4)	3.50	2.50	1.40	1.35	1.50	1.50	1.75	N/A	N/A
4K (Slow, 4Kx1)	3.80	2.90	1.60	1.60	1.75	N/A	N/A	N/A	N/A
4K (Fast, 1Kx4)	11.50	5.00	3.50	3.75	3.25	3.80	4.00	N/A	N/A
4K (Fast, 4Kx1)	8.00	4.50	3.00	3.25	3.25	3.50	4.00	N/A	N/A
8K (All Types)	9.00	6.75	4.25	3.80	4.00	N/A	N/A	N/A	N/A
16K (Sub-100ns, 2Kx8)	N/A	40.00	12.00	6.00	4.50	4.25	4.00	3.25	2.75
16K (Slow, 2Kx8)	40.00	8.50	4.50	3.25	2.75	2.50	2.25	2.00	2.25
16K (4Kx4)	N/A	30.00	12.00	6.50	4.50	4.00	3.50	3.00	2.75
16K (16Kx1)	75.00	35.00	16.00	8.50	6.25	4.75	4.00	3.25	2.75
64K (All Types)	N/A	N/A	N/A	N/A	35.00	10.00	6.50	5.00	3.50
Bits (Billions)									
1K (All Types)	24	19	11	5	3	2	0	0	0
4K (Slow, 1Kx4)	154	206	256	205	123	49	20	0	0
4K (Slow, 4Kx1)	61	43	22	8	8	0	0	0	0
4K (Fast, 1Kx4)	2	6	10	14	14	8	3	0	0
4K (Fast, 4Kx1)	32	37	37	41	31	18	8	0	0
8K (All Types)	13	25	33	25	20	0	0	0	0
16K (Sub-100ns, 2Kx8)	0	2	7	41	131	246	229	164	82
16K (Slow, 2Kx8)	2	56	246	573	819	737	492	246	115
16K (4Kx4)	0	1	18	82	197	328	492	573	573
16K (16Kx1)	0	6	41	115	164	246	410	492	410
64K (All Types)	0	0	0	0	13	131	328	655	786
Total Bits	288	402	681	1109	1524	1765	1982	2130	1966
Percent Change From Previous Year	48	39	69	63	37	16	12	7	(8)
Price Per Bit									
(Millicents per Bit)									
1K (All Types)	122.1	107.4	146.5	170.9	244.1	244.1	N/A	N/A	N/A
4K (Slow, 1Kx4)	85.4	61.0	34.2	33.0	36.6	36.6	42.7	N/A	N/A
4K (Slow, 4Kx1)	92.8	70.8	39.1	39.1	42.7	N/A	N/A	N/A	N/A
4K (Fast, 1Kx4)	280.8	122.1	85.4	91.6	79.3	92.8	97.7	N/A	N/A
4K (Fast, 4Kx1)	195.3	109.9	73.2	79.3	79.3	85.4	97.7	N/A	N/A
8K (All Types)	109.9	82.4	51.9	46.4	48.8	N/A	N/A	N/A	N/A
16K (Sub-100ns, 2Kx8)	N/A	244.1	73.2	36.6	27.5	25.9	24.4	19.8	16.8
16K (Slow, 2Kx8)	244.1	51.9	27.5	19.8	16.8	15.3	13.7	12.2	13.7
16K (4Kx4)	N/A	183.1	73.2	39.7	27.5	24.4	21.4	18.3	16.8
16K (16Kx1)	457.8	213.6	97.7	51.9	38.1	29.0	24.4	19.8	16.8
64K (All Types)	N/A	N/A	N/A	N/A	53.4	15.3	9.9	7.6	5.3
Avg Price Per Bit	106.5	73.0	42.8	32.2	26.2	22.2	19.2	14.8	12.0
Percent Change From Previous Year	(22)	(31)	(41)	(25)	(19)	(15)	(14)	(23)	(19)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

CMOS STATIC RAMS

Table 8 details expected unit shipments and prices for a variety of CMOS SRAM devices. This category includes both full CMOS (6 Tx cell) and mixed MOS (a.k.a. N/CMOS, pseudo-CMOS, etc.) having a 4 Tx cell, as with Hitachi's 6147.

The mix of MOS SRAMs has, since about 1980, become increasingly CMOS-like. Among all memory products, the CMOS die-size penalty for static RAMs is lowest. From a manufacturing-cost point of view, this penalty can be translated into "learning curve" time, which has encouraged several manufacturers to "run down the learning curve" with CMOS, further reducing their own manufacturing-cost penalty.

CMOS has demonstrated device speeds as fast as those of NMOS, but to date, the narrow supplier base has left the high-speed SRAM market still dominated by NMOS devices. In addition, much of the low power advantage of CMOS goes away when the devices are exercised at high clock rates. However, at the 16K density, fast CMOS has increased its share compared to fast NMOS, and it is expected that CMOS will be dominant in terms of market share when 64K SRAMs become mature in the 1986-88 period.

Already in the 2Kx8 market, CMOS in its varied forms constitutes 70 percent of units shipped in 1983. No NMOS byte-wide 64Ks have been announced, while four companies offer CMOS 8Kx8s today, and at least that many additional companies will enter the market in 1984.

Assumptions

- We expect little slow byte-wide activity in NMOS at 64K. At that density, CMOS will essentially have the field to itself.
- An increasing share of the fast SRAM market will move to CMOS (vs. NMOS) at the 64K density.
- CMOS 256K SRAM announcements are expected in early 1984, perhaps at ISSCC, with samples to customers in 1985 and volumes in 1986.

Uncertainties

CMOS dynamic RAMs, with and without on-chip refresh, and x8 dynamic RAMs will undoubtedly displace some CMOS SRAMs. Given the early state of market development for these devices, it is difficult to assess the eventual impact of these approaches at this time. However, the potential is large but the impact will likely be in the 1986-88 time frame.

MOS Memory Market Forecast

Table 8

CMOS STATIC RAMS

		1980	1981	1982	1983	1984	1985	1986	1987	1988
1	**Value (Millions of Dollars)**									
2										
3	1K	21	13	9	7	4	0	0	0	0
4	4K (Fast)	15	13	13	12	9	6	4	0	0
5	4K (Slow)	125	90	90	63	38	30	20	7	0
6	16K (Fast, 16Kx1)	0	4	7	19	30	40	60	88	60
7	16K (Fast, 4Kx4)	0	0	1	7	24	57	75	105	80
8	16K (Fast, 2Kx8)	0	0	5	8	40	55	80	.7	60
9	16K (Slow, 2Kx8)	23	50	113	240	325	303	150	79	55
10	64K (Fast, 64Kx1)	0	0	0	0	45	72	100	110	123
11	64K (Fast, 16Kx4)	0	0	0	0	15	55	96	120	160
12	64K (Fast, 8Kx8)	0	0	0	0	16	60	120	175	225
13	64K (Slow, 8Kx8)	0	0	10	60	150	350	600	700	688
14	256K (Slow, 32Kx8)	0	0	0	0	0	15	125	330	600
15	Total Dollars	184	170	240	414	695	1042	1429	1790	2050
16	Percent Change From									
17	Previous Year	71		39	67	68	50	37	25	15
18	**Units (Millions)**									
19										
20	1K	7.0	5.5	4.0	3.0	2.0	N/A	N/A	N/A	N/A
21	4K (Fast)	0.6	1.5	2.5	2.7	2.5	2.0	1.0	N/A	N/A
22	4K (Slow)	12.5	23.0	30.0	25.0	15.0	12.0	6.0	2.0	N/A
23	16K (Fast, 16Kx1)	N/A	0.1	0.6	2.5	6.0	10.0	17.0	25.0	15.0
24	16K (Fast, 4Kx4)	N/A	N/A	0.1	0.7	4.0	12.0	20.0	30.0	20.0
25	16K (Fast, 2Kx8)	N/A	N/A	0.2	0.5	5.0	10.0	20.0	22.0	15.0
26	16K (Slow, 2Kx8)	0.5	4.8	22.7	60.0	100.0	110.0	60.0	35.0	20.0
27	64K (Fast, 64Kx1)	N/A	N/A	N/A	N/A	1.5	4.0	10.0	20.0	35.0
28	64K (Fast, 16Kx4)	N/A	N/A	N/A	N/A	0.3	2.5	8.0	20.0	40.0
29	64K (Fast, 8Kx8)	N/A	N/A	N/A	N/A	0.2	2.0	8.0	25.0	50.0
30	64K (Slow, 8Kx8)	N/A	N/A	0.1	2.5	15.0	50.0	120.0	200.0	250.0
31	256K (Slow, 32Kx8)	N/A	N/A	N/A	N/A	N/A	0.2	5.0	30.0	100.0
32	Total Units	20.6	34.9	60.1	94.9	151.5	214.7	275.0	409.0	545.0
33	**Average Selling Price**									
34										
35	1K	3.00	2.40	2.25	2.25	2.00	N/A	N/A	N/A	N/A
36	4K (Fast)	25.00	8.50	5.00	4.50	3.50	3.00	3.50	N/A	N/A
37	4K (Slow)	10.00	4.25	3.00	2.50	2.50	2.50	3.25	3.50	N/A
38	16K (Fast, 16Kx1)	N/A	40.00	12.00	7.50	5.00	4.00	3.50	3.50	4.00
39	16K (Fast, 4Kx4)	N/A	N/A	18.00	9.50	6.00	4.75	3.75	3.50	4.00
40	16K (Fast, 2Kx8)	N/A	N/A	25.00	15.00	8.00	5.50	4.00	3.50	4.00
41	16K (Slow, 2Kx8)	45.00	10.50	5.00	4.00	3.25	2.75	2.50	2.25	2.75
42	64K (Fast, 64Kx1)	N/A	N/A	N/A	N/A	30.00	18.00	10.00	5.50	3.50
43	64K (Fast, 16Kx4)	N/A	N/A	N/A	N/A	50.00	22.00	12.00	6.00	4.00
44	64K (Fast, 8Kx8)	N/A	N/A	N/A	N/A	80.00	30.00	15.00	7.00	4.50
45	64K (Slow, 8Kx8)	N/A	N/A	100.00	24.00	10.00	7.00	5.00	3.50	2.75
46	256K (Slow, 32Kx8)	N/A	N/A	N/A	N/A	N/A	75.00	25.00	11.00	6.00
47	**Bits (Billions)**									
48										
49	1K	7	6	4	3	2	0	0	0	0
50	4K (Fast)	2	6	10	11	10	8	4	0	0
51	4K (Slow)	51	94	123	102	61	49	25	8	0
52	16K (Fast, 16Kx1)	0	2	10	41	98	164	279	410	246
53	16K (Fast, 4Kx4)	0	0	1	11	66	197	328	492	328
54	16K (Fast, 2Kx8)	0	0	3	8	82	164	328	360	246
55	16K (Slow, 2Kx8)	8	79	372	983	1638	1802	983	573	328
56	64K (Fast, 64Kx1)	0	0	0	0	98	262	655	1311	2294
57	64K (Fast, 16Kx4)	0	0	0	0	20	164	524	1311	2621
58	64K (Fast, 8Kx8)	0	0	0	0	13	131	524	1638	3277
59	64K (Slow, 8Kx8)	0	0	7	164	983	3277	7864	13107	16384
60	256K (Slow, 32Kx8)	0	0	0	0	0	52	1311	7864	26214
61	Total Bits	69	186	530	1324	3072	6270	12825	27075	51937
62	Percent Change From									
63	Previous Year	134	170	184	150	132	104	105	111	92
64	**Price Per Bit**									
65										
66	(Millicents Per Bit)									
67	1K	293.0	234.4	219.7	219.7	195.3	N/A	N/A	N/A	N/A
68	4K (Fast)	610.4	207.5	122.1	109.9	85.4	73.2	85.4	N/A	N/A
69	4K (Slow)	244.1	103.8	73.2	61.0	61.0	61.0	79.3	85.4	N/A
70	16K (Fast, 16Kx1)	N/A	244.1	73.2	45.8	30.5	24.4	21.4	21.4	24.4
71	16K (Fast, 4Kx4)	N/A	N/A	109.9	58.0	36.6	29.0	22.9	21.4	24.4
72	16K (Fast, 2Kx8)	N/A	N/A	152.6	91.6	48.8	33.6	24.4	21.4	24.4
73	16K (Slow, 2Kx8)	274.7	64.1	30.5	24.4	19.8	16.8	15.3	13.7	16.8
74	64K (Fast, 64Kx1)	N/A	N/A	N/A	N/A	45.8	27.5	15.3	8.4	5.3
75	64K (Fast, 16Kx4)	N/A	N/A	N/A	N/A	76.3	33.6	18.3	9.2	6.1
76	64K (Fast, 8Kx8)	N/A	N/A	N/A	N/A	122.1	45.8	22.9	10.7	6.9
77	64K (Slow, 8Kx8)	N/A	N/A	152.6	36.6	15.3	10.7	7.6	5.3	4.2
78	256K (Slow, 32Kx8)	N/A	N/A	N/A	N/A	N/A	28.6	9.5	4.2	2.3
79	Avg Price Per Bit	265.9	95.6	46.8	31.3	22.6	16.6	11.1	6.6	3.9
80	Percent Change From									
81	Previous Year	(27)	(64)	(51)	(33)	(28)	(27)	(33)	(41)	(40)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

NMOS UV-EPROMS

Table 9 shows details of expected shipments and prices of NMOS UV-EPROMs. Because we have separated one-time programmable (OTP), or plastic-packaged, EPROMs in Table 11, Table 9 data is limited to only those devices having a quartz window for reprogramming.

NMOS EPROMs immediately became much more than the mask ROM prototyping tool that they were originally intended to be. Over the past several years, EPROM has become increasingly price competitive with MOS ROM on a per-unit basis, and on a per-bit basis. The historical data shown in Tables 2a-5a give ample evidence of the success of EPROMs: fastest bit growth, most rapid price-per-bit decline, and fastest market revenue growth for the 1977-82 period.

Today, NMOS EPROMs embody some of the most advanced technology available in any MOS memory, and leading edge products, while requiring a more complex manufacturing process, have die sizes substantially smaller than their ROM counterparts of the same density.

As a result of the technical advances in NMOS EPROMs over the last three or four years, EPROMS have very often been the software carrier of choice in many applications.

Assumptions

- NMOS devices will increasingly be replaced by CMOS UV-EPROMS.
- OTPs (see Table 11) will gradually displace windowed UV-EPROMs in production environments, while prototyping applications will remain with the higher-priced, reusable UV-EPROMs.
- NMOS EPROMs will continue to make inroads into the mature densities and the lower-unit-count MOS ROMs market.

Uncertainties

The impact of OTPs is difficult to judge, since delivery has just begun and manufacturers' process mastery and user acceptance are still uncertain. Our expectation is, however, that the impact will be significant, with OTPs becoming established in 1984 and rapidly replacing the majority of the unnecessary CERDIP or ceramic-packaged EPROMs in 1985 and 1986.

MOS Memory Market Forecast

Table 9

NMOS UV-EPROMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
2K	5	4	2	0	0	0	0	0	0
8K	70	20	7	4	0	0	0	0	0
16K	368	212	128	90	49	18	0	0	0
32K	88	125	240	162	81	32	6	2	0
64K	4	39	124	289	300	114	30	9	3
128K	0	0	10	90	113	135	42	15	6
256K	0	0	0	20	75	135	75	28	16
512K	0	0	0	0	16	70	130	75	44
1M	0	0	0	0	0	10	36	48	45
Total Dollars	535	399	510	655	633	513	318	177	115
Percent Change From Previous Year	33	(25)	28	28	(3)	(19)	(38)	(45)	(35)
Units (Millions)									
2K	2.0	1.5	0.5	N/A	N/A	N/A	N/A	N/A	N/A
8K	15.6	6.0	1.9	1.0	N/A	N/A	N/A	N/A	N/A
16K	28.3	44.6	42.8	30.0	15.0	5.0	N/A	N/A	N/A
32K	3.5	16.6	45.2	48.5	27.0	11.5	2.0	0.5	N/A
64K	0.0	1.4	14.6	52.5	75.0	35.0	10.0	3.0	1.0
128K	N/A	N/A	0.2	6.0	15.0	30.0	12.0	5.0	2.0
256K	N/A	N/A	N/A	0.2	3.0	15.0	15.0	7.0	5.0
512K	N/A	N/A	N/A	N/A	0.2	2.0	10.0	10.0	8.0
1M	N/A	N/A	N/A	N/A	N/A	0.1	1.2	4.0	5.0
Total Units	49.4	70.1	105.2	138.2	135.2	98.6	50.2	29.5	21.0
Average Selling Price									
2K	2.70	2.90	3.25	N/A	N/A	N/A	N/A	N/A	N/A
8K	4.50	3.25	3.50	3.50	N/A	N/A	N/A	N/A	N/A
16K	13.00	4.75	3.00	3.00	3.25	3.50	N/A	N/A	N/A
32K	25.00	7.50	5.30	3.35	3.00	2.75	2.75	3.00	N/A
64K	110.00	28.00	8.50	5.50	4.00	3.25	3.00	3.00	3.25
128K	N/A	N/A	50.00	15.00	7.50	4.50	3.50	3.00	3.00
256K	N/A	N/A	N/A	100.00	25.00	9.00	5.00	4.00	3.25
512K	N/A	N/A	N/A	N/A	80.00	35.00	13.00	7.50	5.50
1M	N/A	N/A	N/A	N/A	N/A	100.00	30.00	12.00	9.00
Bits (Billions)									
2K	4	3	1	0	0	0	0	0	0
8K	128	49	16	8	0	0	0	0	0
16K	464	731	701	492	246	82	0	0	0
32K	115	544	1481	1589	885	377	66	16	0
64K	3	92	957	3441	4915	2294	655	197	66
128K	0	0	26	786	1966	3932	1573	655	262
256K	0	0	0	52	786	3932	3932	1835	1311
512K	0	0	0	0	105	1049	5243	5243	4194
1M	0	0	0	0	0	105	1258	4194	5243
Total Bits	713	1419	3182	6368	8903	11770	12727	12141	11076
Percent Change From Previous Year	98	99	124	100	40	32	8	(5)	(9)
Price Per Bit									
(Millicents Per Bit)									
2K	131.8	141.6	158.7	N/A	N/A	N/A	N/A	N/A	N/A
8K	54.9	39.7	42.7	42.7	N/A	N/A	N/A	N/A	N/A
16K	79.3	29.0	18.3	18.3	19.8	21.4	N/A	N/A	N/A
32K	76.3	22.9	16.2	10.2	9.2	8.4	8.4	9.2	N/A
64K	167.8	42.7	13.0	8.4	6.1	5.0	4.6	4.6	5.0
128K	N/A	N/A	38.1	11.4	5.7	3.4	2.7	2.3	2.3
256K	N/A	N/A	N/A	38.1	9.5	3.4	1.9	1.5	1.2
512K	N/A	N/A	N/A	N/A	15.3	6.7	2.5	1.4	1.0
1M	N/A	N/A	N/A	N/A	N/A	9.5	2.9	1.1	0.9
Avg Price Per Bit	75.1	28.2	16.0	10.3	7.1	4.4	2.5	1.5	1.0
Percent Change From Previous Year	(30)	(63)	(43)	(36)	(31)	(39)	(43)	(42)	(29)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

CMOS UV-EPROMs

Table 10 shows details of estimated unit shipments and prices for CMOS UV-EPROMs, again excluding OTP devices in plastic packages, which are included in Table 11.

CMOS EPROMs have heretofore been an underserviced market, with only a handful of suppliers pursuing the business. Eurotechnique, Fujitsu, Hitachi, National Semiconductor, and Toshiba are the only suppliers at present. Also, die sizes, more complicated processes, and a narrow supplier base have combined to keep CMOS EPROM prices high and utilization minimal.

Assumptions

- The supplier base for CMOS EPROMs will broaden significantly in 1984, but will remain a secondary CMOS priority for most vendors.

- Reprogrammable CMOS UV-EPROMs will be subject to the same plastic package (OTP) pressures as will be NMOS devices, i.e., after the price reaches about $8-$10, a significant portion of the market will probably shift to CMOS OTP.

- Once the marketplace base has separated into (1) applications requiring reprogammming capability and (2) those for which OTP is adequate, we expect the core market, (1), to resume growth.

Uncertainties

Our estimates for this market for 1984-85 have been reduced substantially from earlier expectations. However, we remain confident of the long-term substitution of CMOS for NMOS EPROMs.

A larger question lies in the expected progress of development of CMOS EEPROMs. By 1988, progress in CMOS EEPROMs may be sufficient to take over the prototyping and erasability requirement in the marketplace, which will effectively short-circuit any resumption of growth in reprogrammable EPROM. However, the EEPROM-EPROM price differential is now far too great to allow much EEPROM to be used as software prototyping devices.

Table 10

CMOS UV-EPROMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
4K	4	3	1	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0	0
16K	0	6	3	11	12	8	4	0	0
32K	0	4	6	9	23	30	16	7	0
64K	0	0	8	18	28	68	35	16	9
128K	0	0	0	0	36	30	33	12	4
256K	0	0	0	8	35	96	100	158	140
512K	0	0	0	0	0	20	54	40	72
1M	0	0	0	0	0	5	40	90	213
Total Dollars	4	12	18	46	134	256	282	323	437
Percent Change From Previous Year	67	233	41	161	189	92	10	14	35
Units (Millions)									
4K	0.5	0.5	0.3	0.1	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	0.1	0.5	2.5	3.0	2.0	1.0	N/A	N/A
32K	N/A	0.1	0.8	1.5	5.0	8.0	5.0	2.0	N/A
64K	N/A	N/A	0.3	1.5	4.0	15.0	10.0	5.0	2.5
128K	N/A	N/A	N/A	N/A	2.0	4.0	7.0	3.0	1.0
256K	N/A	N/A	N/A	0.1	1.0	8.0	20.0	35.0	35.0
512K	N/A	N/A	N/A	N/A	N/A	0.4	3.0	5.0	12.0
1M	N/A	N/A	N/A	N/A	N/A	0.1	1.0	6.0	25.0
Total Units	0.5	0.7	1.8	5.6	15.0	37.4	47.0	56.0	75.5
Average Selling Price									
4K	7.50	6.00	5.00	4.00	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	40.00	5.00	4.50	4.00	3.75	3.75	N/A	N/A
32K	N/A	70.00	8.00	6.00	4.50	3.75	3.25	3.50	N/A
64K	N/A	N/A	25.00	12.00	7.00	4.50	3.50	3.25	3.50
128K	N/A	N/A	N/A	N/A	18.00	7.50	4.75	4.00	3.50
256K	N/A	N/A	N/A	150.00	35.00	12.00	5.00	4.50	4.00
512K	N/A	N/A	N/A	N/A	N/A	50.00	18.00	8.00	6.00
1M	N/A	N/A	N/A	N/A	N/A	100.00	40.00	15.00	8.50
Bits (Billions)									
4K	2	2	1	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0	0
16K	0	2	8	41	49	33	16	0	0
32K	0	2	26	49	164	262	164	66	0
64K	0	0	20	98	262	983	655	328	164
128K	0	0	0	0	262	524	918	393	131
256K	0	0	0	13	262	2097	5243	9175	9175
512K	0	0	0	0	0	210	1573	2621	6291
1M	0	0	0	0	0	52	1049	6291	26214
Total Bits	2	6	55	202	999	4162	9617	18874	41976
Percent Change From Previous Year	233	200	797	267	395	316	131	96	122
Price Per Bit									
(Millicents Per Bit)									
4K	183.1	146.5	122.1	97.7	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	244.1	30.5	27.5	24.4	22.9	22.9	N/A	N/A
32K	N/A	213.6	24.4	18.3	13.7	11.4	9.9	10.7	N/A
64K	N/A	N/A	38.1	18.3	10.7	6.9	5.3	5.0	5.3
128K	N/A	N/A	N/A	N/A	13.7	5.7	3.6	3.1	2.7
256K	N/A	N/A	N/A	57.2	13.4	4.6	1.9	1.7	1.5
512K	N/A	N/A	N/A	N/A	N/A	9.5	3.4	1.5	1.1
1M	N/A	N/A	N/A	N/A	N/A	9.5	3.8	1.4	0.8
Avg Price Per Bit	183.1	203.5	32.0	22.9	13.4	6.2	2.9	1.7	1.0
Percent Change From Previous Year	(50)	11	(84)	(29)	(42)	(54)	(52)	(42)	(39)

Source: DATAQUEST
December 1983

ONE-TIME PROGRAMMABLE (OTP) EPROMS

Table 11 provides detailed unit shipment and ASP data for one-time programmable (OTP) EPROMs. This category is actually a special package type for UV-EPROMs, in which the devices are packaged in inexpensive plastic packages to be programmed only once. See the DATAQUEST Research Newsletter "OTP—One-Time Programmable EPROMs Promise to Impact MOS Read-Only-Memory Market," dated 18 October 1983, for a fuller discussion of this market. These new devices have yet to take hold, but are beginning to appear in the portfolios of many leading suppliers of UV-EPROMs, including Intel, AMD, Hitachi, and NEC.

We expect that at least six vendors will offer 32K, 64K, or 128K OTP devices in 1984, and that users will quickly warm to the superior economics of OTPs. While the initial impact will be on MOS EPROMs, the improved pricing of OTPs will accelerate the penetration of the mature part of the MOS ROMs market by electrically programmable devices.

Assumptions

- Present issues of speed-sorting OTPs, and product reliability will be satisfactorily resolved by most vendors by year-end 1984.
- OTPs will eventually displace at least 90 percent of mature UV-EPROMs and 15-25 percent of MOS ROMs of the same densities.
- Once UV-EPROM prices drop to less than $8-$10 per unit, OTPs become increasingly the proper economic choice for users. However, most of the first two years' production of any density device will likely be the windowed package type.
- The initial pricing of OTPs will be slightly less than that of windowed CERDIP UV-EPROMs. As a competitive market develops, prices will more closely reflect true manufacturing costs, at a savings of perhaps $1.50 compared to CERDIP devices.

Uncertainties

CMOS and NMOS, not shown separately here, are eventually expected to be represented in the OTP market in about the same proportion as in the traditional UV-EPROM market, as shown in Table 9 (NMOS) and Table 10 (CMOS). However, at this time, no CMOS OTPs are known to be on the market.

MOS Memory Market Forecast

Table 11

ONE-TIME PROGRAMMABLE EPROMS (OTP)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
4K	0	0	0	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0	0
16K	0	0	0	0	0	0	0	0	0
32K	0	0	0	2	10	19	9	3	0
64K	0	0	0	6	131	175	120	83	20
128K	0	0	0	0	39	215	180	120	56
256K	0	0	0	0	0	216	500	550	900
512K	0	0	0	0	0	0	50	300	340
1M	0	0	0	0	0	0	0	120	300
Total Dollars	0	0	0	8	180	614	859	1176	1616
Percent Change From Previous Year	(100)	(100)	(100)	(100)	2219	242	40	37	37
Units (Millions)									
4K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32K	N/A	N/A	N/A	0.5	5.0	5.0	5.0	1.5	N/A
64K	N/A	N/A	N/A	1.0	35.0	70.0	60.0	45.0	10.0
128K	N/A	N/A	N/A	N/A	7.0	65.0	80.0	60.0	30.0
256K	N/A	N/A	N/A	N/A	N/A	27.0	125.0	200.0	400.0
512K	N/A	N/A	N/A	N/A	N/A	N/A	5.0	50.0	80.0
1M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.0	40.0
Total Units	0.0	0.0	0.0	1.5	47.0	167.0	275.0	368.5	560.0
Average Selling Price									
4K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32K	N/A	N/A	N/A	3.50	2.00	1.75	1.75	1.75	N/A
64K	N/A	N/A	N/A	6.00	3.75	2.50	2.00	1.85	2.00
128K	N/A	N/A	N/A	N/A	5.50	3.30	2.25	2.00	1.85
256K	N/A	N/A	N/A	N/A	N/A	8.00	4.00	2.75	2.25
512K	N/A	N/A	N/A	N/A	N/A	N/A	10.00	6.00	4.25
1M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.00	7.50
Bits (Billions)									
4K	0	0	0	0	0	0	0	0	0
8K	0	0	0	0	0	0	0	0	0
16K	0	0	0	0	0	0	0	0	0
32K	0	0	0	16	164	164	164	49	0
64K	0	0	0	66	2294	4588	3932	2949	655
128K	0	0	0	0	918	8520	10486	7864	3932
256K	0	0	0	0	0	7078	32768	52429	104858
512K	0	0	0	0	0	0	2621	26214	41943
1M	0	0	0	0	0	0	0	12583	41943
Total Bits	0	0	0	82	3375	20349	49971	102089	193331
Percent Change From Previous Year	(100)	(100)	(100)	(100)	4020	503	146	104	89
Price Per Bit									
(Millicents Per Bit)									
4K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
32K	N/A	N/A	N/A	10.7	6.1	5.3	5.3	5.3	N/A
64K	N/A	N/A	N/A	9.2	5.7	3.8	3.1	2.8	3.1
128K	N/A	N/A	N/A	N/A	4.2	2.5	1.7	1.5	1.4
256K	N/A	N/A	N/A	N/A	N/A	3.1	1.5	1.0	0.9
512K	N/A	N/A	N/A	N/A	N/A	N/A	1.9	1.1	0.8
1M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.0	0.7
Avg Price Per Bit	0.0	0.0	0.0	9.5	5.3	3.0	1.7	1.2	0.8
Percent Change From Previous Year	(100)	(100)	(100)	(100)	(44)	(43)	(43)	(33)	(27)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

P/NMOS MASK ROMS

Table 12 shows details of estimated unit shipments and ASPs for PMOS and NMOS ROMs for 1980 through 1988.

The (N)MOS ROM market was, during 1981 and 1982, the only MOS memory market with growth and profits. In 1983, it became the only MOS memory market to experience a decline in total market size--down about 25 percent from 1982. All this, in rise and in decline, has been due to video games. Behind this more transient business has been a steady and growing business for ROMs as <u>the</u> low-cost, high-volume software carrier to most MPU-based electronic systems.

Strong unit growth during the 1980s has been the impetus for the continually improving pricing for mask ROMs. While considerable business has been lost to EPROM in mature densities, the ROM market has managed to exhibit remarkable growth, due to demand for (1) high density, where ROM is unchallenged in price, and (2) extraordinarily high volumes of identical code, often in excess of 250K to 500K units.

Because decimal ROMs (2Kx10, 4Kx10, etc.) were included in the closest byte-wide categories in Table 12, the data here tend to understate total bits slightly and to overstate the associated prices per bit from the actual "best market estimates."

Assumptions

- The video game "bubble" has receded considerably from its 1982 peak, although the "cartridge ROM" concept remains attractive and will persist in a variety of small systems, e.g., IBM's PCjr.

- ROM will continue to be displaced in some low-volume or mature density applications by UV-EPROM, and more severely as the OTP market develops. (See Tables 9, 10, and 11.)

- Though activity in CMOS ROMs is great, NMOS devices have managed to stay well ahead on manufacturing economies, and in 1983 commanded 85 percent of the total ROMs market.

- NMOS or PMOS 1-megabit ROMs are expected to play a minor role at that density compared to CMOS.

- PMOS will continue to be used in low-cost encoded speech applications.

MOS Memory Market Forecast

Table 12

P/NMOS MASK ROMS

		1980	1981	1982	1983	1984	1985	1986	1987	1988
1	Value (Millions of Dollars)									
2										
3	4K	2	2	2	0	0	0	0	0	0
4	8K	10	7	7	6	4	0	0	0	0
5	16K	135	140	80	38	14	6	0	0	0
6	32K	116	163	293	96	32	13	6	0	0
7	64K	33	85	221	215	108	56	17	10	11
8	128K	7	8	29	35	49	75	40	21	15
9	256K	0	6	30	65	195	225	210	210	140
10	512K	0	0	0	0	5	30	30	28	11
11	1M	0	0	0	3	14	30	38	45	12
12	4M	0	0	0	0	0	0	0	0	0
13	Total Dollars	302	410	661	457	421	435	340	314	188
14	Percent Change From									
15	Previous Year	45	36	61						
16	Units (Millions)									
17										
18	4K	1.5	1.4	1.3	N/A	N/A	N/A	N/A	N/A	N/A
19	8K	5.0	4.0	3.8	3.4	2.5	N/A	N/A	N/A	N/A
20	16K	60.0	80.0	50.0	25.0	10.0	4.0	N/A	N/A	N/A
21	32K	22.0	50.0	130.0	60.0	18.0	8.5	4.0	N/A	N/A
22	64K	3.0	13.0	55.1	100.0	60.0	35.0	12.0	7.0	7.0
23	128K	0.2	0.5	3.0	7.0	14.0	30.0	20.0	12.0	9.0
24	256K	N/A	0.1	1.5	5.0	30.0	50.0	70.0	100.0	80.0
25	512K	N/A	N/A	N/A	N/A	0.2	2.5	5.0	7.0	3.0
26	1M	N/A	N/A	N/A	0.1	0.4	2.0	5.0	9.0	3.0
27	4M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	Total Units	91.7	149.0	244.9	200.4	135.1	132.0	116.0	135.0	102.0
29	Average Selling Price									
30										
31	4K	1.45	1.40	1.40	N/A	N/A	N/A	N/A	N/A	N/A
32	8K	1.95	1.85	1.75	1.65	1.65	N/A	N/A	N/A	N/A
33	16K	2.25	1.75	1.60	1.50	1.40	1.50	N/A	N/A	N/A
34	32K	5.25	3.25	2.25	1.60	1.75	1.50	1.40	N/A	N/A
35	64K	11.00	6.50	4.00	2.15	1.80	1.60	1.40	1.40	1.50
36	128K	35.00	15.00	9.50	5.00	3.50	2.50	2.00	1.75	1.65
37	256K	N/A	60.00	20.00	13.00	6.50	4.50	3.00	2.10	1.75
38	512K	N/A	N/A	N/A	N/A	25.00	12.00	6.00	4.00	3.50
39	1M	N/A	N/A	N/A	50.00	35.00	15.00	7.50	5.00	4.00
40	4M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
41	Bits (Billions)									
42										
43	4K	6	6	5	0	0	0	0	0	0
44	8K	41	33	31	28	20	0	0	0	0
45	16K	983	1311	819	410	164	66	0	0	0
46	32K	721	1638	4260	1966	590	279	131	0	0
47	64K	197	852	3624	6554	3932	2294	786	459	459
48	128K	26	66	393	918	1835	3932	2621	1573	1180
49	256K	0	26	393	1311	7864	13107	18350	26214	20972
50	512K	0	0	0	0	105	1311	2621	3670	1573
51	1M	0	0	0	52	419	2097	5243	9437	3146
52	4M	0	0	0	0	0	0	0	0	0
53	Total Bits	1974	3931	9526	11238	14930	23085	29753	41353	27329
54	Percent Change From									
55	Previous Year	77	99	142	18	33	55	29	39	(34)
56	Price Per Bit									
57										
58	(Millicents Per Bit)									
59	4K	35.4	34.2	34.2	N/A	N/A	N/A	N/A	N/A	N/A
60	8K	23.8	22.6	21.4	20.1	20.1	N/A	N/A	N/A	N/A
61	16K	13.7	10.7	9.8	9.2	8.5	9.2	N/A	N/A	N/A
62	32K	16.0	9.9	6.9	4.9	5.3	4.6	4.3	N/A	N/A
63	64K	16.8	9.9	6.1	3.3	2.7	2.4	2.1	2.1	2.3
64	128K	26.7	11.4	7.2	3.8	2.7	1.9	1.5	1.3	1.3
65	256K	N/A	22.9	7.6	5.0	2.5	1.7	1.1	0.8	0.7
66	512K	N/A	N/A	N/A	N/A	4.8	2.3	1.1	0.8	0.7
67	1M	N/A	N/A	N/A	4.8	3.3	1.4	0.7	0.5	0.4
68	4M	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
69	Avg Price Per Bit	15.3	10.4	6.9	4.1	2.8	1.9	1.1	0.8	0.7
70	Percent Change From									
71	Previous Year	(18)	(32)	(33)	(41)	(31)	(33)	(39)	(34)	(9)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

CMOS MASK ROMS

Table 13 details the expected market development for CMOS mask ROMs. Through 1982, the vast majority of CMOS devices were sold in close association to CMOS MPUs such as the RCA 1802, i.e., as the MPU control program. Increasingly, a standalone CMOS ROM market is developing.

CMOS ROMs are available from many vendors at every density from 2K to more than 1 Mb. Overall, there are few suppliers who are broadline CMOS ROM suppliers, but at least 12 vendors participate in the market at two or three densities each. Even today, however, the market for CMOS ROMs is still small, due to a continuing CMOS price penalty, which few users are willing to pay unless CMOS is absolutely necessary to fulfill their systems requirements.

Assumptions

- CMOS will gradually displace NMOS and will first exceed NMOS shipments in the mature 256K market. At that time, prices for CMOS ROMs will be within 10 percent of NMOS devices of the same density.

- With 256K and 1Mb devices already on the market, we don't expect that either the 128K or 512K market will develop as fully as the adjacent densities (64K, 256K, 1Mb).

- Virtually all ROMs through the forecast period will have access times greater than 150 ns, although minor markets exist as fast as sub-100 ns and as slow as the microsecond range.

- As with NMOS ROMs, more mature densities of CMOS ROM will lose designs to UV-EPROMs, and increasingly as a CMOS OTP market develops.

Uncertainties

The CMOS ROM market, like the CMOS EPROM market, has been slower to develop than earlier expected by DATAQUEST. In the 256K ROM market today, NMOS is by far the dominant technology employed. At 1Mb, however, more CMOS devices than NMOS have been introduced as Japanese Kanji character generators. Full replacement of NMOS ROMs by CMOS devices must necessarily be coincident with the broad availability of CMOS MPUs and implementation of entire CMOS systems.

Table 13

CMOS MASK ROMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
4K	4	4	6	3	0	0	0	0	0
8K	8	8	12	12	12	10	8	0	0
16K	7	8	16	18	32	16	8	0	0
32K	1	2	7	8	12	10	5	0	0
64K	0	2	8	14	28	24	12	7	5
128K	0	2	6	28	36	88	36	7	3
256K	0	0	3	6	75	165	300	375	175
512K	0	0	0	0	5	20	55	70	80
1M	0	0	0	14	35	75	188	475	1125
4M	0	0	0	0	0	8	15	38	150
Total Dollars	19	26	58	102	234	415	626	971	1538
Percent Change From Previous Year	(46)	37	118	77	130	77	51	55	58
Units (Millions)									
4K	1.0	1.2	2.0	1.2	N/A	N/A	N/A	N/A	N/A
8K	1.5	2.0	3.5	4.0	4.0	3.0	2.5	N/A	N/A
16K	0.5	1.0	2.5	3.5	8.0	5.0	3.0	N/A	N/A
32K	0.1	0.3	1.2	2.0	4.0	5.0	3.0	N/A	N/A
64K	N/A	0.2	1.0	3.0	7.0	10.0	6.0	4.0	3.0
128K	N/A	0.1	0.5	5.0	8.0	22.0	13.0	3.0	2.0
256K	N/A	N/A	0.1	0.4	10.0	33.0	80.0	150.0	100.0
512K	N/A	N/A	N/A	N/A	0.1	1.0	5.0	10.0	20.0
1M	N/A	N/A	N/A	0.2	1.0	5.0	25.0	95.0	300.0
4M	N/A	N/A	N/A	N/A	N/A	0.1	0.5	2.5	25.0
Total Units	3.1	4.8	10.8	19.3	42.1	84.1	138.0	264.5	450.0
Average Selling Price									
4K	4.00	3.00	2.75	2.50	N/A	N/A	N/A	N/A	N/A
8K	5.00	4.00	3.50	3.00	3.00	3.25	3.25	N/A	N/A
16K	13.00	8.00	6.50	5.25	4.00	3.25	2.50	N/A	N/A
32K	12.00	8.00	5.50	4.00	2.90	2.00	1.80	N/A	N/A
64K	N/A	12.00	8.00	4.50	4.00	2.40	2.00	1.80	1.60
128K	N/A	20.00	12.00	5.50	4.50	4.00	2.75	2.25	1.70
256K	N/A	N/A	30.00	14.00	7.50	5.00	3.75	2.50	1.75
512K	N/A	N/A	N/A	N/A	45.00	20.00	11.00	7.00	4.00
1M	N/A	N/A	N/A	70.00	35.00	15.00	7.50	5.00	3.75
4M	N/A	N/A	N/A	N/A	N/A	75.00	30.00	15.00	6.00
Bits (Billions)									
4K	4	5	8	5	0	0	0	0	0
8K	12	16	29	33	33	25	20	0	0
16K	8	16	41	57	131	82	49	0	0
32K	3	10	39	66	131	164	98	0	0
64K	0	13	66	197	459	655	393	262	197
128K	0	13	66	655	1049	2884	1704	393	262
256K	0	0	26	105	2621	8651	20972	39322	26214
512K	0	0	0	0	52	524	2621	5243	10486
1M	0	0	0	210	1049	5243	26214	99615	314573
4M	0	0	0	0	0	419	2097	10486	104858
Total Bits	28	74	274	1327	5525	18647	54170	155320	456589
Percent Change From Previous Year	106	165	272	384	316	238	191	187	194
Price Per Bit									
(Millicents Per Bit)									
4K	97.7	73.2	67.1	61.0	N/A	N/A	N/A	N/A	N/A
8K	61.0	48.8	42.7	36.6	36.6	39.7	39.7	N/A	N/A
16K	79.3	48.8	39.7	32.0	24.4	19.8	15.3	N/A	N/A
32K	36.6	24.4	16.8	12.2	8.9	6.1	5.5	N/A	N/A
64K	N/A	18.3	12.2	6.9	6.1	3.7	3.1	2.7	2.4
128K	N/A	15.3	9.2	4.2	3.4	3.1	2.1	1.7	1.3
256K	N/A	N/A	11.4	5.3	2.9	1.9	1.4	1.0	0.7
512K	N/A	N/A	N/A	N/A	8.6	3.8	2.1	1.3	0.8
1M	N/A	N/A	N/A	6.7	3.3	1.4	0.7	0.5	0.4
4M	N/A	N/A	N/A	N/A	N/A	1.8	0.7	0.4	0.1
Avg Price Per Bit	68.9	35.8	21.0	7.7	4.2	2.2	1.2	0.6	0.3
Percent Change From Previous Year	(74)	(48)	(41)	(63)	(45)	(47)	(48)	(46)	(46)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

EEPROMS/EAROMS

This market includes MNOS (or SNOS), as well as devices incorporating a floating gate, manufactured by a variety of suppliers. Also, non-volatile RAMs are included in the Table 14 summaries (because of their EEPROM backup feature) and probably constitute an approximately $15 million market in 1983.

The EEPROM market contains a diverse collection of distinct products, technical approaches, and end markets under this one heading. The high-density market (16K and up) is totally different from the low-density business (2K and down); there is little business in between. Vendors practice nitrox (SNOS or MNOS) technology or floating gate technology, but not both.

Important progress has been made in the EEPROM market during 1983. In addition to several standards being established (5-volt programming, 10,000 cycles durability, and latched output and data), 32K and 64K devices have appeared in modest quantities. The 64K EEPROM die sizes are small enough that they have the prospect of being manufacturable at reasonable cost. Difficult technical problems remain, the foremost being a consistent mastery of the delicate manufacturing processes involved, e.g., thin oxides.

Assumptions

- Price and volume forecasts, especially at densities of 16K and below, are aggregates of a diversity of products. Different vendors' products differ widely in functionality, and as a consequence, also in price.

- Lack of standards has inhibited, and will continue to inhibit, market growth, although several primary issues have been laid to rest within the last 12-15 months.

- No significant displacement of EPROM or ROM by EEPROM is anticipated for most of the forecast period. EEPROM is essentially a new capability, creating its own new application base.

Uncertainties

Achievement of the market forecast presented in Table 14 necessarily presumes some significant technical advances will occur. The EEPROM market, slow to grow during the 1970s, has experienced a renaissance of interest since about 1980. We expect that this tremendous focusing of attention, talent, and resources into EEPROM technology will result in revolutionary technical advances, as well as increased user awareness, leading to broad utilization.

MOS Memory Market Forecast

Table 14

EEPROMS/EAROMS

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Value (Millions of Dollars)									
Less Than 1K	8	9	14	30	40	47	61	70	88
1K	6	6	6	6	5	6	7	-	5
2K	5	5	4	3	3	2	2	2	2
4K	7	8	9	9	8	6	2	2	2
8K	3	4	6	7	5	4	2	0	0
16K	2	6	11	45	84	77	65	55	38
32K	0	0	1	1	10	56	45	42	30
64K	0	0	0	2	30	120	220	280	325
128K	0	0	0	0	5	50	120	150	140
256K	0	0	0	0	0	5	60	180	400
Total Dollars	31	37	49	103	190	373	583	787	1029
Percent Change From Previous Year	12	22	30	113	84	96	56	35	31
Units (Millions)									
Less Than 1K	4.0	5.0	8.0	15.0	20.0	25.0	33.0	40.0	50.0
1K	1.6	1.8	2.0	2.5	2.0	2.0	2.2	2.0	1.8
2K	1.0	1.2	1.0	0.9	0.7	0.6	0.5	0.5	0.5
4K	1.0	1.6	2.0	2.2	2.0	1.5	0.5	0.5	0.5
8K	0.2	0.4	0.7	1.2	1.0	1.0	0.5	N/A	N/A
16K	0.0	0.1	0.6	3.0	12.0	17.0	20.0	20.0	15.0
32K	N/A	N/A	0.0	0.1	1.0	8.0	10.0	12.0	10.0
64K	N/A	N/A	N/A	0.0	1.2	12.0	40.0	70.0	100.0
128K	N/A	N/A	N/A	N/A	0.1	2.5	15.0	25.0	35.0
256K	N/A	N/A	N/A	N/A	N/A	0.1	1.2	10.0	50.0
Total Units	7.8	10.1	14.3	...9	39.9	69.6	122.9	180.0	262.8
Average Selling Price									
Less Than 1K	2.00	1.75	1.75	2.00	2.00	1.90	1.85	1.75	1.75
1K	3.75	3.25	2.75	2.50	2.60	2.75	3.00	3.00	3.00
2K	5.00	4.00	3.75	3.50	3.75	3.50	3.50	3.50	3.50
4K	7.00	5.00	4.25	4.00	4.00	4.25	3.75	3.50	3.50
8K	15.00	10.00	8.00	6.00	5.00	4.00	3.50	N/A	N/A
16K	85.00	60.00	18.00	15.00	7.00	4.50	3.25	2.75	2.50
32K	N/A	N/A	50.00	20.00	10.00	7.00	4.50	3.50	3.00
64K	N/A	N/A	N/A	100.00	25.00	10.00	5.50	4.00	3.25
128K	N/A	..A	N/A	N/A	100.00	20.00	8.00	6.00	4.00
256K	N/A	N/A	N/A	N/A	N/A	100.00	50.00	18.00	8.00
Bits (Billions)									
Less Than 1K	2	3	4	8	10	13	17	20	25
1K	2	2	2	3	2	2	2	2	2
2K	2	2	2	2	1	1	1	1	1
4K	4	7	8	9	8	6	2	2	2
8K	2	3	[illegible]	10	8	8	4	0	0
16K	0	2	10	49	197	279	328	328	246
32K	0	0	0	2	33	262	328	393	328
64K	0	0	0	1	79	786	2621	4588	6554
128K	0	0	0	0	7	328	1966	3277	4588
256K	0	0	0	0	0	13	315	2621	13107
Total Bits	12	18	32	83	344	1698	5583	11232	24852
Percent Change From Previous Year	[illegible]	[illegible]	76	157	316	393	229	101	121
Price Per Bit									
(Millicents Per Bit)									
Less Than 1K	400.0	350.0	350.0	400.0	400.0	380.0	370.0	350.0	350.0
1K	366.2	317.4	268.6	244.1	253.9	268.6	293.0	293.0	293.0
2K	244.1	195.3	183.1	170.9	183.1	170.9	170.9	170.9	170.9
4K	170.9	122.1	103.8	97.7	97.7	103.8	91.6	85.4	85.4
8K	183.1	122.1	97.7	73.2	61.0	48.8	42.7	N/A	N/A
16K	518.8	366.2	109.9	91.6	42.7	27.5	19.8	16.8	15.3
32K	N/A	N/A	152.6	61.0	30.5	21.4	13.7	10.7	9.2
64K	N/A	N/A	N/A	152.6	38.1	15.3	8.4	6.1	5.0
128K	N/A	N/A	N/A	N/A	76.3	15.3	6.1	4.6	3.1
256K	N/A	N/A	N/A	N/A	N/A	38.1	19.1	6.9	3.1
Avg Price Per Bit	261.3	204.7	151.2	124.8	55.1	22.0	10.4	7.0	4.1
Percent Change From Previous Year	(24)	(22)	(26)	(17)	(56)	(60)	(52)	(33)	(41)

Source: DATAQUEST
December 1983

MOS Memory Market Forecast

FORECAST METHODOLOGY

Principal data sources used for establishing the historical data base for 1980-82, as well as forecast methodology, are described below.

Historical Data

The principal data source for the detail data is the DATAQUEST quarterly newsletter series "MOS Memory Shipments," which has been published regularly since 1976. The newsletters originally covered MOS DRAMs, SRAMs, and EPROMs, and in 1982 were enlarged to cover some densities of ROMs and EEPROMs. The newsletters have provided estimates of quarterly industry unit shipments, as well as of prevailing prices during that time period.

In addition, trade association data published by the SIA have been used as a check of the top-level totals, both for units shipped as well as total market revenues. These data, too, involve some degree of estimation for nonparticipating companies, and in certain cases must be considered approximate.

Japanese data are available on total industry memory production in Japan. Adjustments must be made for foreign firms producing in Japan and Japanese firms producing in the United States and Europe in order to count all production once and only once. Occasionally, finer detail is available on Japanese production as well.

These top-level data provide a valuable check on the DATAQUEST unit and value data, and although all data differences cannot be reconciled all the time, we believe that all historical unit shipments and market revenue estimates are within 10 percent of the actual values.

Forecast

Having established a good historical basis from which to judge trends in (1) revenue growth, (2) bit growth, (3) ASP decline, and (4) unit shipments growth, we can understand how the market has developed in the past seven or eight years. Further, the time series of units and prices can tell us a lot about typical product life cycles, and pricing as a function of units shipped or as a function of the point in the product life cycle. In addition, an understanding of the manufacturing process can provide insight into expected die sizes, yields, process difficulty, and, ultimately, the cost of production for the products listed here. In the long term, these costs track closely with relative unit costs and costs per bit.

To all this historical data must be added an element of the unprecedented. We make judgments as to: (1) the potential long-range replacement of NMOS by CMOS, and the attendant price premium; (2) or the potential for "pseudostatic RAMs" to displace DRAM or SRAM, or both; or, the potential for EEPROMs to overcome technical difficulties and build a new market or to replace EPROM as a reprogrammable prototyping tool. All these are, admittedly, quite subjective and involve a large degree of give and take with other industry analysts in order to arrive at a "maximum likelihood" market development scenario based on our quantitative and qualitative assumptions.

Our forecast begins with an overall MOS memory bit growth envelope. This is primarily an extrapolation of the historical bit growth rate, with some allowances made for transient phenomena (e.g., video games) and business cycles. From this we make assumptions about the long-term split into DRAM, SRAM, EPROM, ROM, and EEPROM, based on application types, the supplier base, technological momentum, etc. Next, each market can be segmented into devices of different densities (at different points in their life cycle, at different prices) competing for essentially the same application. All the while, attention is paid to relative prices and rates of change of prices, and other factors affecting ease of use, such as EPROMs vs. ROMs or EEPROMs. An interactive process, the data are reviewed and inconsistencies and illogical trends are ferreted out and corrected.

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Introduction to MOS Memory

SEMICONDUCTOR INDUSTRY SERVICE

Dataquest's Semiconductor Industry Service (SIS) is a comprehensive information service covering the worldwide semiconductor industry. It is a product-oriented, executive-level perspective intended to assist key executives and product managers with their strategic decisions. In recognition of the fact that some semiconductor manufacturers focus on a single product area within the industry, Dataquest offers various service options. These product-focused options provide greater depth of analysis in a selected area while omitting information about other product areas.

MEMORIES

This research notebook focuses on the product, marketing, and technological issues of the memories market. The product areas covered in this study include the following:

- Dynamic random-access memory (DRAM)
- Static random-access memory (SRAM)
- Erasable programmable read-only memory (EPROM)
- Read-only memory (ROM)
- Electrically erasable programmable read-only memory (EEPROM)

MEMORY OVERVIEW

This notebook opens with a general overview of the memory market. This section provides the reader with an understanding of the market by summarizing the information presented in each of the product sections, as follows:

- Executive Summary—Identifies the pertinent issues influencing this market in easy-to-read bullet form
- Forecast Summary—Combines the individual product forecasts into a total market forecast by product category, region, and end-use market
- Market Dynamics—Discusses the global issues affecting this market and the players in it

Each product section is designed to provide the reader with in-depth detailed information on the structure and makeup of the market segment that these products represent. Topics discussed may include the following:

- Forecast—Summarizes Dataquest's five-year forecast for this product segment
- Product Analysis—Compares market share, product features, pricing, life cycles, and design wins on a product type or family basis
- Competitive Analysis—Discusses the configuration of the market based on market share, product positioning, and number of suppliers
- Historical Shipment Data—Records the shipment history of the various products in this category by manufacturer

COMPANY PROFILES

The major semiconductor companies that manufacture memory products are profiled through Dataquest's Central Research Division. Each company's strengths and weaknesses are discussed.

NEWSLETTERS

In addition to general executive-issue newsletters, the subscriber receives specifically focused newsletters on the memory market. These newsletters provide summaries of key industry events or serve to underscore significant changes in the reference material in this notebook. Other newsletters provide analyses of emerging trends or other situations that are of interest to the industry but are not yet large enough in scope to warrant ongoing analysis.

INQUIRY PRIVILEGE

Three forms of inquiry are available to the client: access to the Semiconductor Inquiry Center, access to the semiconductor research staff, and access to Dataquest's On-Line Service. The registered subscriber and one designated alternate have the privilege of direct access to Dataquest. The inquiry center provides assistance in finding or interpreting material in the database notebooks or other Dataquest published material. The client may seek additional commentary on or clarification of the published material from the semiconductor research staff. Using this feature, clients may interact with industry experts on a one-on-one basis to discuss attitudes and opinions about topics covered in the service. In addition, the client may access the convenient On-Line service, featuring *DQ Monday,* a weekly service that focuses on current events within the industry and industries closely related to semiconductors.

MOS Memory Market Overview

MOS MEMORY MARKET OVERVIEW

Total MOS memory revenue worldwide was more than $16.5 billion in 1989, an increase of approximately 32.3 percent over 1988 revenue. Total MOS memory revenue is expected to grow at a compound annual growth rate (CAGR) of approximately 15.3 percent for the 1989 through 1994 period compared with 19.8 percent for the preceding 1984 through 1989 five-year period. Of this revenue, the dynamic random-access memory (DRAM) portion represents nearly 58.9 percent, whereas static random-access memory (SRAM) accounts for almost 20.4 percent of revenue. All categories within MOS memory, except erasable programmable read-only memory (EPROM), experienced revenue growth. Dataquest forecasts a change in this trend for 1990. Products that are forecast to grow during 1990 are fast static RAM, electrically erasable programmable read-only memory (EEPROM), and flash devices. All the other categories, such as DRAM, slow static RAM, EPROM, and read-only memory (ROM), are predicted to decline compared with their 1989 revenue levels. The revenue declines primarily are attributable to depressed average selling prices (ASPs), not to the unit growth.

The most significant factor expected to affect the worldwide semiconductor forecast is an improvement in the US computer industry by mid-1990.

The Market

The following observations were made while examining the 1989 MOS memory market:

- Japanese manufacturers still dominate the MOS memory market with 91.7 percent of the 1989 market.
- US suppliers have increased their market share in MOS memory to 7.2 percent in 1989, up from 5.0 percent in 1988.
- NEC is ranked number one in revenue for 1989, with 10.9 percent of the worldwide available market.
- The units for 1989 increased 7.8 percent over 1988, compared with an increase of 27.6 percent for 1988 units.
- The ASPs for total MOS memory increased from an overall average of $5.14 in 1988 to $6.30 in 1989, an increase of 22.7 percent. However, Dataquest anticipates that the overall ASPs during 1990 will decline in the 20 percent range.
- During 1989, DRAMs enjoyed the strongest revenue growth within the MOS memory product categories—45.1 percent over 1988.
- The 1989 EPROM revenue declined 6.4 percent, compared with 1988 revenue.

Trends and Issues

The following points should be noted about the competition in the MOS memory market:

- DRAM production decreased by switching product mix to other products (such as SSRAMs and PSRAMs).

- Samsung ranked third in 1989's market share as a DRAM producer.
- The quarterly pricing trends of 1Mb devices showed a decline starting in the second quarter of 1989.
- The 4Mb DRAMs are slow in coming to market; this could be, in part, due to 1Mb DRAM price erosions and rapid development of the 16Mb DRAM.
- Japanese manufacturers announced plans to build more capacity for MOS memory products in Europe and North America.
- Cutbacks in unit production for DRAMs occurred during the end of 1989 in an effort to prevent further price erosion.
- Fast SRAMs revenue continued to increase in 1989, with a growth rate of 23.5 percent.
- Slow SRAMs grew 32.1 percent in revenue over 1988.
- The applications areas of data processing and consumer products were the leading drivers for the consumption of memory products.
- SRAMs were unable to meet market demands during the first half of 1989.
- BiCMOS is anticipated to become increasingly used because of its faster speeds at more conservative line geometries and its capability of operating at both ECL and TTL I/O levels.
- Caches made from high-speed SRAMs will become a near necessity in the workstation market and will develop as a desired feature for PCs.
- ROMs enjoyed strong demands during the later part of 1989 because of the healthy games sales in Japan.
- Motorola announced plans to resume building a MOS memory fab facility in Sendai, Japan.
- Sony purchased AMD's unused facility in San Antonio, Texas, and announced plans to produce SRAMs in that facility.

Memory

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

- MOS Memory Market Forecast
- DRAM Forecast
- DRAM Data
- MOS SRAM Forecast
- Fast MOS SRAM Data
- Fast MOS SRAM Data Update
- Slow MOS SRAM Data
- Slow MOS SRAM Data Update
- MOS EPROM Forecast
- MOS EPROM Data
- MOS ROM Forecast
- MOS EEPROM Forecast
- MOS EEPROM Data

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Memory

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

- *MOS Memory Market Forecast*
- *DRAM—Forecast*
- *DRAM—Data*
- *MOS SRAM—Forecast*
- *Fast MOS SRAM—Data*
- *Slow MOS SRAM—Data*
- *MOS EPROM—Forecast*
- *MOS EPROM—Data*
- *MOS ROM—Forecast*
- *MOS EEPROM—Forecast*
- *MOS EEPROM—Data*

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

MOS Memory—Forecast

MOS MEMORY TOTAL WORLDWIDE FORECAST

The Dataquest MOS memory forecast is presented in Tables 1 through 5. Revenue, unit shipments, and average selling prices (ASPs) are forecast for each of the major MOS memory product areas for the years 1990 through 1994. These product areas are dynamic RAMs (DRAMs), static RAMs (SRAMs), EPROMs, mask-programmable ROMs, EEPROMs, flash devices, and other memory devices, which include specialty memory devices. Historical data from 1988 and 1989 also are provided for reference. Tables contained in this forecast are as follows:

- Table 1—Worldwide MOS Memory Market Revenue and Forecast
- Table 2—Worldwide MOS Memory Market Revenue Trends
- Table 3—Worldwide MOS Memory Market Unit Shipments
- Table 4—Worldwide MOS Memory Market Unit Shipment Trends
- Table 5—Worldwide MOS Memory Market Average Selling Prices

For more detailed forecasts of each product family, refer to the appropriate product section.

Table 1

Worldwide MOS Memory Market Revenue and Forecast
(Millions of Dollars)

Product	1988	1989	1990	1991	1992	1993	1994
Dynamic RAM	6,708	9,736	6,647	8,485	11,377	15,722	18,705
Static RAM	2,608	3,375	3,396	4,410	5,507	7,272	8,367
Slow SRAM	1,792	2,367	2,214	2,841	3,510	4,634	5,171
Fast SRAM	816	1,008	1,182	1,569	1,997	2,638	3,196
EPROM	1,905	1,783	1,690	2,079	2,440	2,571	2,480
ROM	929	1,220	1,203	1,445	1,504	1,682	1,892
EEPROM	273	305	318	371	493	599	692
Flash	3	12	37	134	335	727	1,196
Others	73	103	145	193	238	305	400
Total MOS Memory	12,499	16,534	13,436	17,117	21,894	28,878	33,732
Percent Change from Previous Year	107.0%	32.3%	(18.7%)	27.4%	27.9%	31.9%	16.8%

Source: Dataquest (August 1990)

Table 2

Worldwide MOS Memory Market Revenue Trends (Percentage)

Product	1988	1989	1990	1991	1992	1993	1994
Dynamic RAM	53.7%	58.9%	49.5%	49.6%	52.0%	54.4%	55.5%
Static RAM	20.9	20.4	25.3	25.8	25.2	25.2	24.8
Slow SRAM	14.3	14.3	16.5	16.6	16.0	16.0	15.3
Fast SRAM	6.5	6.1	8.8	9.2	9.1	9.1	9.5
EPROM	15.2	10.8	12.6	12.1	11.1	8.9	7.4
ROM	7.4	7.4	9.0	8.4	6.9	5.8	5.6
EEPROM	2.2	1.8	2.4	2.2	2.3	2.1	2.1
Flash	0	0.1	0.3	0.8	1.5	2.5	3.5
Others	0.6	0.6	1.1	1.1	1.1	1.1	1.2
Total MOS Memory	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (August 1990)

Table 3

Worldwide MOS Memory Market Unit Shipments (Millions of Units)

Product	1988	1989	1990	1991	1992	1993	1994
Dynamic RAM	1,298	1,426	1,351	1,498	1,628	1,914	2,169
Static RAM	503	549	576	613	666	782	834
Slow SRAM	398	433	434	450	470	543	560
Fast SRAM	105	116	142	163	196	239	274
EPROM	359	395	405	425	455	483	469
ROM	238	305	296	324	294	289	273
EEPROM	100	122	118	109	107	109	118
Flash	0	1	3	14	41	96	167
Others	9	12	17	20	23	28	34
Total MOS Memory	2,508	2,809	2,766	3,002	3,215	3,700	4,064
Percent Change from Previous Year	31.5%	12.0%	(1.6%)	8.6%	7.1%	15.1%	9.8%

Source: Dataquest (August 1990)

Table 4

Worldwide MOS Memory Market Unit Shipment Trends
(Percentage)

Product	1988	1989	1990	1991	1992	1993	1994
Dynamic RAM	51.8%	50.8%	48.8%	49.9%	50.6%	51.7%	53.4%
Static RAM	20.1	19.5	20.8	20.4	20.7	21.1	20.5
Slow SRAM	15.9	15.4	15.7	15.0	14.6	14.7	13.8
Fast SRAM	4.2	4.1	5.1	5.4	6.1	6.5	6.7
EPROM	14.3	14.1	14.6	14.1	14.2	13.1	11.5
ROM	9.5	10.9	10.7	10.8	9.1	7.8	6.7
EEPROM	4.0	4.3	4.3	3.6	3.3	2.9	2.9
Flash	0	0	0.1	0.5	1.3	2.6	4.1
Others	0.4	0.4	0.6	0.7	0.7	0.7	0.8
Total MOS Memory	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (August 1990)

Table 5

Worldwide MOS Memory Market Average Selling Prices
(Dollars per Unit)

Product	1988	1989	1990	1991	1992	1993	1994
Dynamic RAM	5.17	6.83	4.92	5.66	6.99	8.21	8.62
Static RAM	5.18	6.15	5.90	7.19	8.27	9.30	10.03
Slow SRAM	4.50	5.47	5.10	6.31	7.47	8.53	9.23
Fast SRAM	7.77	8.69	8.32	9.63	10.19	11.04	11.66
EPROM	5.31	4.52	4.17	4.90	5.36	5.32	5.29
ROM	3.91	3.99	4.07	4.47	5.12	5.82	6.93
EEPROM	2.72	2.51	2.70	3.40	4.59	5.51	5.85
Flash	21.17	17.84	13.63	9.47	8.13	7.61	7.18
Others	7.77	8.69	8.32	9.63	10.19	11.04	11.66
Total MOS Memory	4.98	5.89	4.86	5.70	6.81	7.81	8.30
Percent Change from Previous Year	57.4%	18.1%	(17.5%)	17.3%	19.5%	14.6%	6.3%

Source: Dataquest (August 1990)

REVIEW OF 1989 MOS MEMORY MARKET PERFORMANCE

On a worldwide basis, MOS memory market revenue grew 32.3 percent in 1989 compared with 1988. The number of units increased by 12.0 percent to 2,809 million units in 1989, with the ASP increasing 18.1 percent to an overall average of $5.89.

DRAMs

DRAM prices started dropping during the third quarter of 1989 and have continued to decline, with periods of stabilization, through the middle of 1990. Interestingly, the average 1989 DRAM price improved by 32.1 percent when compared with the 1988 average, indicating that DRAM prices had been much stronger during the first half of 1989, primarily because of the 1Mb volume shift. Also, because of a 9.7 percent increase in 1989 unit shipments over 1988 and the improved average price, the overall revenue performance for DRAMs increased 45.1 percent compared with 1988. DRAMs still continue to dominate the total MOS memory product category with 58.8 percent of total revenue in 1989.

SRAMs

Static RAM revenue in 1989 improved 29.4 percent over 1988. The strongest growth occurred in the slow SRAM area, which improved 32.1 percent in 1989; the fast SRAM area grew 23.5 percent over the same period. Unit shipments improved 9.1 percent in the total SRAM product category in 1989, with the ASP improving by 18.7 percent. Next to DRAMs, SRAMs are the largest product segment of the total MOS category.

EPROMs

The EPROM revenue portion of total MOS memories dropped off in 1989 by 6.4 percent compared with 1988. Unit shipments increased by 10 percent and the ASP declined 15.0 percent.

ROMs

ROMs enjoyed a resurgence in revenue because of increased demands made by game manufacturers in Japan and for office automation systems equipment. ROM revenue improved 31.3 percent in 1989 over the previous period. The number of units shipped increased 28.2 percent in 1989, with prices increasing to an annual average of $3.99, an improvement of 2.0 percent.

EEPROMs

The EEPROM revenue market improved 11.7 percent in 1989, with an increase of 22 percent in units shipped and the ASP declining 7.7 percent compared with the previous year.

Flash Devices

Flash devices grew 400 percent in 1989 compared with 1988, a growth that was anticipated because these products were only introduced in 1988. Flash devices are expected to follow a similar learning curve as DRAMs. The ASP also declined, which is a typical trend with a new product.

Others

Revenue for other memory devices, which include FIFO deep SRAM, dual-port SRAM, video DRAMs, and SRAMs with a battery RAM, grew 41.1 percent in 1989 compared with 1988. The products that grew rapidly in 1989 included specialty DRAMs (DRAM FIFO, frame, line, and field memories) and video DRAMs. Units shipped in 1989 were 33.3 percent higher than the previous year, with ASPs 11.8 percent stronger than 1988.

HIGHLIGHTS OF THE MOS MEMORY FORECAST

The short-term forecast indicates that MOS memory revenue in 1990 will decline worldwide by 18.7 percent from 1989. Dataquest is optimistic that the market will improve beginning in the latter part of 1990, with this trend continuing through 1994. The MOS memory market is expected to grow at a compound annual growth rate (CAGR) of 15.3 percent compared with 19.8 percent from 1984 through 1989.

Following is a summary of Dataquest's forecast high points:

- On a CAGR basis, the faster-growing product families from 1989 through 1994 will be the flash devices (152.3 percent), fast SRAMs (26.0 percent), and EEPROMs (17.8 percent).
- On a CAGR basis, units are forecast to be at 9.3 percent from 1989 through 1994. Flash devices, as a new technology, are expected to have a strong 202.3 percent CAGR.
- The overall ASP is expected to have a CAGR of 7.3 percent from 1989 through 1994, with EEPROMs having the strongest at 18.4 percent.
- The market is expected to continue its maturing process with double-digit growth rates; in the past (e.g., in 1988), however, the MOS memory growth rate was 107.0 percent.
- The applications area of the semiconductor business will continue to develop new products, thus increasing consumption of semiconductors.
  - The data processing segment, which historically has been the largest consumer of semiconductors, is expected to show a CAGR from 1988 through 1994 of 16.5 percent.
  - The communications and industrial segments show strong CAGRs at 14.1 and 14.7 percent, respectively.

LONG-TERM MARKET OUTLOOK

Dataquest's assumptions in making the previous long-range forecasts include the following:

- Densities of memory products are expected to increase.
- BiCMOS products will become more commonplace.
- Demand for cache memory products will increase.
- Further new applications in graphics, speech, and HDTV will emerge.
- Growing consumption in the Rest of World (ROW) geographical region will increase.

The MOS memory market promises to reach out beyond its traditional applications boundaries into other segments that require performance interface and processing-related functions. Submicron processes will continue to match or exceed the speeds of bipolar memory devices. Dataquest expects the specialty memory segment to grow substantially throughout the forecast period and beyond.

MOS Memory Market Forecast

MOS MEMORY TOTAL WORLDWIDE FORECAST

The Dataquest MOS memory forecast is presented in Tables 1 through 7. Revenue, unit shipments, average selling price, bit shipments, and average price per bit are forecast for each of the major MOS memory product areas for the years 1987 to 1991. These product areas are dynamic RAMs (DRAMs), static RAMs (SRAMs), EPROMs, mask-programmable ROMs, and EEPROMs. Historical data from 1984 to 1986 are also provided for your reference. Tables contained in this forecast are as follows:

Table 1--Worldwide MOS Memory Market--Revenue

Table 2--Worldwide MOS Memory Market--Revenue Trends

Table 3--Worldwide MOS Memory Market--Unit Shipments

Table 4--Worldwide MOS Memory Market--Unit Shipment Trends

Table 5--Worldwide MOS Memory Market--Average Selling Prices

Table 6--Worldwide MOS Memory Market--Bit Shipments

Table 7--Worldwide MOS Memory Market--Average Selling Price per Bit

For more detailed forecasts of each product family, refer to the appropriate product section.

Comparison to Earlier Forecasts

The last Dataquest MOS memory forecast was published in September 1986. Although actual 1986 MOS memory revenue is the same as that of the previous forecast, unit shipments are higher and the average selling price (ASP) is lower. Despite the U.S.-Japan Semiconductor Trade Arrangement and the accompanying foreign market values (FMVs), DRAM prices dropped considerably in the last quarter of 1986 after a brief increase in the third quarter. Prices of MOS memories in Europe and the Asia Pacific region were consistently and markedly lower than in the United States.

The projected growth in 1987 has been revised to 21 percent, compared to 40 percent in the September forecast. Although U.S. book-to-bill ratios have crossed unity, European ratios have not shown the same strength and Japan's economy is hurting because of the depreciating dollar. Yet, 21 percent is a healthy growth, a welcome relief after the soft market conditions of 1985 and 1986.

MOS Memory Market Forecast

Tempered optimism characterizes the 1988 to 1991 outlook in this forecast. The MOS memory market is expected to grow at a compound annual growth rate (CAGR) of 14.7 percent, compared to 22.0 percent in the previous forecast. New product introduction schedules (4Mb DRAM, 1Mb SRAM, and others) have been adjusted. Conservatism in capital spending for production equipment for new products is prevalent after the severe financial losses incurred in 1985 and 1986.

For Japanese companies, this problem is compounded by the strong yen and an expected weak domestic consumption. Japanese government intervention in pricing and production of MOS memories is expected to continue.

Highlights of the MOS Memory Forecast

We expect the following to occur in the MOS memory market:

- The market achieved $4.4 billion in revenue in 1986 and is expected to grow to $5.3 billion in 1987 and $8.8 billion by 1991.
- The market will grow at 14.7 percent CAGR from 1986 to 1991, compared to a 16.7 percent CAGR from 1981 to 1986.
- The fastest-growing product families are the fast SRAM and EEPROM.
  - Fast SRAMs and EEPROMs will grow at 17 percent and 36 percent CAGRs, respectively.
  - DRAM revenue will have an above-average 16 percent CAGR in this period.
- Average selling prices are expected to improve beginning in 1987, as the industry improves and newer products increasingly are produced.
- The market is expected to experience narrower swings in annual growth rates, similar to those of the latter years of the last decade.
  - There is no apparent application like the personal computer that will cause the wild swings of recent years.
  - We believe that the industry will be better prepared for the next downturn.

MOS Memory Market Forecast

- The year 1989 is projected to be a soft year for the whole semiconductor industry, based on projections of the industry's cycles. However, Dataquest expects a milder downturn in 1989 than that of 1985.

- MOS memory bits are expected to grow at a 63 percent CAGR from 1986 to 1991, versus a 92 percent CAGR from 1981 to 1986.

MARKET OUTLOOK

The Short-Term Outlook

The book-to-bill ratio of U.S. suppliers and the general increased purchasing activity in the early months of 1987 are positive market signs that are expected to fuel the 21 percent growth in 1987. Market opportunities abound. Personal computer manufacturers such as IBM and Apple have announced new products with denser and faster memories. Furthermore, several mainframe and minicomputer companies are performing well, boosting static RAM sales, and the 256K EEPROM is being designed into several military applications. More companies are expected to slowly return to profitability. In the United States, lead times for certain DRAMs and EPROMs have stretched out and are expected to remain so through the third quarter.

Nevertheless, negative factors exist as well. Japanese consumption is expected to be weak in 1987 because of the strong yen. Investments in new, expensive lines for new densities and packages are being constrained by the low level of profitability in the industry, increasing the potential for 1Mb DRAM shortages. The U.S.-Japan trade war is escalating with the semiconductor industry as the more visible battlefield. Consequently, Japanese producers have implemented production cuts that could lead to severe 256K DRAM shortages.

The Long-Term Outlook

Dataquest believes that the following factors will lend to the anticipated 14.7 percent CAGR for MOS memories through 1991:

- The traditional growth of new, higher-density memories

- The penetration of the bipolar market by high-speed MOS memories

- The expansion of the market into nontraditional memory uses

MOS Memory Market Forecast

- The emergence of new applications in graphics, speech, and digital television
- Consumption growth in the Asia Pacific countries other than Japan

We believe that higher-density memories will dominate the market. We expect 1Mb and 4Mb DRAMs, for example, to account for 93 percent of the total DRAM market in 1991, compared to only 8 percent in 1986.

The MOS memory market promises to reach out beyond its traditional boundaries. Submicron processes have given birth to CMOS SRAMs and EPROMs that approximate bipolar speeds. These products are expected to take a slice out of the bipolar memory market. With additional on-chip logic, memories are being used in applications that perform interface and processing-related functions, a departure from conventional storage tasks. Classified as specialty memories, they include FIFOs, dual-port RAMs, video RAMs, and cache tag RAMs. Dataquest expects the specialty memory market segment to grow significantly in the next years.

New applications in graphics, speech, IC cards, digital television, and other areas are projected to pick up in activity, although real expansion in these markets is not expected until after the turn of the decade. Faster, high-density memories are being developed to meet future needs of 32-bit microprocessor-based systems.

The anticipated consumption growth in the Asia Pacific region will also contribute to the growth in MOS memory revenue. MOS memory revenue in this region is expected to reach $880 million by 1991.

MOS Memory Market Forecast

Table 1

WORLDWIDE MOS MEMORY MARKET REVENUE
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	$4,850	$2,473	$2,905	$3,463	$4,438	$4,056	$4,743	$5,999
Dynamic RAM	$3,540	$1,592	$2,102	$2,467	$3,371	$3,110	$3,478	$4,360
NMOS	3,523	1,560	1,896	1,746	1,416	860	401	288
CMOS	17	32	206	721	1,955	2,250	3,077	4,072
Static RAM	$1,310	$ 881	$ 803	$ 996	$1,067	$ 946	$1,265	$1,639
Fast SRAM	323	339	353	446	520	524	677	763
Slow SRAM	987	542	450	550	547	422	588	876
NMOS	481	315	198	128	84	47	28	15
CMOS	830	569	606	869	982	898	1,236	1,623
Read-Only Memory	$1,774	$1,406	$1,467	$1,826	$2,085	$2,147	$2,555	$2,696
EPROM	$1,185	$ 876	$ 910	$1,052	$1,176	$1,225	$1,497	$1,616
UV EPROM	1,164	856	861	989	1,055	1,097	1,346	1,428
OTP	21	20	49	63	121	128	151	188
NMOS	1,071	791	720	725	681	560	594	593
CMOS	114	85	190	326	495	665	902	1,023
ROM	$ 434	$ 388	$ 418	$ 543	$ 564	$ 493	$ 453	$ 442
NMOS	321	255	243	283	256	160	112	81
CMOS	113	133	175	260	308	333	341	361
EEPROM	$ 155	$ 142	$ 139	$ 231	$ 345	$ 429	$ 605	$ 638
NMOS	145	130	117	158	208	185	268	282
CMOS	10	12	22	73	137	244	337	356
Other MOS Memory	$ 50	$ 45	$ 55	$ 65	$ 75	$ 80	$ 100	$ 100
Total MOS Memory	$6,674	$3,924	$4,427	$5,354	$6,598	$6,283	$7,398	$8,795
Percent Change from Previous Year	63.0%	(41.2%)	12.8%	20.9%	23.2%	(4.8%)	17.7%	18.9%

Source: Dataquest
April 1987

MOS Memory Market Forecast

Table 2

WORLDWIDE MOS MEMORY MARKET--REVENUE TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	73%	64%	72%	71%	76%	77%	73%	73%
Percent SRAM	27	36	28	29	24	23	27	27
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	67%	62%	62%	58%	56%	57%	59%	60%
Percent Mask ROM	24	28	28	30	27	23	18	16
Percent EEPROM	9	10	9	13	17	20	24	24
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	73%	63%	66%	65%	67%	65%	64%	68%
Percent Read Only Memory	27	36	33	34	32	34	35	31
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	84%	79%	73%	57%	41%	29%	19%	14%
Percent CMOS	16	21	27	43	59	71	81	86
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	25%	38%	44%	45%	49%	55%	54%	47%
Percent Slow SRAM	75	62	56	55	51	45	46	53
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	2%	4%	5%	7%	7%	7%	8%
Percent Reprogrammable	98%	98%	96%	95%	93%	93%	93%	92%
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

MOS Memory Market Forecast

Table 3

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENTS
(Millions of Units)

	1984	1985	1986	1987	1988	1989	1990	1991
Read/Write Memory	1,304	1,080	1,363	1,448	1,549	1,643	1,736	1,878
Dynamic RAM	1,012	782	1,060	1,135	1,230	1,311	1,355	1,454
NMOS	1,010	777	1,043	1,060	870	622	326	240
CMOS	3	5	17	75	361	689	1,029	1,214
Static RAM	291	298	304	313	318	333	381	424
Fast SRAM	60	68	79	94	101	112	143	166
Slow SRAM	232	230	225	219	217	221	238	258
NMOS	138	121	89	47	31	20	12	6
CMOS	154	177	214	266	287	313	369	418
Read-Only Memory	396	427	470	501	538	541	569	602
EPROM	221	245	267	287	311	322	349	357
UV EPROM	216	237	250	264	281	285	308	304
OTP	5	8	17	23	30	37	40	53
NMOS	208	228	227	228	218	183	173	160
CMOS	13	17	40	60	93	139	176	197
ROM	132	137	154	159	160	146	135	140
NMOS	110	106	108	103	86	55	41	32
CMOS	22	31	46	55	74	91	94	108
EEPROM	43	45	49	55	67	73	86	105
NMOS	42	42	41	44	44	39	38	49
CMOS	1	4	7	12	24	35	48	56
Other MOS Memory	10	9	11	13	15	16	20	20
Total MOS Memory	1,710	1,516	1,844	1,962	2,102	2,200	2,325	2,500
Percent Change from Previous Year	33.0%	(11.3%)	21.6%	6.4%	7.1%	4.7%	5.6%	7.5%

Source: Dataquest
April 1987

MOS Memory Market Forecast

Table 4

WORLDWIDE MOS MEMORY MARKET--UNIT SHIPMENT TRENDS
(Percent)

	1984	1985	1986	1987	1988	1989	1990	1991
Percent DRAM	78%	72%	78%	78%	79%	80%	78%	77%
Percent SRAM	22	28	22	22	21	20	22	23
Total RAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent EPROM	56%	57%	57%	57%	58%	59%	61%	59%
Percent Mask ROM	33	32	33	32	30	27	24	23
Percent EEPROM	11	11	10	11	13	14	15	17
Total ROM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Read/Write Memory	76%	71%	74%	74%	74%	75%	75%	75%
Percent Read Only Memory	23	28	25	26	26	25	24	24
Percent Other MOS Memory	1	1	1	1	1	1	1	1
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent P or NMOS	89%	84%	82%	76%	60%	42%	26%	20%
Percent CMOS	11	16	18	24	40	58	74	80
Total MOS Memory	100%	100%	100%	100%	100%	100%	100%	100%
Percent Fast SRAM	20%	23%	26%	30%	32%	34%	38%	39%
Percent Slow SRAM	80	77	74	70	68	66	62	61
Total SRAM	100%	100%	100%	100%	100%	100%	100%	100%
Percent Once Programmable	2%	3%	5%	6%	7%	8%	8%	10%
Percent Reprogrammable	98	97	95	94	93	92	92	90
Total Programmable	100%	100%	100%	100%	100%	100%	100%	100%

Source: Dataquest
April 1987

Table 5

WORLDWIDE MOS MEMORY MARKET--AVERAGE SELLING PRICES
(Dollars per Unit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	$3.50	$2.03	$1.98	$2.17	$2.74	$2.37	$2.57	$3.00
Static RAM	$4.50	$2.97	$2.64	$3.18	$3.35	$2.84	$3.32	$3.86
Fast SRAM	$5.41	$5.00	$4.47	$4.76	$5.13	$4.70	$4.72	$4.60
Slow SRAM	$4.26	$2.36	$2.00	$2.51	$2.52	$1.91	$2.47	$3.39
EPROM	$5.37	$3.57	$3.41	$3.66	$3.78	$3.81	$4.29	$4.53
UV EPROM	$5.40	$3.62	$3.45	$3.75	$3.76	$3.85	$4.36	$4.69
OTP	$4.10	$2.40	$2.84	$2.69	$3.98	$3.49	$3.76	$3.57
ROM	$3.28	$2.83	$2.72	$3.42	$3.54	$3.37	$3.37	$3.15
EEPROM	$3.58	$3.15	$2.86	$4.17	$5.13	$5.85	$7.05	$6.09
Other MOS Memory	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00
Overall MOS Memory	$3.90	$2.59	$2.40	$2.73	$3.14	$2.86	$3.18	$3.52
Percent Change from Previous Year	19.9%	(33.7%)	(7.2%)	13.7%	15.0%	(9.1%)	11.5%	10.6%

Source: Dataquest
April 1987

MOS Memory Market Forecast

Table 6

WORLDWIDE MOS MEMORY MARKET--BIT SHIPMENTS
(Billions of Bits)

	1984	1985	1986	1987
Dynamic RAM	68,162	98,184	196,182	295,585
Static RAM	5,197	7,257	11,134	21,774
Fast SRAM	618	885	1,436	2,695
Slow SRAM	4,580	6,371	9,698	19,078
EPROM	12,933	21,827	36,445	58,123
UV EPROM	12,720	21,231	33,474	52,396
OTP	213	596	2,971	5,727
ROM	13,649	23,032	41,701	75,579
EEPROM	126	188	290	598
Overall MOS Memory	100,067	150,488	285,752	451,659
Percent Change from Previous Year	95.0%	50.4%	89.9%	58.1%

	1988	1989	1990	1991
Dynamic RAM	572,680	887,279	1,353,967	2,538,471
Static RAM	34,750	51,947	99,590	198,468
Fast SRAM	5,285	8,955	18,357	34,005
Slow SRAM	29,465	42,992	81,234	164,463
EPROM	90,006	133,829	201,282	259,797
UV EPROM	77,526	112,932	168,677	204,584
OTP	12,480	20,897	32,605	55,213
ROM	112,853	132,710	175,112	261,554
EEPROM	1,668	3,360	8,428	15,931
Overall MOS Memory	811,957	1,209,125	1,838,379	3,274,221
Percent Change from Previous Year	79.8%	48.9%	52.0%	78.1%

Source: Dataquest
April 1987

Table 7

WORLDWIDE MOS MEMORY MARKET--AVERAGE SELLING PRICE PER BIT
(Millicents per Bit)

	1984	1985	1986	1987	1988	1989	1990	1991
Dynamic RAM	5.2	1.6	1.1	0.8	0.6	0.4	0.3	0.2
Static RAM	25.2	12.2	7.2	4.6	3.1	1.8	1.3	0.8
Fast SRAM	52.3	38.3	24.6	16.6	9.8	5.9	3.7	2.2
Slow SRAM	21.5	8.5	4.6	2.9	1.9	1.0	0.7	0.5
EPROM	18.8	7.3	4.3	3.0	2.4	1.6	1.3	1.0
UV EPROM	9.2	4.0	2.6	1.9	1.4	1.0	0.8	0.7
OTP	9.6	3.3	1.7	1.1	1.0	0.6	0.5	0.3
ROM	3.2	1.7	1.0	0.7	0.5	0.4	0.3	0.2
EEPROM	122.6	75.5	48.2	38.6	20.7	12.8	7.2	4.0
Overall MOS Memory	6.6	2.6	1.5	1.2	0.8	0.5	0.4	0.3
Percent Change from Previous Year	(18.0%)	(61.1%)	(40.6%)	(23.5%)	(31.4%)	(36.1%)	(22.6%)	(33.1%)

Source: Dataquest
April 1987

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DYNAMIC RAMs

DRAM—Forecast

SUMMARY

The current economic slowdown, begun during the last half of 1989 and continuing through the first half of 1990, has dramatically impacted 1990 DRAM revenue. DRAM revenue for 1990 is forecast to be more than $3 billion lower than that for 1989! However, recovery from the 1989/1990 cyclic downturn is expected to occur during the second half of 1990.

Dataquest forecasts moderate growth during 1991, solid growth during 1992 and 1993, and the peak year of the growth cycle occurring in 1993. We predict a slowdown in revenue growth rate for 1994, indicating early signs of the next major cyclic downturn.

DATAQUEST'S DRAM FORECAST

Table 1 presents Dataquest's worldwide total DRAM forecast. Tables 2 and 3 present the NMOS and CMOS DRAM forecasts, respectively. The DRAM forecast includes three years (1987 through 1989) of historic perspective and five years (1990 through 1994) of predictions. Revenue in dollars ("dollarized units" computed as the product of units and worldwide ASP), unit shipments, and average selling price (ASP) are detailed for each DRAM density and process technology.

Comparison with Earlier Forecasts

Dataquest's last published forecast for the DRAM market was dated August 1988. (Updates have been available on request or via Dataquest's on-line service.) The major changes from our last forecast are summarized in the following paragraphs.

The revenue, unit shipments, and ASPs for 1988 and 1989 have been adjusted to reflect the final historical data collected from manufacturers. Our previous forecast overstated the 1988 unit shipments of 64K DRAMs by 10.0 percent, understated the 256K DRAMs by 6.2 percent, and understated the 1Mb DRAMs by 11.9 percent. The 1988 unit shipments for all DRAM densities were understated by 5.3 percent.

For 1989, 64K DRAM units were decreased from the previous forecast of 74.8 million units to 67.0 million units, 256K DRAM units increased from the forecast 720.0 million units to 853.7 million units, 1Mb DRAMs decreased from 533.3 million units to 503.0 million units, and 4Mb DRAMs decreased from 2.2 million units to 1.9 million units. The decreased 1Mb DRAM forecast was due to suppliers reducing production of 1Mb DRAMs when an oversupply situation occurred as a result of the industry entering the 1989/1990 cyclic slowdown. Unit shipments for all DRAM densities increased by 7.2 percent in 1989 over the previous forecast; the increase was due to higher-than-expected 256K DRAM shipments reported by suppliers.

The 1988 and 1989 revenue growth rates were higher than previously forecast; actual revenue growth for 1988 was 155 percent and for 1989 was 45 percent compared with the previously forecast growth of 115 percent for 1988 and 13 percent for 1989. The increases in revenue were due to higher unit growth and higher ASPs during 1988 and the first half of 1989 than originally forecast.

Table 1

Total Worldwide DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	3	2	0	0	0	0	0	0
16K (5-Volt Only)	3	3	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	165	191	115	31	12	8	6	2
128K (2-Chip Package)	12	0	0	0	0	0	0	0
256K	1,808	2,915	2,544	1,159	671	449	314	186
1Mb	636	3,590	6,845	4,741	5,290	4,454	3,825	2,978
4Mb	0	7	232	716	2,513	6,245	9,627	10,464
16Mb	0	0	0	0	0	220	1,950	5,075
Total Dollars	2,627	6,708	9,736	6,647	8,485	11,377	15,722	18,705
Percent Change from Previous Year	29%	155%	45%	(32%)	28%	34%	38%	19%

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	2.0	1.0	0	0	0	0	0	0
16K (5-Volt Only)	1.5	1.0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	152.6	127.1	67.0	21.5	7.8	5.7	4.0	1.0
128K (2-Chip Package)	3.0	0	0	0	0	0	0	0
256K	766.3	955.9	853.7	582.3	370.6	240.0	165.0	93.0
1Mb	42.6	212.7	503.0	726.1	1,000.0	960.0	850.0	730.0
4Mb	0	0	1.9	21.2	119.2	420.0	865.0	1,200.0
16Mb	0	0	0	0	0	2.0	30.0	145.0
Total Units	968.0	1,297.8	1,425.6	1,351.1	1,497.6	1,627.7	1,914.0	2,169.0

(Continued)

Table 1 (Continued)

Total Worldwide DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	1.50	2.00	0	0	0	0	0	0
16K (5-Volt Only)	2.00	2.50	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.08	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	4.00	0	0	0	0	0	0	0
256K	2.36	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.93	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	0	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	2.71	5.17	6.83	4.92	5.67	6.99	8.21	8.62

NA = Not available
Source: Dataquest (June 1990)

Table 2

Worldwide NMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	3	2	0	0	0	0	0	0
16K (5-Volt Only)	3	3	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	165	187	115	31	12	8	6	2
128K (2-Chip Package)	12	0	0	0	0	0	0	0
256K	1,639	2,558	2,056	927	530	350	241	141
1Mb	0	206	399	190	159	134	115	60
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total Dollars	1,822	2,955	2,570	1,148	700	492	362	202
Percent Change from Previous Year	(2%)	62%	(13%)	(55%)	(39%)	(30%)	(26%)	(44%)

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	2.0	1.0	0	0	0	0	0	0
16K (5-Volt Only)	1.5	1.0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	152.5	124.6	66.8	21.5	7.8	5.7	4.0	1.0
128K (2-Chip Package)	3.0	0	0	0	0	0	0	0
256K	712.7	838.7	689.9	465.8	292.8	187.2	127.1	70.7
1Mb	0	12.2	29.3	29.0	30.0	28.8	25.5	14.6
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total Units	871.7	977.5	786.1	516.4	330.6	221.7	156.6	86.3

(Continued)

Table 2 (Continued)

Worldwide NMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual				Forecast			
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	1.50	2.00	0	0	0	0	0	0
16K (5-Volt Only)	2.00	2.50	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.08	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	3.90	0	0	0	0	0	0	0
256K	2.30	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.95	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	NA	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	2.09	3.02	3.27	2.22	2.12	2.22	2.31	2.35

NA = Not available
Source: Dataquest (June 1990)

Table 3

Worldwide CMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	0	4	0	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	169	357	488	232	141	99	72	45
1Mb	637	3,384	6,446	4,552	5,131	4,321	3,710	2,919
4Mb	0	7	231	716	2,513	6,245	9,627	10,464
16Mb	0	0	0	0	0	220	1,950	5,075
Total Dollars	806	3,753	7,166	5,499	7,785	10,885	15,360	18,502
Percent Change from Previous Year	342%	366%	91%	(23%)	42%	40%	41%	20%

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	0.1	2.5	0.2	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	53.6	117.2	163.8	116.5	77.8	52.8	38.0	22.3
1Mb	42.6	200.5	473.7	697.1	970.0	931.2	824.5	715.4
4Mb	0	0	1.9	21.2	119.2	420.0	865.0	1,200.0
16Mb	0	0	0	0	0	2.0	30.0	145.0
Total Units	96.3	320.2	639.5	834.7	1,167.0	1,406.0	1,757.5	2,082.7

(Continued)

Table 3 (Continued)

Worldwide CMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual				Forecast			
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.25	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	3.15	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.95	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	0	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	8.37	11.72	11.21	6.59	6.67	7.74	8.74	8.88

NA = Not available
Source: Dataquest (June 1990)

Compared with the previous forecast, unit shipments for 1990, 1991, and 1992 decreased by 29.8 million units, 1.3 million units, and 36.8 million units, respectively.

The compound annual growth rate (CAGR) for revenue from 1986 to 1994 is expected to be 31.8 percent, compared with the previous forecast of 32.1 percent CAGR during the period from 1986 through 1992. DRAM revenue from 1990 to 1994 is expected to grow at a 29.5 percent CAGR. Revenue for 1990 has been increased by 3.6 percent over the previous forecast, but will drop by 32.0 percent from the previous year. This large decrease is due to sharp declines in ASPs and reduced shipment volumes during the later part of 1989 and first part of 1990.

Major Factors Supporting this Forecast

Major factors supporting Dataquest's current DRAM forecast include the following:

- Industry slowdown from mid-1988 through mid-1990
- Continuing market dominance by the Japanese
- Increasing market share of non-Japanese vendors
- Movement of manufacturing to North America and Europe
- High cost and difficulty of submicron technology
- Continued political influences in the market
- Unification of Europe in 1992
- No major influence on market by new applications

The Short-Term Outlook

The mid-1989 downturn, predicted by Dataquest in the August 1988 forecast, occurred as expected. Prices dropped as the industry entered the slowdown, even though prices had been sustained at unhistorically high levels since the implementation of the foreign market value (FMV) system during 1987. Prices are expected to continue to decline through the first half of 1990, but ASP declines are expected to slow down, returning to more historical patterns, during the latter part of the year when user demand picks up. Momentary price increases could occur during the second half of 1990 if manufacturers do not increase production volumes fast enough to support increasing user demand.

As a result of recent declines in 1Mb prices during late 1989 and early 1990, the 4Mb price crossover (4X unit price of 1Mb) is not expected to occur until the first quarter of 1991. This delayed crossover will impede the growth of the 4Mb DRAM market during 1990.

The Long-Term Outlook

Dataquest forecasts a decline in DRAM unit growth of negative 5.2 percent during 1990, moderate growth during 1991 and 1992, and strong growth during 1993. Unit shipment growth will not be as rapid; quadrupling of chip densities will cause unit shipments to grow at a slower rate. Bit growth during 1990 is forecast at 31.0 percent, but it will average 70.0 percent per year from 1991 through 1994.

The major driver of bit growth will continue to be the increased pervasiveness of memory. High-bit-usage applications, such as HDTV, are not expected to have a significant influence on the DRAM market until after 1994. However, Dataquest believes that more specialty and intelligent memories will emerge. Video RAMs, frame/field buffers, and wide-word memories are in production today, and other specialty DRAMs such as cached DRAMs and high-speed nonmultiplexed DRAMs have been introduced. The integration of complete systems on a single chip, including large-size DRAM memory storage, is expected within the decade.

DRAM—Forecast

SUMMARY

The current economic slowdown, begun during the last half of 1989 and continuing through the first half of 1990, has dramatically impacted 1990 DRAM revenue. DRAM revenue for 1990 is forecast to be more than $3 billion lower than that for 1989! However, recovery from the 1989/1990 cyclic downturn is expected to occur during the second half of 1990.

Dataquest forecasts moderate growth during 1991, solid growth during 1992 and 1993, and the peak year of the growth cycle occurring in 1993. We predict a slowdown in revenue growth rate for 1994, indicating early signs of the next major cyclic downturn.

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Table 1 presents Dataquest's worldwide total DRAM forecast. Tables 2 and 3 present the NMOS and CMOS DRAM forecasts, respectively. The DRAM forecast includes three years (1987 through 1989) of historic perspective and five years (1990 through 1994) of predictions. Revenue in dollars ("dollarized units" computed as the product of units and worldwide ASP), unit shipments, and average selling price (ASP) are detailed for each DRAM density and process technology.

Comparison with Earlier Forecasts

Dataquest's last published forecast for the DRAM market was dated August 1988. (Updates have been available on request or via Dataquest's on-line service.) The major changes from our last forecast are summarized in the following paragraphs.

The revenue, unit shipments, and ASPs for 1988 and 1989 have been adjusted to reflect the final historical data collected from manufacturers. Our previous forecast overstated the 1988 unit shipments of 64K DRAMs by 10.0 percent, understated the 256K DRAMs by 6.2 percent, and understated the 1Mb DRAMs by 11.9 percent. The 1988 unit shipments for all DRAM densities were understated by 5.3 percent.

For 1989, 64K DRAM units were decreased from the previous forecast of 74.8 million units to 67.0 million units, 256K DRAM units increased from the forecast 720.0 million units to 853.7 million units, 1Mb DRAMs decreased from 533.3 million units to 503.0 million units, and 4Mb DRAMs decreased from 2.2 million units to 1.9 million units. The decreased 1Mb DRAM forecast was due to suppliers reducing production of 1Mb DRAMs when an oversupply situation occurred as a result of the industry entering the 1989/1990 cyclic slowdown. Unit shipments for all DRAM densities increased by 7.2 percent in 1989 over the previous forecast; the increase was due to higher-than-expected 256K DRAM shipments reported by suppliers.

The 1988 and 1989 revenue growth rates were higher than previously forecast; actual revenue growth for 1988 was 155 percent and for 1989 was 45 percent compared with the previously forecast growth of 115 percent for 1988 and 13 percent for 1989. The increases in revenue were due to higher unit growth and higher ASPs during 1988 and the first half of 1989 than originally forecast.

Table 1

Total Worldwide DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	3	2	0	0	0	0	0	0
16K (5-Volt Only)	3	3	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	165	191	115	31	12	8	6	2
128K (2-Chip Package)	12	0	0	0	0	0	0	0
256K	1,808	2,915	2,544	1,159	671	449	314	186
1Mb	636	3,590	6,845	4,741	5,290	4,454	3,825	2,978
4Mb	0	7	232	716	2,513	6,245	9,627	10,464
16Mb	0	0	0	0	0	220	1,950	5,075
Total Dollars	2,627	6,708	9,736	6,647	8,485	11,377	15,722	18,705
Percent Change from Previous Year	29%	155%	45%	(32%)	28%	34%	38%	19%

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	2.0	1.0	0	0	0	0	0	0
16K (5-Volt Only)	1.5	1.0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	152.6	127.1	67.0	21.5	7.8	5.7	4.0	1.0
128K (2-Chip Package)	3.0	0	0	0	0	0	0	0
256K	766.3	955.9	853.7	582.3	370.6	240.0	165.0	93.0
1Mb	42.6	212.7	503.0	726.1	1,000.0	960.0	850.0	730.0
4Mb	0	0	1.9	21.2	119.2	420.0	865.0	1,200.0
16Mb	0	0	0	0	0	2.0	30.0	145.0
Total Units	968.0	1,297.8	1,425.6	1,351.1	1,497.6	1,627.7	1,914.0	2,169.0

(Continued)

Table 1 (Continued)

Total Worldwide DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual				Forecast			
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	1.50	2.00	0	0	0	0	0	0
16K (5-Volt Only)	2.00	2.50	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.08	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	4.00	0	0	0	0	0	0	0
256K	2.36	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.93	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	0	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	2.71	5.17	6.83	4.92	5.67	6.99	8.21	8.62

NA=Not available
Source: Dataquest (June 1990)

Table 2

Worldwide NMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	3	2	0	0	0	0	0	0
16K (5-Volt Only)	3	3	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	165	187	115	31	12	8	6	2
128K (2-Chip Package)	12	0	0	0	0	0	0	0
256K	1,639	2,558	2,056	927	530	350	241	141
1Mb	0	206	399	190	159	134	115	60
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total Dollars	1,822	2,955	2,570	1,148	700	492	362	202
Percent Change from Previous Year	(2%)	62%	(13%)	(55%)	(39%)	(30%)	(26%)	(44%)

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	2.0	1.0	0	0	0	0	0	0
16K (5-Volt Only)	1.5	1.0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	152.5	124.6	66.8	21.5	7.8	5.7	4.0	1.0
128K (2-Chip Package)	3.0	0	0	0	0	0	0	0
256K	712.7	838.7	689.9	465.8	292.8	187.2	127.1	70.7
1Mb	0	12.2	29.3	29.0	30.0	28.8	25.5	14.6
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total Units	871.7	977.5	786.1	516.4	330.6	221.7	156.6	86.3

Table 2 (Continued)

Worldwide NMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual				Forecast			
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	1.50	2.00	0	0	0	0	0	0
16K (5-Volt Only)	2.00	2.50	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.08	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	3.90	0	0	0	0	0	0	0
256K	2.30	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.95	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	NA	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	2.09	3.02	3.27	2.22	2.12	2.22	2.31	2.35

NA=Not available
Source: Dataquest (June 1990)

Table 3

Worldwide CMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual				Forecast			
	1987	1988	1989	1990	1991	1992	1993	1994
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	0	4	0	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	169	357	488	232	141	99	72	45
1Mb	637	3,384	6,446	4,552	5,131	4,321	3,710	2,919
4Mb	0	7	231	716	2,513	6,245	9,627	10,464
16Mb	0	0	0	0	0	220	1,950	5,075
Total Dollars	806	3,753	7,166	5,499	7,785	10,885	15,360	18,502
Percent Change from Previous Year	342%	366%	91%	(23%)	42%	40%	41%	20%

	1987	1988	1989	1990	1991	1992	1993	1994
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	0.1	2.5	0.2	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	53.6	117.2	163.8	116.5	77.8	52.8	38.0	22.3
1Mb	42.6	200.5	473.7	697.1	970.0	931.2	824.5	715.4
4Mb	0	0	1.9	21.2	119.2	420.0	865.0	1,200.0
16Mb	0	0	0	0	0	2.0	30.0	145.0
Total Units	96.3	320.2	639.5	834.7	1,167.0	1,406.0	1,757.5	2,082.7

(Continued)

Table 3 (Continued)

Worldwide CMOS DRAM Forecast Revenue, Unit Shipments, ASP (1987-1994)

	Actual					Forecast		
	1987	1988	1989	1990	1991	1992	1993	1994
Average Selling Price (Dollars/Unit)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3 Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.25	1.50	1.72	1.45	1.48	1.49	1.52	1.55
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	3.15	3.05	2.98	1.99	1.81	1.87	1.90	2.00
1Mb	14.95	16.88	13.61	6.53	5.29	4.64	4.50	4.08
4Mb	0	460.00	122.90	33.77	21.08	14.87	11.13	8.72
16Mb	NA	NA	NA	NA	300.00	110.00	65.01	35.00
Overall ASP	8.37	11.72	11.21	6.59	6.67	7.74	8.74	8.88

NA=Not available
Source: Dataquest (June 1990)

Compared with the previous forecast, unit shipments for 1990, 1991, and 1992 decreased by 29.8 million units, 1.3 million units, and 36.8 million units, respectively.

The compound annual growth rate (CAGR) for revenue from 1986 to 1994 is expected to be 31.8 percent, compared with the previous forecast of 32.1 percent CAGR during the period from 1986 through 1992. DRAM revenue from 1990 to 1994 is expected to grow at a 29.5 percent CAGR. Revenue for 1990 has been increased by 3.6 percent over the previous forecast, but will drop by 32.0 percent from the previous year. This large decrease is due to sharp declines in ASPs and reduced shipment volumes during the later part of 1989 and first part of 1990.

Major Factors Supporting this Forecast

Major factors supporting Dataquest's current DRAM forecast include the following:

- Industry slowdown from mid-1988 through mid-1990
- Continuing market dominance by the Japanese
- Increasing market share of non-Japanese vendors
- Movement of manufacturing to North America and Europe
- High cost and difficulty of submicron technology
- Continued political influences in the market
- Unification of Europe in 1992
- No major influence on market by new applications

The Short-Term Outlook

The mid-1989 downturn, predicted by Dataquest in the August 1988 forecast, occurred as expected. Prices dropped as the industry entered the slowdown, even though prices had been sustained at unhistorically high levels since the implementation of the foreign market value (FMV) system during 1987. Prices are expected to continue to decline through the first half of 1990, but ASP declines are expected to slow down, returning to more historical patterns, during the latter part of the year when user demand picks up. Momentary price increases could occur during the second half of 1990 if manufacturers do not increase production volumes fast enough to support increasing user demand.

As a result of recent declines in 1Mb prices during late 1989 and early 1990, the 4Mb price crossover (4X unit price of 1Mb) is not expected to occur until the first quarter of 1991. This delayed crossover will impede the growth of the 4Mb DRAM market during 1990.

The Long-Term Outlook

Dataquest forecasts a decline in DRAM unit growth of negative 5.2 percent during 1990, moderate growth during 1991 and 1992, and strong growth during 1993. Unit shipment growth will not be as rapid; quadrupling of chip densities will cause unit shipments to grow at a slower rate. Bit growth during 1990 is forecast at 31.0 percent, but it will average 70.0 percent per year from 1991 through 1994.

The major driver of bit growth will continue to be the increased pervasiveness of memory. High-bit-usage applications, such as HDTV, are not expected to have a significant influence on the DRAM market until after 1994. However, Dataquest believes that more specialty and intelligent memories will emerge. Video RAMs, frame/field buffers, and wide-word memories are in production today, and other specialty DRAMs such as cached DRAMs and high-speed nonmultiplexed DRAMs have been introduced. The integration of complete systems on a single chip, including large-size DRAM memory storage, is expected within the decade.

DRAM—Forecast

SUMMARY

Dataquest projects dramatic changes in the prices and product life cycles of dynamic RAMs. The major trends that will affect these changes are as follows:

- Healthy but slower bit growth
- The next "silicon cycle" downturn
- The high cost and difficulty of submicron technology
- Continuing political influences in the market
- The strong yen versus the dollar

Bit growth will be driven primarily by increased pervasiveness, which we forecast to grow at a 67 percent compound annual growth rate (CAGR) from 1987 to 1992. With the slow bit growth and increasing chip density, unit shipments are projected to grow slowly at a 1987 to 1992 CAGR of 11 percent. However, revenue is expected to grow rapidly because of the relatively higher price levels brought about by submicron products and as a result of political intervention.

FORECAST TABLES

The DRAM forecast for 1988 through 1992 and a three-year historical perspective for 1985 through 1987 are presented in Tables 1 through 3. Revenue in dollars, unit shipments, and the average selling price are forecast for each DRAM density.

- Table 1—Worldwide DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992
- Table 2—Worldwide NMOS DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992
- Table 3—Worldwide CMOS DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992

DRAM--Forecast

Table 1

Worldwide DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	24	16	3	2	0	0	0	0
16K (5-Volt Only)	23	13	3	3	3	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	530	397	165	210	120	34	25	18
128K (2-Chip Package)	141	52	12	0	0	0	0	0
256K	868	1,432	1,808	2,673	1,764	1,150	720	456
1Mb	5	134	637	2,763	4,352	3,893	3,910	3,501
4Mb	0	0	0	5	148	1,338	3,517	6,485
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	3	383
Total	1,591	2,044	2,628	5,656	6,383	6,415	8,175	10,843
Percent Change from Previous Year	(55%)	29%	29%	115%	13%	0	27%	33%

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	20.0	12.0	2.0	1.0	0	0	0	0
16K (5-Volt Only)	15.0	8.0	1.5	1.0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	481.5	382.0	152.6	140.0	74.8	19.9	14.0	10.0
128K (2-Chip Package)	28.0	12.0	3.0	0	0	0	0	0
256K	237.9	620.0	766.3	900.0	720.0	500.0	300.0	190.0
1Mb	0	4.3	42.6	190.0	533.3	817.8	980.0	900.0
4Mb	0	0	0	0	2.2	43.2	204.9	560.0
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.5
Total	782.4	1,038.3	968.0	1,232.0	1,330.3	1,380.9	1,498.9	1,664.5

N/A = Not Available

(Continued)

Table 1 (Continued)

Worldwide DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1985	1986	1987	1988	1989	1990	1991	1992
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	1.20	1.35	1.50	2.00	0	0	0	0
16K (5-Volt Only)	1.50	1.65	2.00	2.50	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.10	1.04	1.08	1.50	1.60	1.70	1.75	1.75
128K (2-Chip Package)	5.05	4.30	3.90	0	0	0	0	0
256K	3.65	2.31	2.36	2.97	2.45	2.30	2.40	2.40
1Mb	162.50	31.11	14.95	14.54	8.16	4.76	3.99	3.89
4Mb	0	0	0	217.50	67.09	30.98	17.16	11.58
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	300.00	85.00
Overall ASP	2.03	1.97	2.71	4.59	4.80	4.65	5.45	6.30 6.31

Note: Columns may not add to totals shown because of rounding.
N/A = Not Available

Source: Dataquest
August 1988

Table 2

Worldwide NMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	24	16	3	2	0	0	0	0
16K (5-Volt Only)	23	13	3	3	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	525	397	164	210	119	34	24	17
128K (2-Chip Package)	141	52	12	0	0	0	0	0
256K	835	1,384	1,635	2,329	1,489	938	585	371
1Mb	0	4	14	108	87	39	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total	1,548	1,864	1,831	2,651	1,695	1,010	609	388
Percent Change from Previous Year	(56%)	20%	(2%)	45%	(36%)	(40%)	(40%)	(36%)

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	20.0	12.0	2.0	1.0	0	0	0	0
16K (5-Volt Only)	15.0	8.0	1.5	1.0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	479.6	380.9	152.3	139.7	74.7	19.9	14.0	10.0
128K (2-Chip Package)	28.0	12.0	3.0	0	0	0	0	0
256K	232.9	602.6	711.1	823.5	655.2	450.0	270.0	171.0
1Mb	0	0.1	0.9	7.4	10.7	8.2	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total	775.5	1,015.6	870.9	972.6	740.5	478.0	284.0	181.0

(Continued)

Table 2 (Continued)

Worldwide NMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1985	1986	1987	1988	1989	1990	1991	1992
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	1.20	1.35	1.50	2.00	0	0	0	0
16K (5-Volt Only)	1.50	1.65	2.00	2.50	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.10	1.04	1.08	1.50	1.60	1.70	1.75	1.75
128K (2-Chip Package)	5.05	4.30	3.90	0	0	0	0	0
256K	3.58	2.30	2.30	2.83	2.27	2.08	2.17	2.17
1Mb	162.50	37.91	14.95	14.54	8.16	4.76	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Overall ASP	2.00	1.84	2.10	2.73	2.29	2.11	2.15	2.14

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

Source: Dataquest
August 1988

Table 3

Worldwide CMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	4	2	0	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	34	48	174	344	275	213	135	86
1Mb	5	130	623	2,655	4,265	3,854	3,910	3,501
4Mb	0	0	0	5	148	1,338	3,517	6,485
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	3	383
Total	43	180	797	3,005	4,688	5,405	7,565	10,455
Percent Change from Previous Year	120%	320%	343%	277%	56%	15%	40%	38%

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.9	1.1	0.3	0.3	0.1	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	5.0	17.4	55.2	76.5	64.8	50.0	30.0	19.0
1Mb	0	4.2	41.7	182.6	522.6	809.6	980.0	900.0
4Mb	0	0	0	0	2.2	43.2	204.9	560.0
16Mb	0	0	0	0	0	0	0	4.5
Total	7.0	22.7	97.1	259.4	589.8	902.9	1,214.9	1,483.5

N/A = Not Available

(Continued)

Table 3 (Continued)

Worldwide CMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1985	1986	1987	1988	1989	1990	1991	1992
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	2.25	2.05	1.25	1.75	2.00	2.00	2.00	2.00
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	6.75	2.75	3.15	4.50	4.25	4.25	4.50	4.50
1Mb	162.50	30.95	14.95	14.54	8.16	4.76	3.99	3.89
4Mb	0	0	0	217.50	67.09	30.98	17.16	11.58
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	300.00	85.00
Overall ASP	6.16	7.93	8.20	11.58	7.95	5.99	6.22	6.81

Note: Columns may not add to totals shown because of rounding.
N/A = Not Available

Source: Dataquest
August 1988

DRAM—Forecast

Comparison with Earlier Forecasts

Dataquest's last published forecast for the DRAM market was dated April 1987. The changes from the last forecast are the following:

- The 1986 actual revenue, unit shipments, and average selling prices have been adjusted to reflect the final numbers completed by the middle of 1987.

- Actual 1987 bit shipments fell 14 percent below that forecast in April 1987 because of the unanticipated production cuts MITI imposed on Japanese DRAM manufacturers in the first half of 1987 and the poor yields and slow capacity buildup of the 1Mb DRAM.

- With the poor production results of the 1Mb DRAM, the 1987 product mix was more concentrated on the 256K DRAM rather than the 1Mb DRAM or the 64K DRAM.

- With the intervention of several political institutions such as the foreign market value (FMV) system and the MITI demand monitoring scheme, we no longer expect prices to drop as readily as we did in April 1987. The FMV system essentially sets a safety net for rapidly falling prices while MITI measures the level of excess capacity on a quarterly basis. The effect is relatively higher prices through 1992 that will more closely follow cost and FMV patterns.

FORECAST HIGHLIGHTS

The highlights of this forecast are as follows:

- Bit growth will be slower in the next five years than in the past. Bits are expected to grow at a 67 percent CAGR from 1987 through 1992. Slower electronic equipment growth and the lack of new, high-bit-usage applications will cause the slowing DRAM bit growth. The major driver of bit growth will be increased pervasiveness or more memory bits per system. For example, the new personal computers have memory capacities of 1 to 2 megabytes that can be upgraded to 4 to 6 megabytes with the growing popularity of new operating systems such as the OS/2 and the Macintosh II.

- Unit shipment growth will not be as rapid. The slower bit growth combined with quadrupling chip densities will cause unit shipments to grow at a projected 11 percent CAGR.

DRAM--Forecast

- The average selling prices are forecast to be at higher levels. Historically, DRAM prices have followed market conditions with little regard to manufacturing cost. This forecast predicts that prices will begin to follow costs more closely and will begin to fluctuate with market demand. Several factors will contribute to this, including the following:

  - Political influences will control the rapid decline of DRAM prices by monitoring costs and excess capacity.

  - Submicron products will require significantly greater capital investment and will cost more to manufacturer. A concern for profit margins will be necessary to recoup the high investment and to accumulate funds to move into the next-generation technology.

  - With the Japanese companies dominating the DRAM market, the strong yen will constrain their pricing flexibility.

- The historical decline in price per bit is expected to be broken for the first time. It is expected to rise in 1988. Beyond that, the price per bit will continue to decline despite the higher price levels of submicron DRAMs. This means that, on a cost-per-bit basis, next-generation DRAMs will continue to be more cost effective than preceding ones, despite the fact that their prices do not drop to extremely low levels.

- Revenue is expected to grow at a 32 percent CAGR from 1987 through 1992, fueled primarily by the higher prices.

- CMOS technology will begin to dominate over NMOS technology as submicron products come into their own. At the 256K DRAM level, more CMOS DRAMs are becoming available with speeds that surpass those of NMOS DRAMs.

SHORT-TERM OUTLOOK

Dataquest believes that the DRAM shortage will last at least through the end of 1988. However, DRAM availability will continue to increase through the year. Prices will stay relatively high: 256K DRAM prices will rise from $2.36 in 1987 to $2.97 in 1988 and 1Mb DRAM prices will remain firm in 1988. However, there are signs of relief. Dataquest believes that there will be adequate physical capacity of 1Mb DRAMs by the second half of 1988 and enough in 1989. Should demand slow, supply could exceed demand in the first half of 1989.

Based on economic forecasts and studies of the "silicon cycle," Dataquest expects a mild downturn in the latter half of 1989, spilling over into 1990. Although unit shipments will still be robust, prices will be lower. The foreign market values recently assigned to companies will allow the forecast price drops in 1989.

DRAM--Forecast

LONG-TERM OUTLOOK

During the forecast period, new applications are not likely to contribute heavily to DRAM bits, except for graphic memory. These new applications—silicon disks, digital television, and speech recording--will emerge beyond 1992. Dataquest believes that these new markets will cause a huge increase in DRAM bit growth in the next decade. These applications will need specialized features such as video RAMs, frame memory, line memory, and field memory incorporated into DRAM memory. Each application will be attractive for specialized products because of the anticipated consumption volume.

DRAM—Forecast

SUMMARY

Dataquest projects dramatic changes in the prices and product life cycles of dynamic RAMs. The major trends that will affect these changes are as follows:

- Healthy but slower bit growth
- The next "silicon cycle" downturn
- The high cost and difficulty of submicron technology
- Continuing political influences in the market
- The strong yen versus the dollar

Bit growth will be driven primarily by increased pervasiveness, which we forecast to grow at a 67 percent compound annual growth rate (CAGR) from 1987 to 1992. With the slow bit growth and increasing chip density, unit shipments are projected to grow slowly at a 1987 to 1992 CAGR of 11 percent. However, revenue is expected to grow rapidly because of the relatively higher price levels brought about by submicron products and as a result of political intervention.

FORECAST TABLES

The DRAM forecast for 1988 through 1992 and a three-year historical perspective for 1985 through 1987 are presented in Tables 1 through 3. Revenue in dollars, unit shipments, and the average selling price are forecast for each DRAM density.

- Table 1—Worldwide DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992
- Table 2—Worldwide NMOS DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992
- Table 3—Worldwide CMOS DRAM Forecast
  Revenue, Unit Shipments, Average Selling Price
  1985 through 1992

Table 1

Worldwide DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	24	16	3	2	0	0	0	0
16K (5-Volt Only)	23	13	3	3	3	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	530	397	165	210	120	34	25	18
128K (2-Chip Package)	141	52	12	0	0	0	0	0
256K	868	1,432	1,808	2,673	1,764	1,150	720	456
1Mb	5	134	637	2,763	4,352	3,893	3,910	3,501
4Mb	0	0	0	5	148	1,338	3,517	6,485
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	3	383
Total	1,591	2,044	2,628	5,656	6,383	6,415	8,172	10,459
Percent Change from Previous Year	(55%)	29%	29%	115%	13%	0	27%	28%

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	20.0	12.0	2.0	1.0	0	0	0	80.0
16K (5-Volt Only)	15.0	8.0	1.5	1.0	0	0	0	40.0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	481.5	382.0	152.6	140.0	74.8	19.9	14.0	10.0
128K (2-Chip Package)	28.0	12.0	3.0	0	0	0	0	0
256K	237.9	620.0	766.3	900.0	720.0	500.0	300.0	190.0
1Mb	0	4.3	42.6	190.0	533.3	817.8	980.0	900.0
4Mb	0	0	0	0	2.2	43.2	204.9	560.0
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.5
Total	782.4	1,038.3	968.0	1,232.0	1,330.3	1,380.9	1,498.9	1,660.0

N/A = Not Available

(Continued)

Table 1 (Continued)

Worldwide DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1984	1985	1986	1987	1988	1989	1990	1991
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	1.20	1.35	1.50	2.00	0	0	0	0
16K (5-Volt Only)	1.50	1.65	2.00	2.50	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.10	1.04	1.08	1.50	1.60	1.70	1.75	1.75
128K (2-Chip Package)	5.05	4.30	3.90	0	0	0	0	0
256K	3.65	2.31	2.36	2.97	2.45	2.30	2.40	2.40
1Mb	162.50	31.11	14.95	14.54	8.16	4.76	3.99	3.89
4Mb	0	0	0	217.50	67.09	30.98	17.16	11.58
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	300.00	85.00
Overall ASP	2.03	1.97	2.71	4.59	4.80	4.65	5.45	6.30

Note: Columns may not add to totals shown because of rounding.
N/A = Not Available

Source: Dataquest
May 1988

Table 2

Worldwide NMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	24	16	3	2	0	0	0	0
16K (5-Volt Only)	23	13	3	3	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	525	397	164	210	119	34	24	17
128K (2-Chip Package)	141	52	12	0	0	0	0	0
256K	835	1,384	1,635	2,329	1,489	938	585	371
1Mb	0	4	14	108	87	39	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Total	1,548	1,864	1,831	2,651	1,695	1,010	609	388
Percent Change from Previous Year	(56%)	20%	(2%)	45%	(36%)	(40%)	(40%)	(36%)

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	20.0	12.0	2.0	1.0	0	0	0	0
16K (5-Volt Only)	15.0	8.0	1.5	1.0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	479.6	380.9	152.3	139.7	74.7	19.9	14.0	10.0
128K (2-Chip Package)	28.0	12.0	3.0	0	0	0	0	0
256K	232.9	602.6	711.1	823.5	655.2	450.0	270.0	171.0
1Mb	0	0.1	0.9	7.4	10.7	8.2	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	4.5
Total	775.5	1,015.6	870.9	972.6	740.5	478.0	284.0	181.0

(Continued)

Table 2 (Continued)

Worldwide NMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1984	1985	1986	1987	1988	1989	1990	1991
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	1.20	1.35	1.50	2.00	0	0	0	0
16K (5-Volt Only)	1.50	1.65	2.00	2.50	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.10	1.04	1.08	1.50	1.60	1.70	1.75	1.75
128K (2-Chip Package)	5.05	4.30	3.90	0	0	0	0	0
256K	3.58	2.30	2.30	2.83	2.27	2.08	2.17	2.17
1Mb	162.50	37.91	14.95	14.54	8.16	4.76	0	0
4Mb	0	0	0	0	0	0	0	0
16Mb	0	0	0	0	0	0	0	0
Overall ASP	2.00	1.84	2.10	2.73	2.29	2.11	2.15	2.14

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

Source: Dataquest
May 1988

Table 3

Worldwide CMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	Actual			Forecast				
	1985	1986	1987	1988	1989	1990	1991	1992
Value ($M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	4	2	0	0	0	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	34	48	174	344	275	213	135	86
1Mb	5	130	623	2,655	4,265	3,854	3,910	3,501
4Mb	0	0	0	5	148	1,338	3,517	6,485
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	3	383
Total	43	180	797	3,005	4,688	5,405	7,562	10,071
Percent Change from Previous Year	120%	320%	343%	277%	56%	15%	40%	33%

	1985	1986	1987	1988	1989	1990	1991	1992
Units (M)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	1.9	1.1	0.3	0.3	0.1	0	0	0
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	5.0	17.4	55.2	76.5	64.8	50.0	30.0	19.0
1Mb	0	4.2	41.7	182.6	522.6	809.6	980.0	900.0
4Mb	0	0	0	0	2.2	43.2	204.9	560.0
16Mb	0	0	0	0	0	0	0	4.5
Total	7.0	22.7	97.1	259.4	589.8	902.9	1,215.0	1,479.0

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(Continued)

Table 3 (Continued)

Worldwide CMOS DRAM Forecast
Revenue, Unit Shipments, Average Selling Price
1985 through 1992

	1984	1985	1986	1987	1988	1989	1990	1991
Average Selling Price (Dollars/Units)								
1K	0	0	0	0	0	0	0	0
4K	0	0	0	0	0	0	0	0
16K (3-Power Supply)	0	0	0	0	0	0	0	0
16K (5-Volt Only)	0	0	0	0	0	0	0	0
32K (2-Chip Package)	0	0	0	0	0	0	0	0
64K	2.25	2.05	1.25	1.75	2.00	2.00	2.00	2.00
128K (2-Chip Package)	0	0	0	0	0	0	0	0
256K	6.75	2.75	3.15	4.50	4.25	4.25	4.50	4.50
1Mb	162.50	30.95	14.95	14.54	8.16	4.76	3.99	3.89
4Mb	0	0	0	217.50	67.09	30.98	17.16	11.58
16Mb	N/A	N/A	N/A	N/A	N/A	N/A	300.00	85.00
Overall ASP	6.16	7.93	8.20	11.58	7.95	5.99	6.22	6.81

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Comparison with Earlier Forecasts

Dataquest's last published forecast for the DRAM market was dated April 1987. The changes from the last forecast are the following:

- The 1986 actual revenue, unit shipments, and average selling prices have been adjusted to reflect the final numbers completed by the middle of 1987.
- Actual 1987 bit shipments fell 14 percent below that forecast in April 1987 because of the unanticipated production cuts MITI imposed on Japanese DRAM manufacturers in the first half of 1987 and the poor yields and slow capacity buildup of the 1Mb DRAM.
- With the poor production results of the 1Mb DRAM, the 1987 product mix was more concentrated on the 256K DRAM rather than the 1Mb DRAM or the 64K DRAM.
- With the intervention of several political institutions such as the foreign market value (FMV) system and the MITI demand monitoring scheme, we no longer expect prices to drop as readily as we did in April 1987. The FMV system essentially sets a safety net for rapidly falling prices while MITI measures the level of excess capacity on a quarterly basis. The effect is relatively higher prices through 1992 that will more closely follow cost and FMV patterns.

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The highlights of this forecast are as follows:

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DRAM--Forecast

- The average selling prices are forecast to be at higher levels. Historically, DRAM prices have followed market conditions with little regard to manufacturing cost. This forecast predicts that prices will begin to follow costs more closely and will begin to fluctuate with market demand. Several factors will contribute to this, including the following:
  - Political influences will control the rapid decline of DRAM prices by monitoring costs and excess capacity.
  - Submicron products will require significantly greater capital investment and will cost more to manufacturer. A concern for profit margins will be necessary to recoup the high investment and to accumulate funds to move into the next-generation technology.
  - With the Japanese companies dominating the DRAM market, the strong yen will constrain their pricing flexibility.
- The historical decline in price per bit is expected to be broken for the first time. It is expected to rise in 1988. Beyond that, the price per bit will continue to decline despite the higher price levels of submicron DRAMs. This means that, on a cost-per-bit basis, next-generation DRAMs will continue to be more cost effective than preceding ones, despite the fact that their prices do not drop to extremely low levels.
- Revenue is expected to grow at a 32 percent CAGR from 1987 through 1992, fueled primarily by the higher prices.
- CMOS technology will begin to dominate over NMOS technology as submicron products come into their own. At the 256K DRAM level, more CMOS DRAMs are becoming available with speeds that surpass those of NMOS DRAMs.

SHORT-TERM OUTLOOK

Dataquest believes that the DRAM shortage will last at least through the end of 1988. However, DRAM availability will continue to increase through the year. Prices will stay relatively high: 256K DRAM prices will rise from $2.36 in 1987 to $2.97 in 1988 and 1Mb DRAM prices will remain firm in 1988. However, there are signs of relief. Dataquest believes that there will be adequate physical capacity of 1Mb DRAMs by the second half of 1988 and enough in 1989. Should demand slow, supply could exceed demand in the first half of 1989.

Based on economic forecasts and studies of the "silicon cycle," Dataquest expects a mild downturn in the latter half of 1989, spilling over into 1990. Although unit shipments will still be robust, prices will be lower. The foreign market values recently assigned to companies will allow the forecast price drops in 1989.

LONG-TERM OUTLOOK

During the forecast period, new applications are not likely to contribute heavily to DRAM bits, except for graphic memory. These new applications—silicon disks, digital television, and speech recording—will emerge beyond 1992. Dataquest believes that these new markets will cause a huge increase in DRAM bit growth in the next decade. These applications will need specialized features such as video RAMs, frame memory, line memory, and field memory incorporated into DRAM memory. Each application will be attractive for specialized products because of the anticipated consumption volume.

DRAM--Forecast

OVERVIEW OF THE DYNAMIC RAM MARKET

The dynamic RAM (DRAM) has historically been the most visible memory IC because of its market size and its role in driving process technology into finer geometries. Highlights of this market include:

- In 1986, the dynamic RAM market achieved total revenue of $2.1 billion, which translates to 47 percent of the MOS memory market.

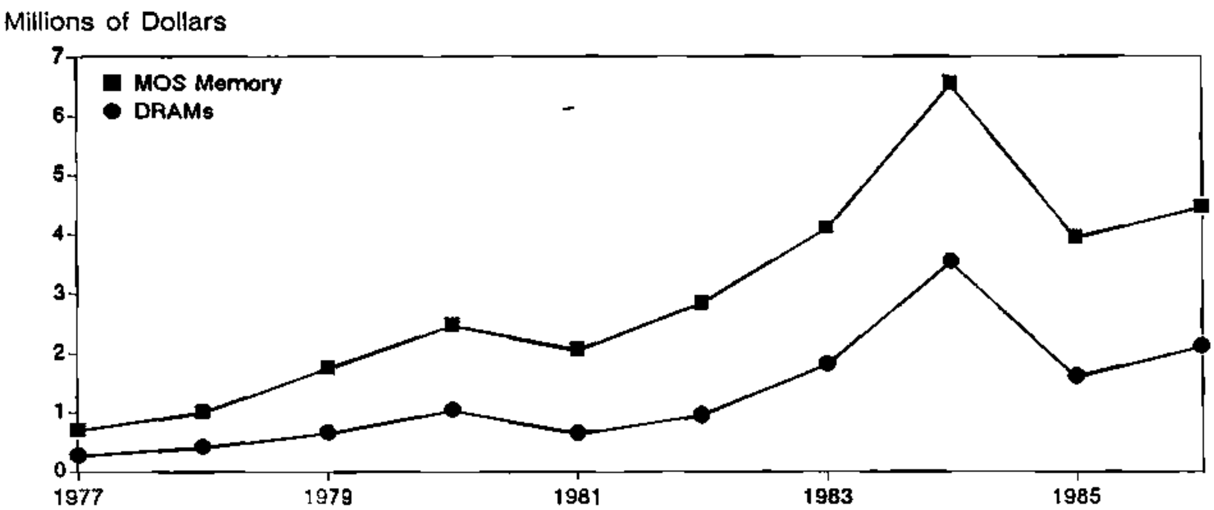
- This market grew at a compound annual growth rate (CAGR) of 12.6 percent from 1980 to 1986 versus a MOS memory CAGR of 10.3 percent, making the DRAM market a truly attractive market in which to participate. Total revenue hit a high of $3.5 billion in 1984 but has declined since due to a slow market and severe price declines.

- A quadrupling of density every three years and the increased use of these higher densities has fueled the growth of the DRAM market. DRAM bits have grown at a CAGR of 78.8 percent since 1980 and reached 196 trillion bits in 1986.

Figure 1 shows the growth of the DRAM market relative to the total MOS memory market. The MOS memory market displays the same pattern as the DRAM market because it is heavily influenced by that device.

Figure 1

MOS MEMORY AND DRAM MARKET
1977-1986



Source: Dataquest
April 1987

DRAM--Forecast

THE DRAM MARKET FORECAST

Dataquest presents the DRAM market forecast from 1987 to 1991 with the following tables:

- Table 1--Worldwide MOS DRAM Market Forecast (Revenue, Units, and Average Selling Price)
- Table 2--Worldwide NMOS DRAM Market Forecast (Revenue, Units, and Average Selling Price)
- Table 3--Worldwide CMOS DRAM Market Forecast (Revenue, Units, and Average Selling Price)

Despite the decline from record revenue in 1984, Dataquest expects a healthy growth of the DRAM market in the future. As in the past, growth will come from the entry and acceptance of 1Mb and 4Mb DRAMs and the emergence of graphics applications for the Multiport Video RAM. Highlights of this forecast are:

- The DRAM market is expected to reach $4.4 billion by 1991 from its present level of $2.1 billion in 1986.
- The market is projected to grow at a CAGR of 15.7 percent from 1986 to 1991. This is a healthy rate compared to the MOS memory CAGR of 15.3 percent for the same period.
- The higher densities--the 1Mb and 4Mb DRAMs--will be the main source of growth, contributing 57.9 percent of total DRAM revenue in 1988 and 93.6 percent in 1991.
- Dataquest anticipates a mild downturn in overall semiconductor business in 1989, based on projections of historical business cycles in the industry.
- The price-per-bit of the 1Mb DRAM is expected to cross over that of the 256K SRAM in the first quarter of 1988, making the 1Mb the most cost-effective DRAM in that year. The price per bit of the 4Mb DRAM is expected to cross over that of the 1Mb DRAM in 1991.
- CMOS DRAMs will dominate the 1Mb and higher densities even if their penetration of the lower-density market is minimal.

DRAM--Forecast

Table 1

TOTAL MOS DRAM MARKET FORECAST

	Value (Millions of Dollars)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	0	0	0	0	0	0	0	0
4K	$ 3	0	0	0	0	0	0	0
16K (3-Power Supply)	88	$ 24	$ 16	$ 3	0	0	0	0
16K (5-Volt Only)	78	23	13	3	0	0	0	0
32K (2-Chip Package)	38	0	0	0	0	0	0	0
64K	2,599	531	418	246	$ 151	$ 92	$ 25	$ 18
128K (2-Chip Package)	40	141	52	11	0	0	0	0
256K	694	869	1,426	1,518	1,268	772	366	262
1Mb	0	3	176	686	1,938	2,037	2,338	1,680
4Mb	0	0	0	0	13	210	750	2,400
Total	$3,540	$1,591	$2,101	$2,467	$3,370	$3,111	$3,479	$4,360
Percent Change from Previous Year	96%	(55%)	32%	17%	37%	(8%)	12%	25%

	Units (Millions)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	0	0	0	0	0	0	0	0
4K	1.0	0	0	0	0	0	0	0
16K (3-Power Supply)	80.0	20.0	12.0	2.0	0	0	0	0
16K (5-Volt Only)	40.0	15.0	8.0	1.5	0	0	0	0
32K (2-Chip Package)	10.0	0	0	0	0	0	0	0
64K	836.8	481.5	404.9	223.0	130.0	74.8	19.9	14.0
128K (2-Chip Package)	5.0	28.0	12.0	3.0	0	0	0	0
256K	39.6	237.9	617.1	850.1	750.1	550.0	300.0	220.0
1Mb	0	0	5.7	55.0	350.1	680.0	975.0	820.0
4Mb	0	0	0	0	0.1	6.0	60.0	400.0
Total	1,012.4	782.4	1,059.7	1,134.6	1,230.3	1,310.8	1,354.9	1,454.0

	Average Selling Price (Dollars/Units)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	$ 3.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K (3-Power Supply)	$ 1.10	$ 1.20	$ 1.35	$ 1.50	N/A	N/A	N/A	N/A
16K (5-Volt Only)	$ 1.95	$ 1.50	$ 1.65	$ 2.00	N/A	N/A	N/A	N/A
32K (2-Chip Package)	$ 3.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A
64K	$ 3.11	$ 1.10	$ 1.03	$ 1.10	$ 1.16	$ 1.23	$ 1.25	$1.30
128K (2-Chip Package)	$ 8.00	$ 5.05	$ 4.30	$ 3.50	N/A	N/A	N/A	N/A
256K	$17.55	$ 3.65	$ 2.31	$ 1.79	$ 1.69	$ 1.40	$ 1.22	$1.19
1Mb	N/A	$162.50	$30.95	$12.48	$ 5.54	$ 3.00	$ 2.40	$2.05
4Mb	N/A	N/A	N/A	N/A	$125.00	$35.00	$12.50	$6.00
Overall ASP	$ 3.50	$ 2.03	$ 1.98	$ 2.17	$ 2.74	$ 2.37	$ 2.57	$3.00

N/A = Not Available

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

Source: Dataquest
April 1987

DRAM--Forecast

Table 2

NMOS DRAM MARKET FORECAST

	Value (Millions of Dollars)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	0	0	0	0	0	0	0	0
4K	$ 3	0	0	0	0	0	0	0
16K (3-Power Supply)	88	$ 24	$ 16	$ 3	0	0	0	0
16K (5-Volt Only)	78	23	13	3	0	0	0	0
32K (2-Chip Package)	38	0	0	0	0	0	0	0
64K	2,585	528	416	245	$ 150	$ 92	$ 25	$ 18
128K (2-Chip Package)	40	141	52	11	0	0	0	0
256K	691	842	1,390	1,459	1,221	731	343	245
1Mb	0	1	9	26	44	37	33	24
4Mb	0	0	0	0	0	0	0	0
Total	$3,523	$1,560	$1,896	$1,746	$1,415	$860	$401	$288
Percent Change from Previous Year	95%	(56%)	22%	(8%)	(19%)	(39%)	(53%)	(28%)

	Units (Millions)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K (3-Power Supply)	80.0	20.0	12.0	2.0	N/A	N/A	N/A	N/A
16K (5-Volt Only)	40.0	15.0	8.0	1.5	N/A	N/A	N/A	N/A
32K (2-Chip Package)	10.0	0	N/A	N/A	N/A	N/A	N/A	N/A
64K	834.0	480.0	403.7	222.3	129.6	74.8	19.9	14.0
128K (2-Chip Package)	5.0	28.0	12.0	3.0	0	0	0	0
256K	39.5	234.0	606.9	828.8	731.3	533.5	291.0	213.4
1Mb	N/A	0	0.3	2.2	8.8	13.6	14.6	12.3
4Mb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	1,009.5	777.0	1,042.9	1,059.8	869.7	621.9	325.5	239.7

	Average Selling Price (Dollars/Units)							
	1984	1985	1986	1987	1988	1989	1990	1991
1K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4K	$ 3.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16K (3-Power Supply)	$ 1.10	$ 1.20	$ 1.35	$ 1.50	N/A	N/A	N/A	N/A
16K (5-Volt Only)	$ 1.95	$ 1.50	$ 1.65	$ 2.00	N/A	N/A	N/A	N/A
32K (2-Chip Package)	$ 3.75	N/A	$ N/A	N/A	N/A	N/A	N/A	N/A
64K	$ 3.10	$ 1.10	$ 1.03	$ 1.10	$1.16	$1.23	$1.25	$ 1.3
128K (2-Chip Package)	$ 8.00	$ 5.05	$ 4.30	$ 3.50	N/A	N/A	N/A	N/A
256K	$17.50	$ 3.60	$ 2.29	$ 1.76	$1.67	$1.37	$1.18	$1.15
1Mb	N/A	$125.00	$30.00	$12.00	$5.00	$2.75	$2.25	$1.95
4Mb	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Overall ASP	$ 3.49	$ 2.01	$ 1.82	$ 1.65	$1.63	$1.38	$1.23	$1.20

N/A = Not Available

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

Source: Dataquest April 1987

Table 3

CMOS DRAM MARKET FORECAST

	Value (Millions of Dollars)							
	1984	1985	1986	1987	1988	1989	1990	1991
64K	$14	$ 3	$ 2	$ 1	$ 1	0	0	0
256K	3	26	36	60	47	$ 41	$ 23	$ 17
1Mb	0	2	167	660	1,894	1,999	2,305	1,656
4Mb	0	0	0	0	13	210	750	2,400
Total	$17	$32	$206	$721	$1,955	$2,250	$3,078	$4,073
Percent Change from Previous Year	6,600%	89%	548%	251%	171%	15%	37%	32%

	Units (Millions)							
	1984	1985	1986	1987	1988	1989	1990	1991
64K	2.8	1.5	1.2	0.7	0.4	0	0	0
256K	0.1	3.9	10.2	21.3	18.8	16.5	9.0	6.6
1Mb	N/A	0	5.4	52.8	341.3	666.4	960.4	807.7
4Mb	N/A	N/A	N/A	0	0.1	6.0	60.0	400.0
Total	2.9	5.4	16.8	74.8	360.6	688.9	1,029.4	1,214.3

	Average Selling Price (Dollars/Unit)							
	1984	1985	1986	1987	1988	1989	1990	1991
64K	$ 5.00	$ 2.25	$ 2.05	$ 2.10	$ 2.10	$ 2.10	$ 2.10	$2.10
256K	$55.00	$ 6.75	$ 3.50	$ 2.80	$ 2.50	$ 2.50	$ 2.50	$2.50
1Mb	N/A	$200.00	$31.00	$12.50	$ 5.55	$ 3.00	$ 2.40	$2.05
4Mb	N/A	N/A	N/A	N/A	$125.00	$35.00	$12.50	$6.00
Overall ASP	$ 5.88	$ 5.86	$12.24	$ 9.64	$ 5.42	$ 3.27	$ 2.99	$3.35

N/A = Not Available

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

Source: Dataquest
April 1987

DRAM--Forecast

Comparison with Earlier Forecasts

Tempered optimism characterizes this latest forecast. Despite the declining profitability of DRAMs, 1986 revenue was 8 percent higher than the previous forecast of $1.9 billion. This increase was caused primarily by the large amount of factory shipments of 256K DRAMs. However, Dataquest remains cautious in its outlook for the next five years because of the following factors:

- Although 617 million 256K DRAMs were shipped out of vendor factories, Dataquest believes that not all were consumed.
  - Inventories exist in the distribution channels between manufacturer and user.
  - Dataquest further believes that a significant portion of these 256K DRAMs are still in the hands of nonfranchised distributors or brokers, more commonly referred to as the gray market or the suitcase brigade.
- The U.S.-Japan semiconductor trade arrangement is clearly not working.
  - Despite the foreign market values, the U.S. market prices for 256K DRAMs are substantially lower and have declined through the second half of 1986.
  - Prices in the Pacific Rim have been declining too and are significantly lower than U.S. market prices.
  - The trade friction will continue; if this scheme fails, then another will certainly replace it whether in the form of reinstated tariffs or something else.
- There are efforts to curb the oversupply situation in the market. For example, MITI has strongly suggested that Japanese manufacturers reduce their production of excess supply devices by anywhere between 10 and 20 percent.

The growth of the 1Mb DRAM was less than expected. The product was partially stifled by a high foreign market value (FMV) in the third quarter of 1986. FMVs are determined by the U.S. Department of Commerce in keeping with the U.S.-Japan semiconductor trade arrangement. They act as the effective minimum prices in the U.S. market for DRAMs fabricated in Japan. The FMVs for the 1Mb DRAMs have declined properly since and have renewed design and purchasing activity for this part.

DRAM--Forecast

The Short-Term Outlook

Dataquest expects the excess supply of 256K DRAMs to diminish gradually through 1987 as Japanese production is brought under control voluntarily or through the prodding of MITI. Competition will remain keen, however, U.S. manufacturers are still stepping up production along with the Korean companies. The 256K DRAM is still the most cost-effective device in 1987 and is expected to have a healthy demand.

DRAM business will increase with the modest upturn that is occurring in the industry in the first months of 1987. The 1Mb DRAM designs are projected to proliferate in anticipation of the price-per-bit crossover at the beginning of 1988. Although already slightly exceeding production, purchases for 1Mb DRAMs are expected to pick up significantly in the second half of 1987. Japanese production is expected to focus on the 1Mb DRAMs for reasons of growth and profit.

The Long-Term Outlook

The DRAM market has bright prospects. Along with the growth of 1Mb and 4Mb DRAMs in main memory applications, the Multiport Video RAMs will gain more acceptance and use in graphics applications. Graphics memory requirements are expected to grow with the emergence of highly sophisticated CAD equipment, imaging systems, desktop publishing, and digital TV.

Dataquest expects the 1Mb and 4Mb DRAM markets to be more fragmented than those of previous devices. Besides being more numerous, the choices of organization, functional mode, access time, and packaging will be made available earlier in the life cycles of this product. DRAM manufacturers are already designing manufacturability into their chips to minimize the cost of production of these diverse products. Dataquest believes that users will find these options beneficial to their needs and applications and will reflect this in their consumption of DRAM devices.

DRAM--Products/Suppliers

INTRODUCTION

The product matrix shown in Table 1 can be used to evaluate dynamic RAM (DRAM) products currently being manufactured by DRAM suppliers. The matrix includes the organizational structures for the 64K, 128K, 256K, and 1Mb DRAM densities.

Table 1

DRAM PRODUCT MATRIX

Density	Process	Org'n	Max. Acc. Time (ns)	Operating Modes	No. of Pins	Package	Special Features
64K	NMOS	64Kx1	100	Page	16	DIP	
					18	PLCC	
					18	LCC	
		64Kx1	150		20	DIP	Multiport Video RAM
					22	PLCC	
		16Kx4	100	Page	18	DIP	
					18	LCC	
	CMOS	64Kx1	100	Page	18	DIP	
128K	NMOS	128Kx1	120	Page	16	DIP	
256K	NMOS	256Kx1	80	Page	16	DIP	
				Nibble	18	PLCC	
					16	ZIP	
					18	LCC	
		64Kx4	100	Page	18	DIP	
					18	PLCC	
					20	ZIP	
					18	LCC	
		64Kx4	120	Page	24	DIP	Multiport Video RAM
	CMOS	256Kx1	100	Page	16	DIP	
				Nibble	18	PLCC	
				Static Column	16	ZIP	

(Continued)

Table 1 (Continued)

DRAM PRODUCT MATRIX

Density	Process	Org'n	Max. Acc. Time (ns)	Operating Modes	No. of Pins	Package	Special Features
256K (Cont.)		64Kx4	120	Page	18	DIP	
					18	PLCC	
				•	20	ZIP	
		64Kx4	120		24	DIP	Multiport Video RAM
					18	PLCC	
					24	ZIP	
1Mb	NMOS	1Mbx1	100	Page	18	DIP	
				Nibble	26/20	SOJ	
		256Kx4	100	Page	20	DIP	
					26/20	SOJ	
		256Kx4			40	DIP	Image Memory
	CMOS	1Mbx1	85	Page	18	DIP	
				Fast Page	20	SOJ	
				Nibble	20	ZIP	
				Static Column			
		256Kx4	100	Fast Page	20	DIP	
				Static	20	SOJ	
				Column	20	ZIP	

Source: Dataquest
April 1987

DRAM--Product Life Cycles

OVERVIEW OF PRODUCT LIFE CYCLES

Product life cycles are an important element of a company's strategic planning. The value of this planning extends to both semiconductor memory manufacturers and users alike, in the following ways:

- Manufacturers match their planned product life cycles (say, for a 256K DRAM) with the cycles of the market to determine if the timing of their entry and departure maximizes their revenue and profits.

- Memory users match their system's life with that of its memory components to develop a commodity plan for purchasing and design engineering that maximizes availability of vital components and minimizes cost.

- Manufacturers use life cycles to evaluate the strength of or to make plans for their product portfolios.

- Vendors can also control and alter the life cycle, given a thorough understanding of its behavior.

THE DRAM PRODUCT LIFE CYCLES

Dataquest analyzes three versions of the dynamic RAM (DRAM) product life cycle, all derived from the same data pool but each presenting a different insight, as follows:

- The stage of each group of DRAM devices in the standard product life cycle and the typical interval of each stage

- The actual behavior of the life cycles and how they vary as density increases

- The behavior of the life cycles through time as density increases

An analysis of bit growth is also presented and reflects whether total use of DRAMs is still increasing or is beginning to saturate.

DRAM—Product Life Cycles

The Standard DRAM Product Life Cycle

The typical life cycle for DRAMs is shown in Figure 1. The highlights include:

- The DRAM market is density driven, and the introduction of a higher density greatly influences the growth of current densities.

  - With densities quadrupling every three years, the DRAM product life cycle has a quick ramp stage and a short maturity phase.

  - The nature of this life cycle poses a problem in DRAM manufacturing.

- The DRAM market is also very cost driven and competitive.

  - High-volume production and automation lend well to success, but automated production should also be flexible enough to handle the sudden drop in units after the short maturity stage of the DRAM life cycle.

- With the short ramp and maturity stages, manufacturers must time the payback of their investment with that of the life cycle.

  - The short depreciation schedule for capital equipment in Japan compared with that of the United States fortifies the success of Japanese companies in this market.

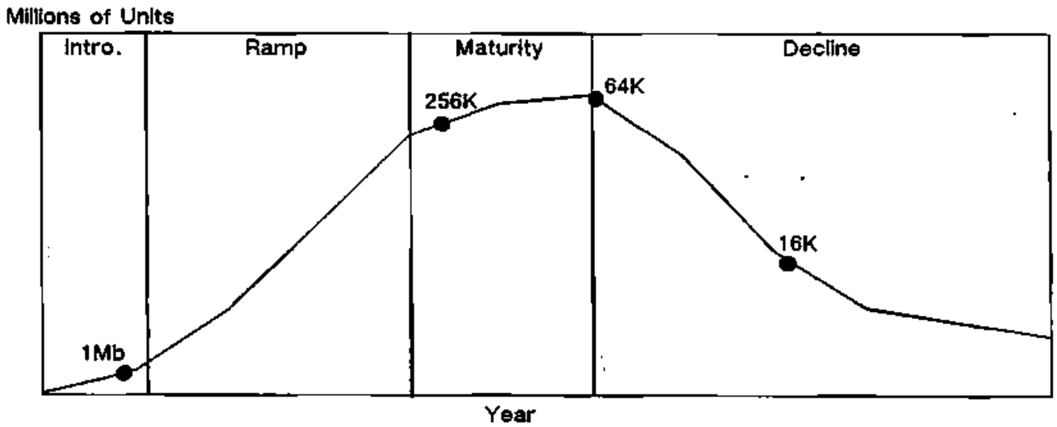
- Because of the sharpness of the peak in their life cycle, DRAMs have a greater chance of being supplied excessively, causing price pressures.

This standard life cycle tells us that success in the DRAM market depends on developing new densities early in the life cycle, manufacturing at low cost, designing flexibility into one's manufacturing scheme, and timing investment payback with the life cycle.

DRAM—Product Life Cycles

Figure 1

TYPICAL DRAM PRODUCT LIFE CYCLES



Stage	Intro.	Ramp	Maturity	Decline
Typical Number of Years	2	3	1-2	5
1986 Products	1Mb	—	256K	64K 16K
1987 Products	—	1Mb	256K	64K 16K
1991 Products	—	4Mb	1Mb	256K 64K

Source: Dataquest
April 1987

The Product Life Cycles by Density

The actual life cycle curves and how they vary by density are illustrated by Figure 2. Highlights include:

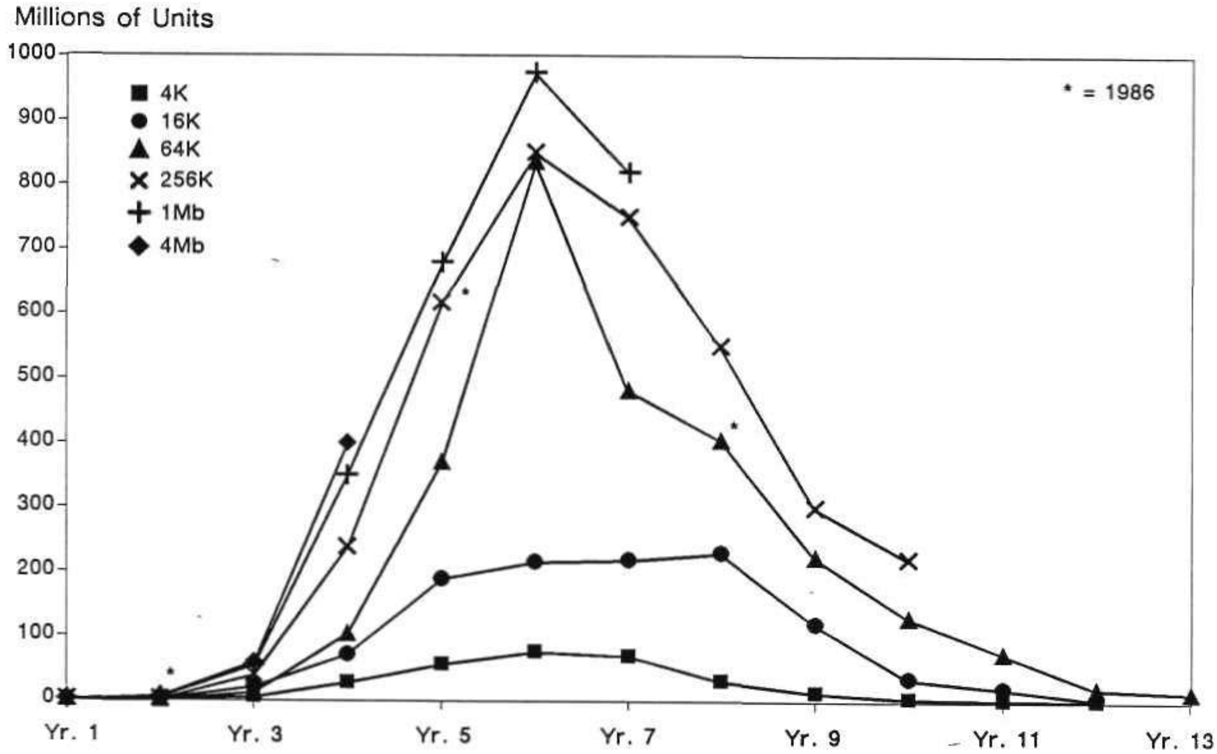
- There is a continuous growth in the peak use of higher densities; the 64K DRAM peak was probably not typical because it occurred in the boom year of 1984.

DRAM--Product Life Cycles

- The maturity stages of earlier densities were much more extended than are the current ones. Since the Japanese domination of the 64K DRAM, production rates of new densities increase more quickly; this puts pressure on the current densities.

Figure 2

DRAM PRODUCT LIFE CYCLES BY DENSITY



Source: Dataquest
April 1987

DRAM--Product Life Cycles

The Product Life Cycles through Time

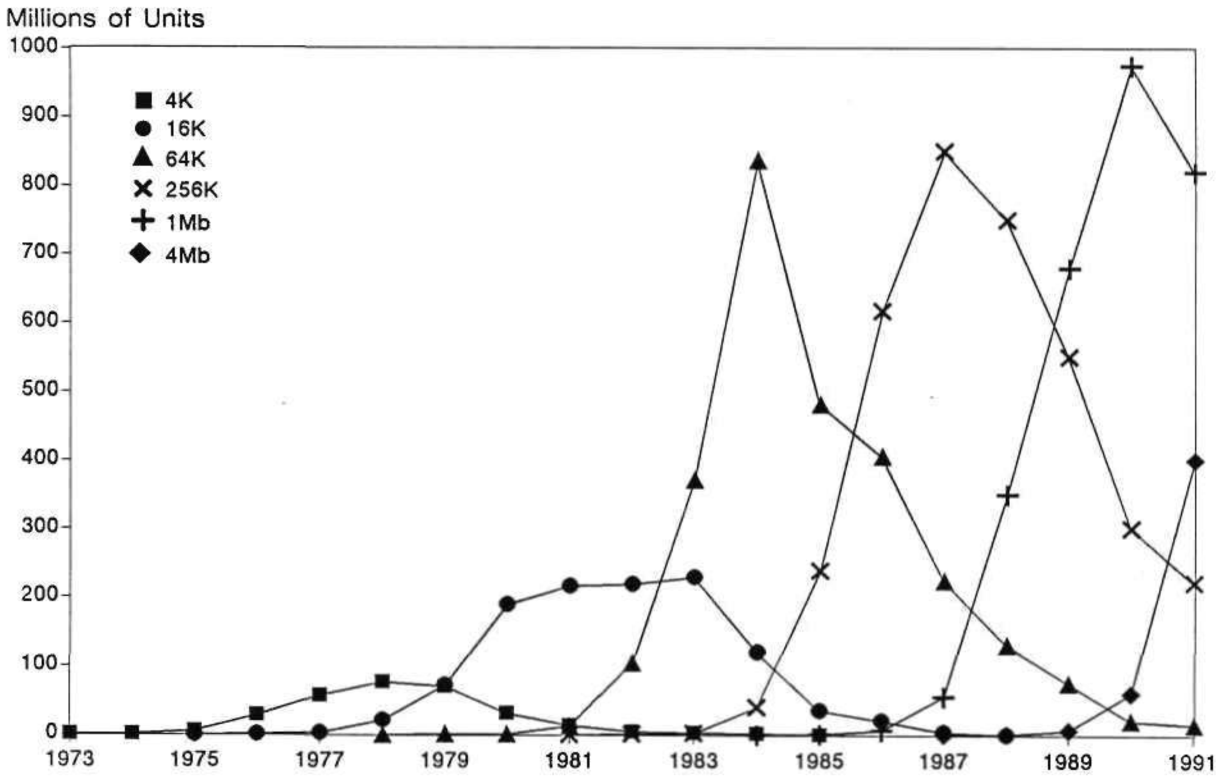
The behavior of each density's life cycle through time is shown in Figure 3. Highlights include:

- The interval between density introductions remains constant at three years. Approaching submicron geometries, new DRAM cell structures have to be applied, and packaging standards become critical issues that need to be addressed.

- The peaks of succeeding densities are not increasing as substantially.

Figure 3

DRAM PRODUCT LIFE CYCLES THROUGH TIME



Source: Dataquest
April 1987

DRAM--Product Life Cycles

BIT-GROWTH ANALYSIS

Bit-growth analysis looks at the life cycle of the whole DRAM product line. So far, discussions have been limited to life cycles of individual devices within the DRAM family. Figure 4 shows the actual and projected growth in bits from 1973 to 1991.

- DRAM bits increased 10 times every three years up to an average density use of 256K bits. That growth is expected to slow down slightly, approaching an average density use of 1Mb.

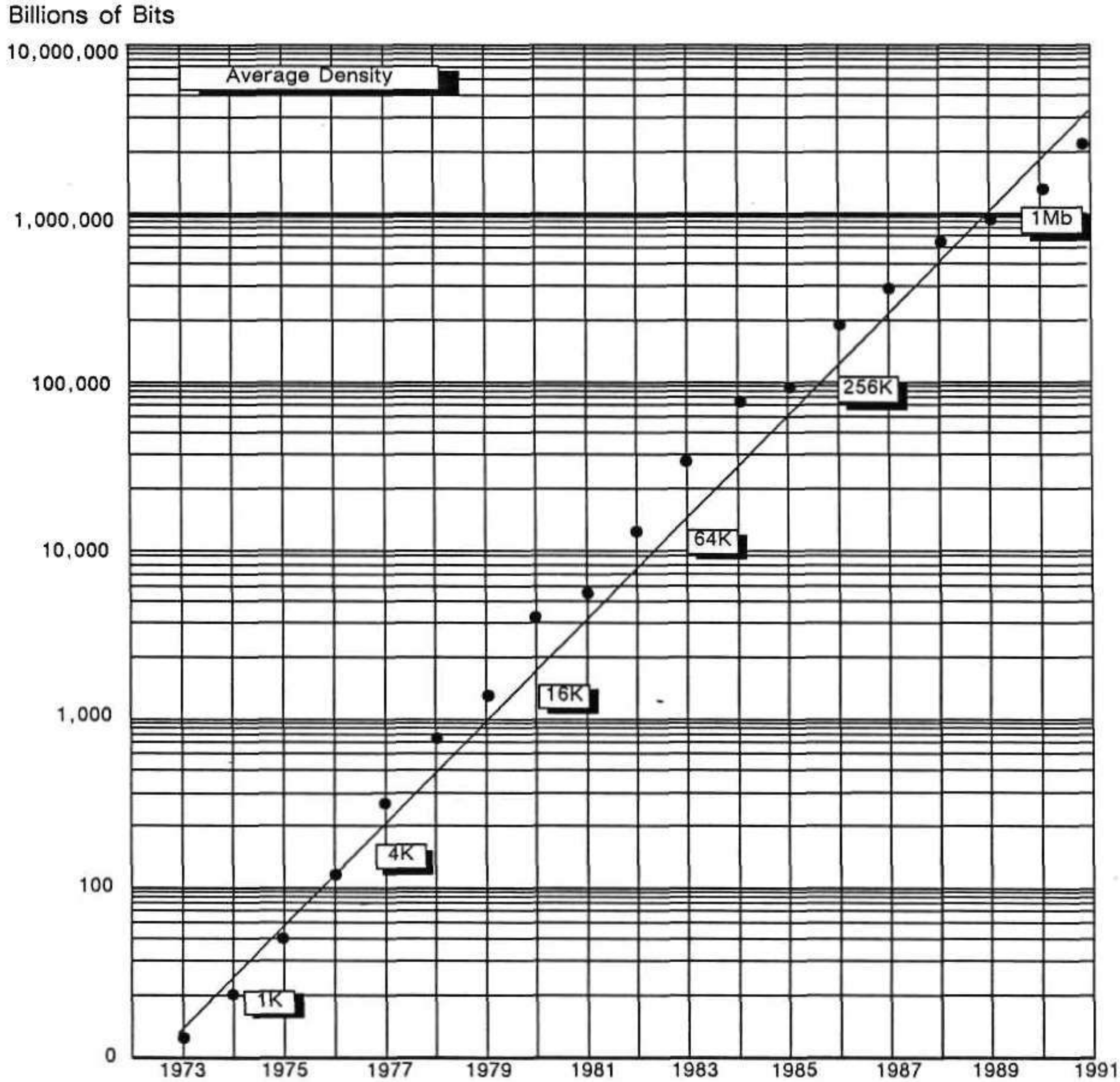
- Early bit growth was fueled by both the quadrupling of density every three years and the increased use of each new density over the previous one.

  - That increased use of new densities is less pronounced at the 1Mb density and greater.

  - Wider organizations are becoming more popular, unlike with the earlier densities, implying less need for deep memory.

Figure 4

ESTIMATED DRAM BIT GROWTH



Source: Dataquest
April 1987

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DRAM—Product Life Cycles

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  - The nature of this life cycle poses a problem in DRAM manufacturing.

DRAM--Product Life Cycles

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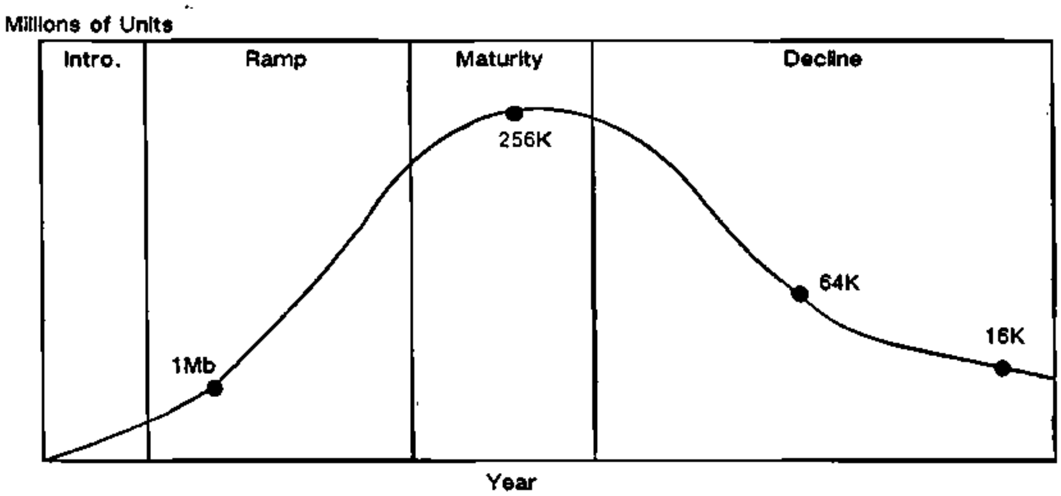
  - High-volume production and automation lend well to success, but automated production should also be flexible enough to handle the sudden drop in units after the short maturity stage of the DRAM life cycle.
- With the short ramp and maturity stages, manufacturers must time the payback of their investment with that of the life cycle.
  - The short depreciation schedule for capital equipment in Japan compared with that of the United States fortifies the success of Japanese companies in this market.
- Because of the sharpness of the peak in their life cycle, DRAMs have a greater chance of being supplied excessively, causing price pressures.

Figure 1

Typical DRAM Product Life Cycles



Stage	Intro.	Ramp	Maturity	Decline
Typical Number of Years	2	3	1-2	5
1987 Products	–	1Mb	256K	64K 16K
1991 Products	–	4Mb	1Mb	256K 64K

Source: Dataquest May 1988

DRAM--Product Life Cycles

This standard life cycle tells us that success in the DRAM market depends on developing new densities early in the life cycle, manufacturing at low cost, designing flexibility into one's manufacturing scheme, and timing investment payback with the life cycle.

Product Life Cycles by Density

Figure 2 presents the actual DRAM life cycles by density versus years after introduction. Dataquest predicts dramatic changes in the shape and duration of DRAM life cycles, which will be caused primarily by the following trends:

- Submicron products are expected to be more difficult to build with the advent of finer geometries and three-dimensional cell capacitor structures. The market has seen this with the prolonged poor yields of the 1Mb DRAM. Dataquest expects future generations, such as the 4Mb and 16Mb DRAMs, to have slower production ramps.

- Submicron products will require significantly higher capital investment with a need for 8-inch wafer fabs in the next decade, along with the escalating cost of fabrication equipment. Estimates for a 1.2- to 0.8-micron 6-inch wafer line are at $100 million, while those for a 0.8- to 0.5-micron 8-inch wafer line run up to $400 million.

- The succession of political events—dumping penalties, foreign market value systems, MITI demand monitoring—has emphasized the need to operate at profitable margins. MITI carries the message further: profits before market share.

Dataquest expects the following effects on the product life cycles:

- The peak years beginning from the 256K density will move a year out to the seventh year of life. The slow ramp of the next-generation DRAM will have to be made up for by the memory bits of the current generation. Companies will also seek a later peak to recover more profits from a DRAM generation because of the longer payback periods that result from escalating capital investment.

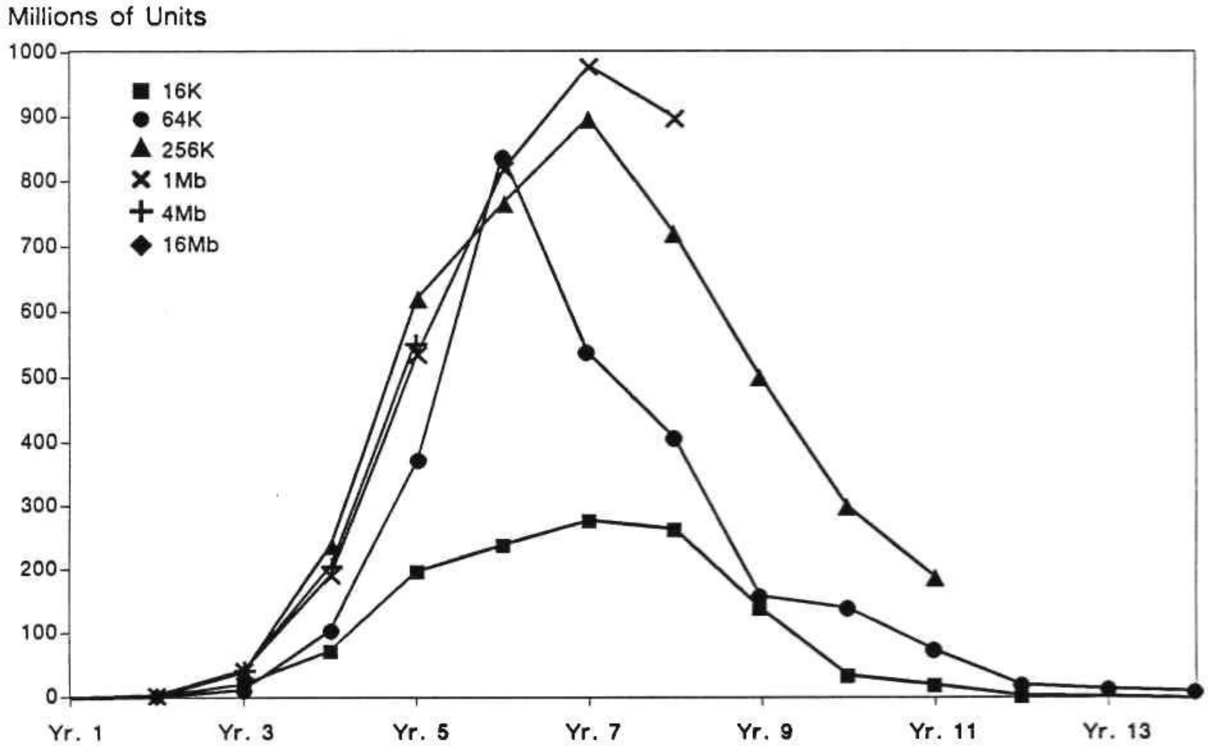
- The shape of the life cycle curves will be less sharp, especially in the maturity and decline stages. Dataquest forecasts that the 256K DRAM will continue to be used heavily through 1992 and expects the 1Mb DRAM and further generations to stay longer in the market. The installed base and segmenting market of personal computers will keep older models around longer and maintain a healthy after-sales replacement market for DRAMs.

- The introduction and ramp stages for future generations are projected to be slow. Introductions and engineering samples are still expected to occur in three-year increments or even less, but actual production will be more difficult in the initial years of next-generation products.

DRAM--Product Life Cycles

Figure 2

DRAM Product Life Cycle



Source: Dataquest May 1988

The altering life cycles may also affect prices. Slower ramping submicron products will have higher prices because of higher costs. In previous generations, costs were sacrificed to build the market. However, with the existing political constraints, this practice may be limited. Price-per-bit crossovers between succeeding densities may also be delayed. We have seen this happen with the 256K and 1Mb DRAMs.

DRAM--Product Life Cycles

The Product Life Cycles through Time

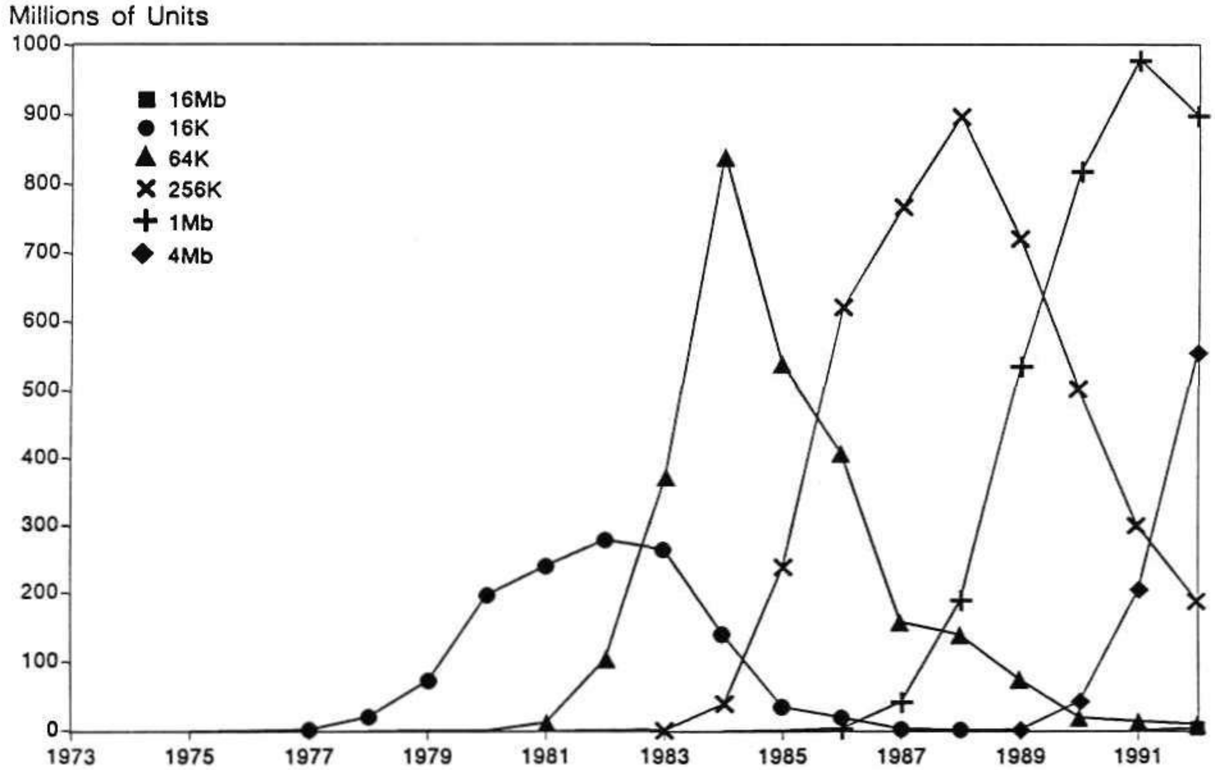
Figure 3 shows the behavior of each density's life cycle through actual time, based on the following:

- Dataquest expects the intervals between density production starts to remain constant at three years. The actual development of future DRAM generations is quickening; however, with 16Mb DRAMs announced within the same two years that 4Mb DRAMs were in ISSCC. Despite the rapid development, capital constraints and the fledgling support for 8-inch wafers will space device production by three years.

- The peaks of the 64K, 256K, and 1Mb DRAMs are not substantially different because they cater to the same major application, the personal computer, and follow its growth trends. Dataquest expects that the peaks of the 4Mb and 16Mb DRAMs will be substantially higher because of the potential bit usage of emerging applications such as digital television, graphics and image processing, silicon disks, and telephone message recorders.

Figure 3

DRAM Product Life Cycles
(By Density over Time)



Source: Dataquest May 1988

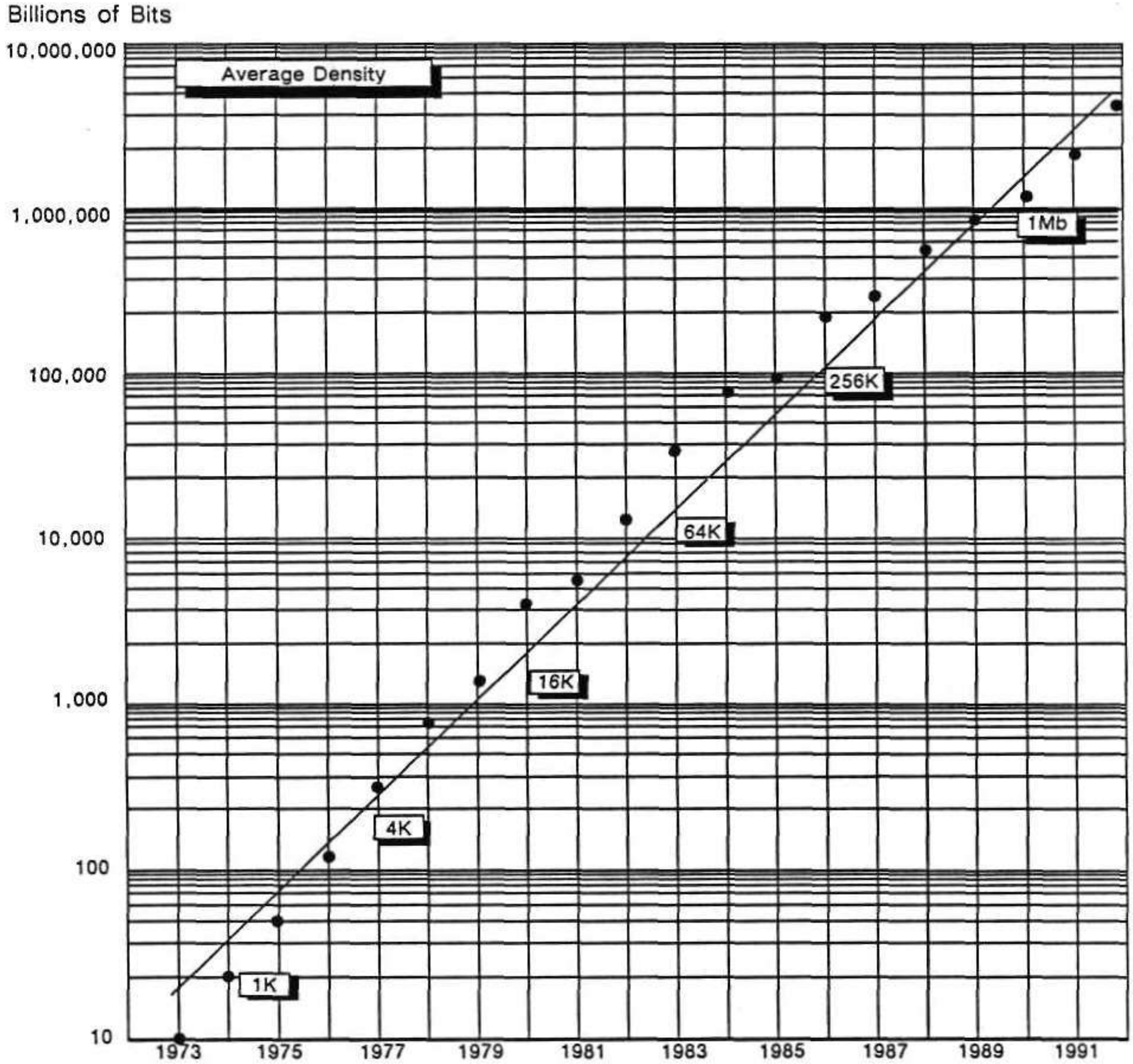
Bit Growth Analysis

Bit-growth analysis looks at the trends in the life cycle of the whole DRAM product line and not its individual densities. From a measurement of bits through time, it is possible to observe whether DRAM technology as a whole is still in its ramp stage as a technology or whether it is maturing rapidly. Figure 4 presents the actual and projected DRAM bits from 1973 to 1992.

- DRAM bits increased 10 times every three years up to an average density of 256K bits. Average density is the result of the total shipped bits divided by the total shipped units in a given year.
- The rate of bit-growth appears to be slowing down, and approaching a knee. DRAM bits are expected to grow by an average of 67 percent a year beyond 1988.
- The slower bit-growth rate is attributable to the slowing growth of traditional DRAM applications, such as personal computers, and the lack of new, high-usage applications.
- Life cycles can always be extended or revitalized. Dataquest believes that despite the slowdown in the growth rate of DRAM bits, the life cycle of DRAMs will be revitalized with the new applications coming after 1992.

Figure 4

DRAM Bit Growth Trends



Source: Dataquest
May 1988

DRAM—Price Learning Curves

OVERVIEW OF PRICE LEARNING CURVES

The price learning curve is an effective tool for forecasting and interpreting the sensitivity of prices to various factors such as business cycles and government intervention. Unlike cost experience curves, price curves are heavily influenced by such extraneous market forces as competition, substitute technology, general economic conditions, or supply/demand dynamics. The following should be noted about the price learning curve for DRAMs:

- The price learning curve is defined by DRAM prices, in millicents per bit, and by accumulated bit shipments, plotted on a log-log scale.
- The price learning curve theoretically follows the drop in the cost learning curve.
  - Cost learning curves assume that a consistent percentage reduction in cost is realized with every doubling of accumulated production. For example, if cost drops by 20 percent for a doubling of accumulated units produced, then the cost learning curve is described as an 80 percent curve.
  - The same description can be applied to price learning curves.

Figures 1 through 4 show the price learning curves for all DRAMs, the 16K DRAM, the 64K DRAM, and the 256K DRAM, respectively.

HIGHLIGHTS OF THE DRAM PRICE LEARNING CURVE

Price breaks in the curve are caused by market forces or other extraneous factors, and each new slope describes the severity of the factor's influence on price. There are four price breaks in the total DRAM price learning curve shown in Figure 1.

From 1974 to the beginning of 1980, DRAM prices declined on a reasonable 80 percent curve. The first price break was created by the U.S. economic recession in the early 1980s; this caused prices to drop faster, on a 55 percent curve. By 1983, an industry boom occurred with the phenomenal growth of the personal computer industry. Product shortages and vendor-controlled prices brought prices to an 84 percent curve. By 1985, the boom fizzled out. Capacity utilization rates plummeted, and a frenzy of price reductions ensued as companies tried to keep market share and to run factories. The industry plunged into its worst recession yet. This is reflected in the severely steep 15 percent curve.

DRAM--Price Learning Curves

Prices stabilized again in 1986 as the U.S. Department of Commerce intervened with tariffs and the eventual U.S.-Japan semiconductor trade arrangement. In this agreement, foreign market values (FMVs) were stipulated to act as minimum prices for DRAMs fabricated in Japan and sold in the United States. FMVs are determined by the U.S. Department of Commerce on a quarterly basis, based on a cost model. The trade arrangement also called for a narrowing of the price differentials between U.S. prices and those of Asia and Europe.

The DRAM price breaks are influenced by industry cycles, increased demand, and, lately, government intervention. The resulting steepness of the price curve after each price break depends mostly on the amount of excess capacity and inventory in the industry.

DATAQUEST ANALYSIS

Dataquest believes that predicting price breaks is more important than predicting the slope of the curve. Manufacturers have an influence over the slope of the curve in the manner by which they manage overall industry capacity. In planning future capacity, they must bear in mind that, although the DRAM market still grows exponentially, there are cycles that inhibit the growth and cause price declines.

The influence of governments in DRAM pricing has just begun. The FMVs have caused a slower decline in prices. We believe that in 1987, government will continue to be the major cause of price breaks. Encouraged by MITI, Japanese manufacturers are reducing production levels in the first half of 1987; this may cause severe 256K DRAM shortages. We expect prices of 256K DRAMs to increase slightly through the year.

DRAM--Price Learning Curves

Figure 1

TOTAL DRAM PRICE LEARNING CURVE

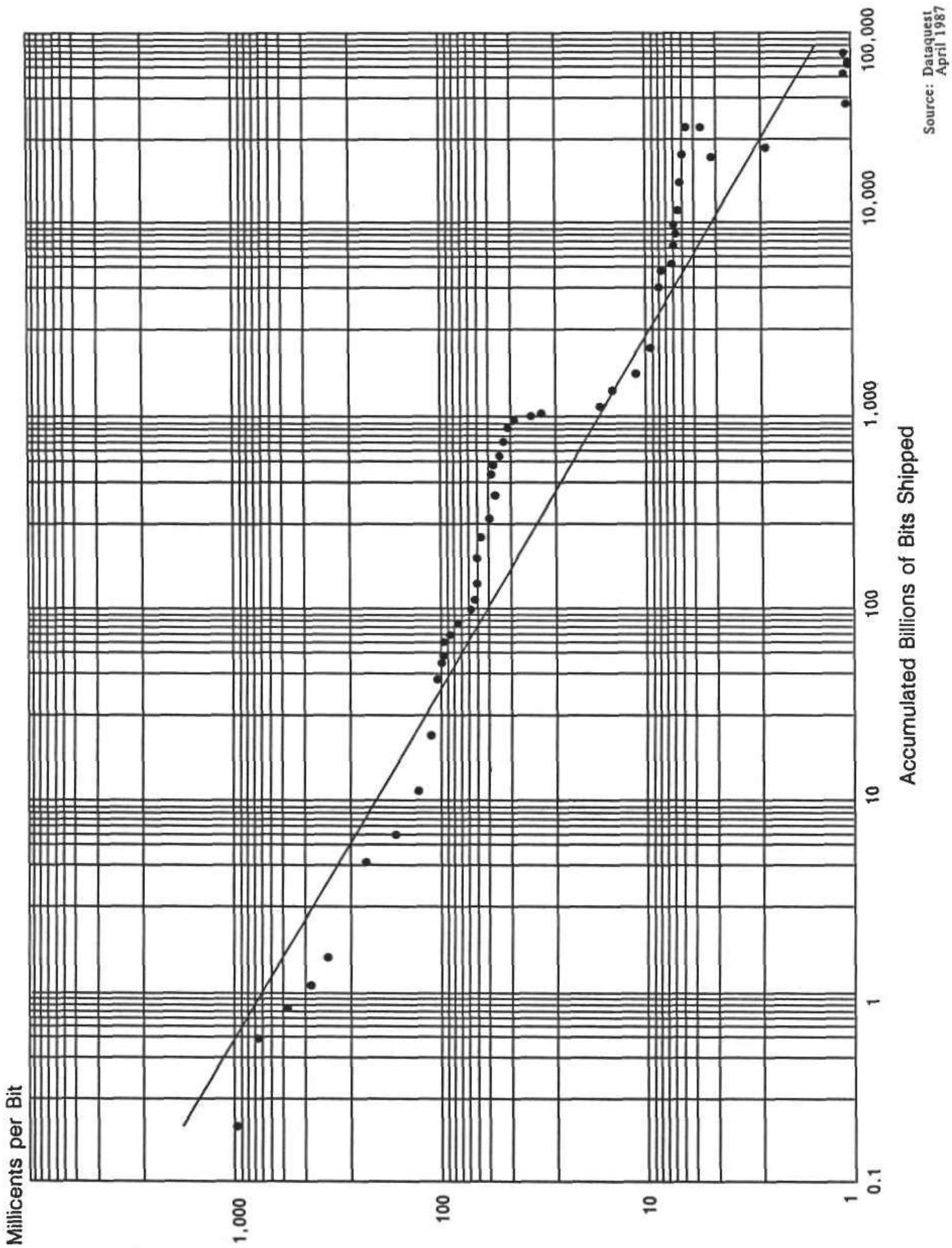


Figure 2

16K DRAM PRICE LEARNING CURVE

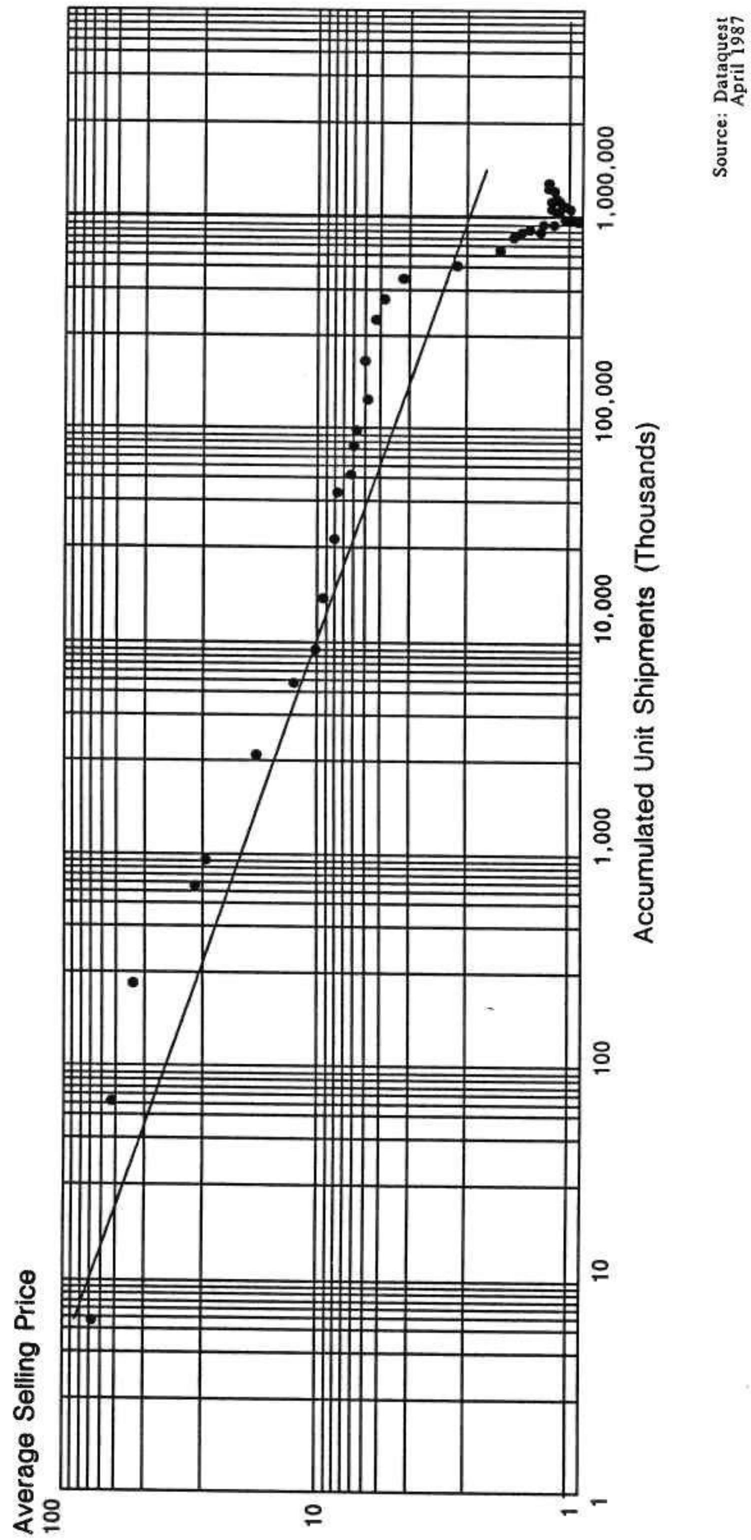
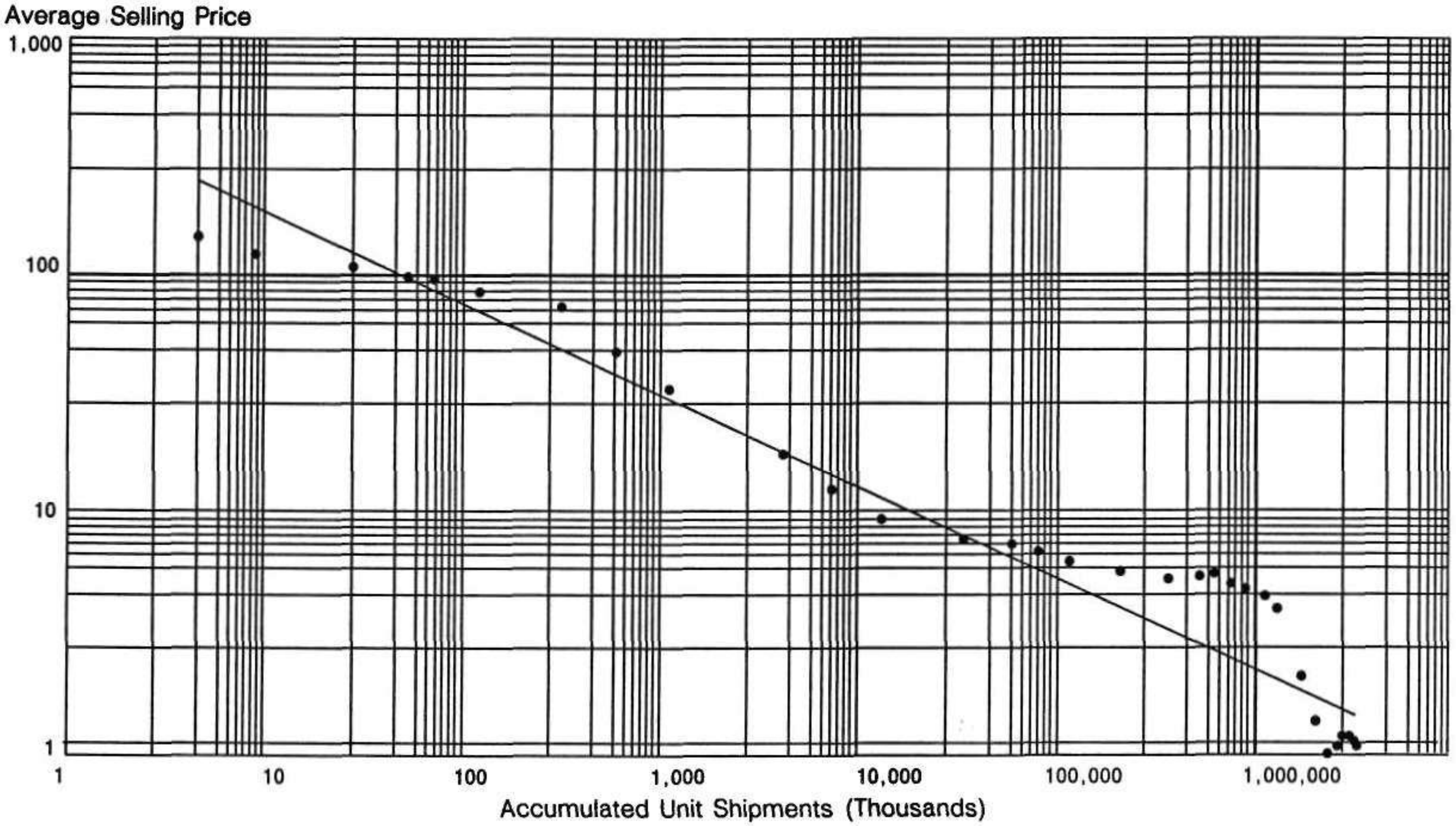


Figure 3

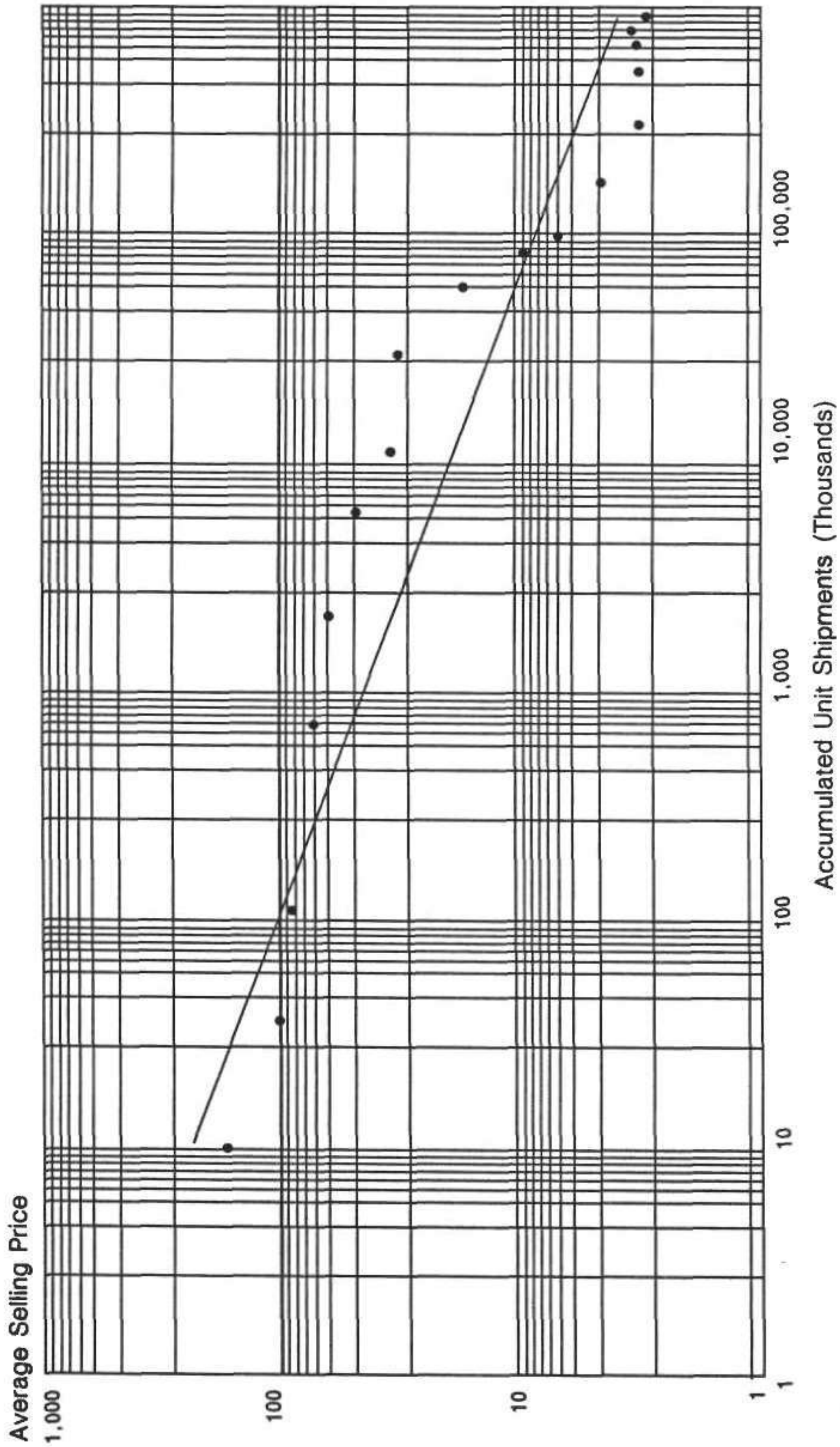
64K DRAM PRICE LEARNING CURVE



Source: Dataquest
April 1987

Figure 4

256K DRAM PRICE LEARNING CURVE



Source: Dataquest
April 1987

DRAM--Price Learning Curves

OVERVIEW OF PRICE LEARNING CURVES

The price learning curve is an effective tool for forecasting and interpreting the sensitivity of prices to various factors such as business cycles and government intervention. Unlike cost experience curves, price curves are heavily influenced by such extraneous market forces as competition, substitute technology, general economic conditions, or supply/demand dynamics. The following should be noted about the price learning curve for DRAMs:

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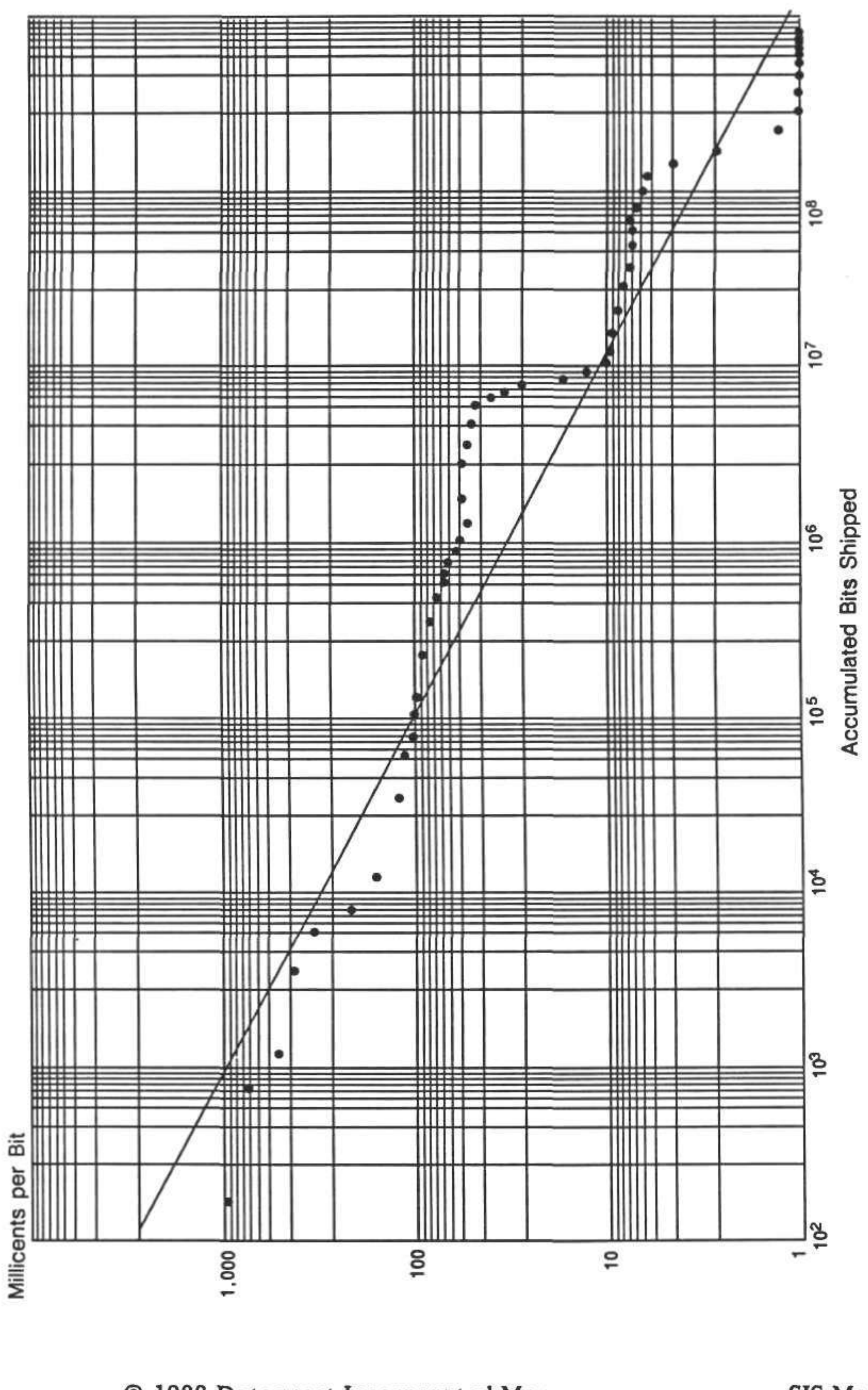
  - The same description can be applied to price learning curves.

Figures 1 through 4 show the price learning curves for all DRAMs, the 16K DRAM, the 64K DRAM, and the 256K DRAM, respectively.

DRAM--Price Learning Curves

Figure 1

DRAM Price Learning Curve*

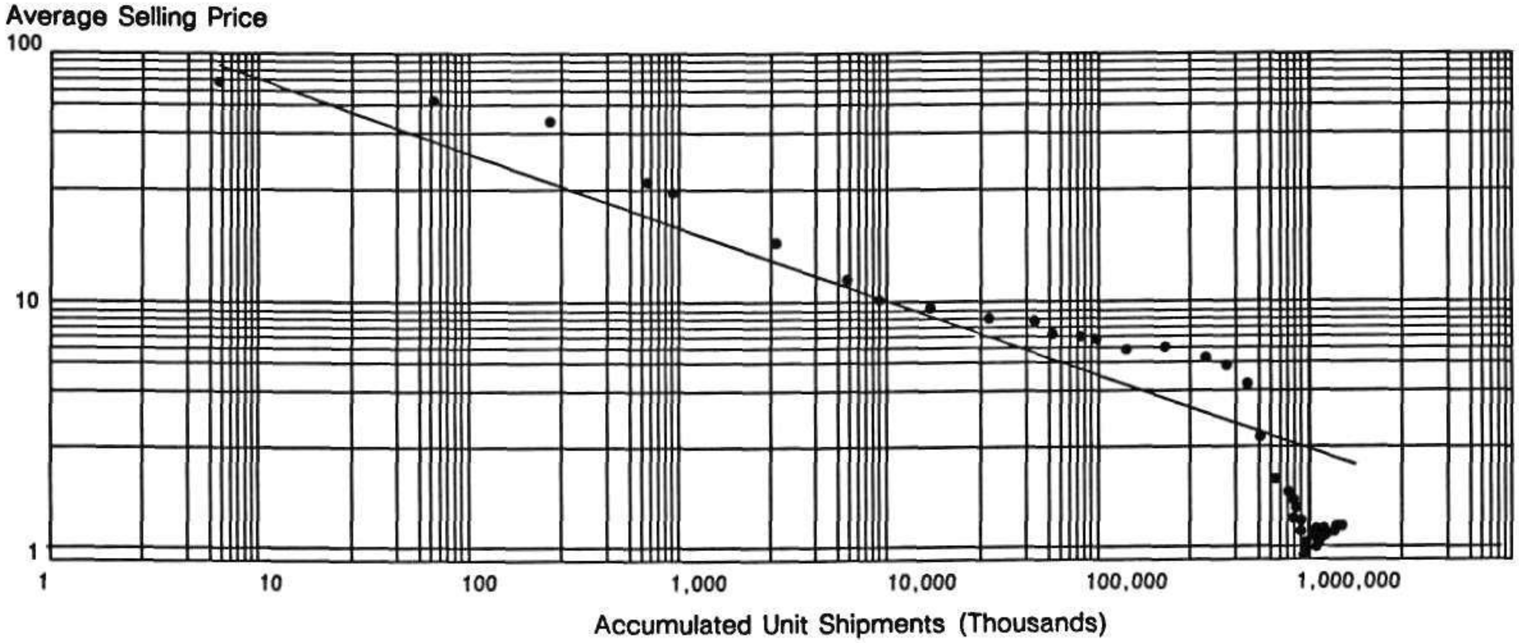


* The DRAM price learning curve is based on quarterly data from 1974 through 1987.

Source: Dataquest
May 1988

Figure 2

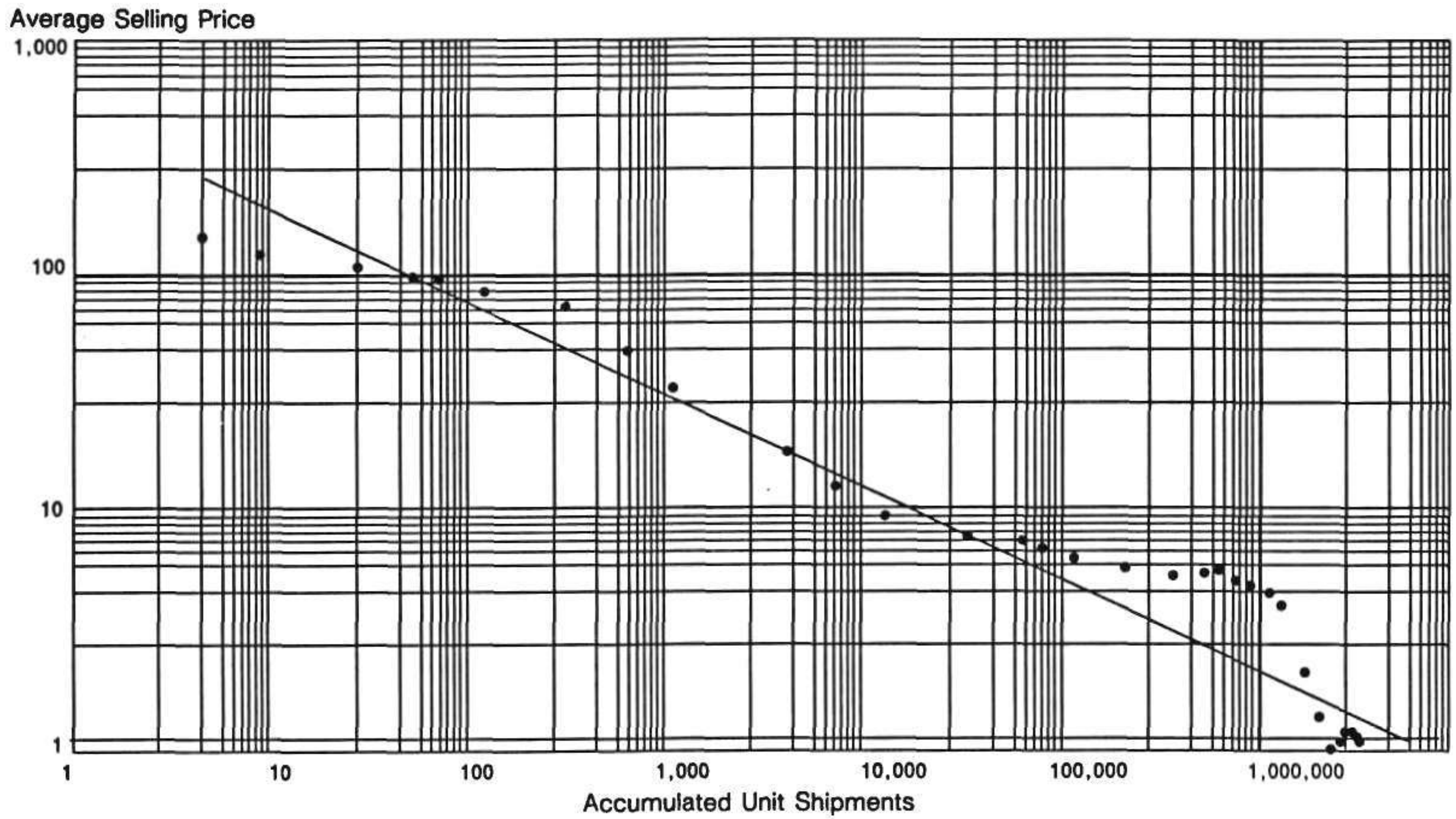
16K DRAM Price Learning Curve



Source: Dataquest
May 1988

Figure 3

64K DRAM Price Learning Curve*



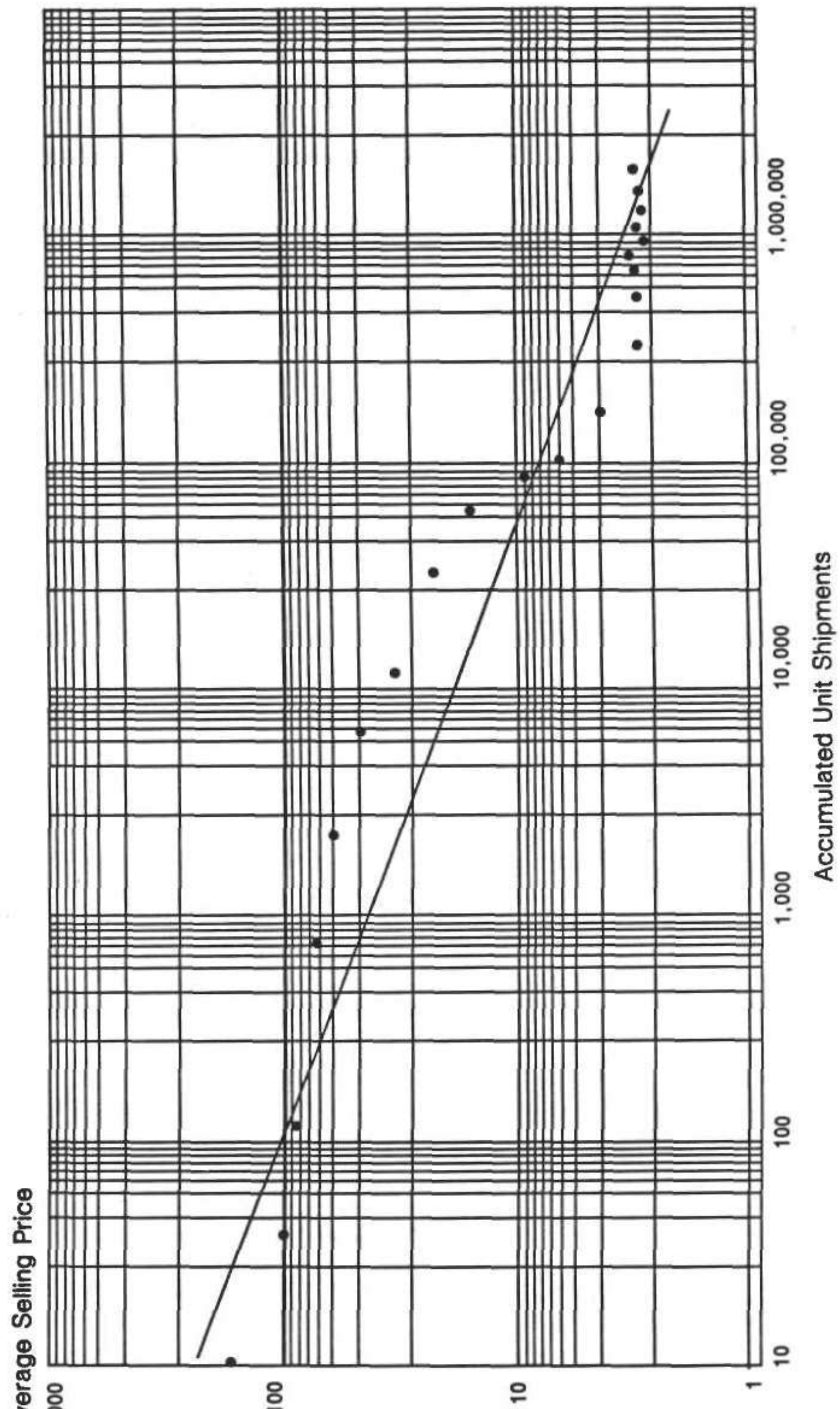
* The 64K DRAM price learning curve is based on actual quarterly data from 1979 through 1987.

Source: Dataquest
May 1988

DRAM--Price Learning Curves

Figure 4

256K DRAM Price Learning Curve*



* The 256K DRAM price learning curve is based on actual quarterly data from 1982 through 1987.

Source: Dataquest
May 1988

DRAM--Price Learning Curves

HISTORICAL PERSPECTIVE

DRAM prices have declined on a 73 percent learning curve from 1974 through 1987, which is dramatically steeper than those of other semiconductor memory devices. Memory devices are believed to have dropped on a 70 to 80 percent price learning curve. However, closer analysis reveals that this belief was only true from 1974 through 1980, when DRAM prices followed an 80 percent curve. A succession of industry recessions has accelerated the price decline.

The first price break was caused by the U.S. economic recession in the early 1980s, when prices slid on a 55 percent curve. By 1983, an industry boom occurred with the phenomenal growth of the personal computer industry. Prices remained relatively firm, following an 84 percent curve. By 1985, the shakeout in the personal computer market drove DRAM prices down on a steep 15 percent curve as manufacturers went into a price-cutting frenzy in an attempt to keep factories going.

Toward the middle of 1986, prices stabilized again, aided heavily by a series of political events. The U.S. Department of Commerce imposed preliminary dumping tariffs on Japanese manufacturers in the first half of 1986. The tariffs were suspended with the adoption of the historical U.S.-Japan semiconductor trade arrangement, which introduced the foreign market value (FMV) system. Under this system, the U.S. Department of Commerce computed FMVs for each company based on actual cost inputs. These FMVs served as the lowest price at which a Japanese vendor could sell a particular DRAM in the U.S. market. In the first half of 1987, MITI imposed DRAM production cuts just as demand was beginning to pick up. The severe shortages and strong demand in 1987 have raised DRAM prices substantially.

HIGHLIGHTS OF THE DRAM PRICE LEARNING CURVES

Figures 2 through 5 present the price learning curves of the 16K, 64K, 256K, and 1Mb DRAMs, respectively. The highlights of these curves are as follows:

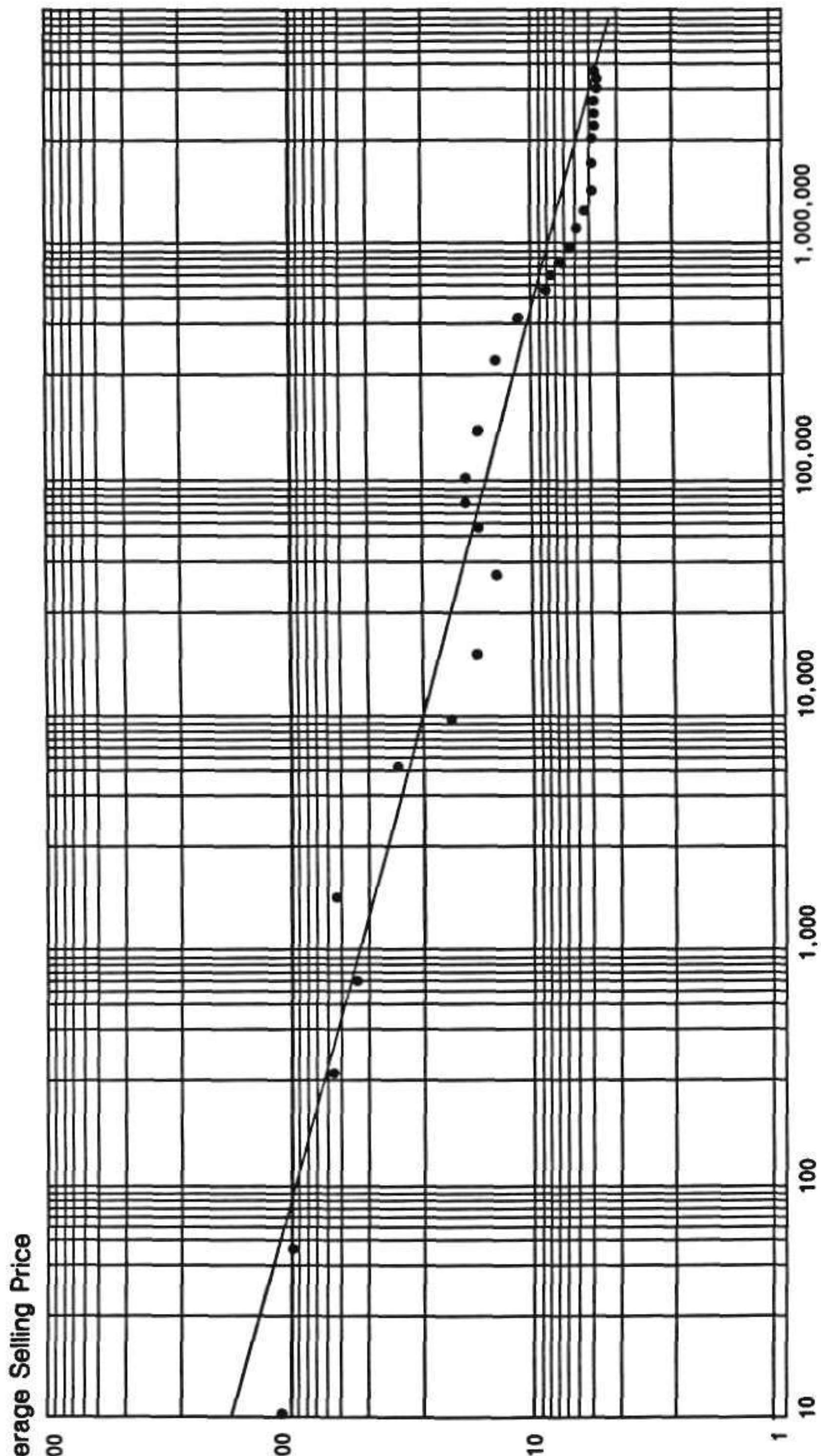
- The 16K, 64K, and 256K DRAM prices have declined on learning curves that are almost parallel with each other, as shown in Figure 6. Table 1 lists the learning curve slopes for each of these densities and for 1Mb DRAMs. As the market graduates into higher densities, the slope of the curve becomes less steep.

- Price levels generally increase as the market moves to higher generations. For the same accumulated volume, 256K DRAM prices are generally higher than those of 64K or 16K DRAMs. In Japan, the bi-rule concept is currently popular. It says that the final price of a DRAM density is about twice that of the preceding density.

- The 1Mb DRAM price learning curve is less steep. The curve began at a lower level than previous generations since the 1Mb DRAM was introduced during the worst semiconductor downturn in history. However, with political intervention, 1Mb DRAM prices have declined very slowly, especially with the current shortages in the market.

Figure 5

1Mb DRAM Price Learning Curve*

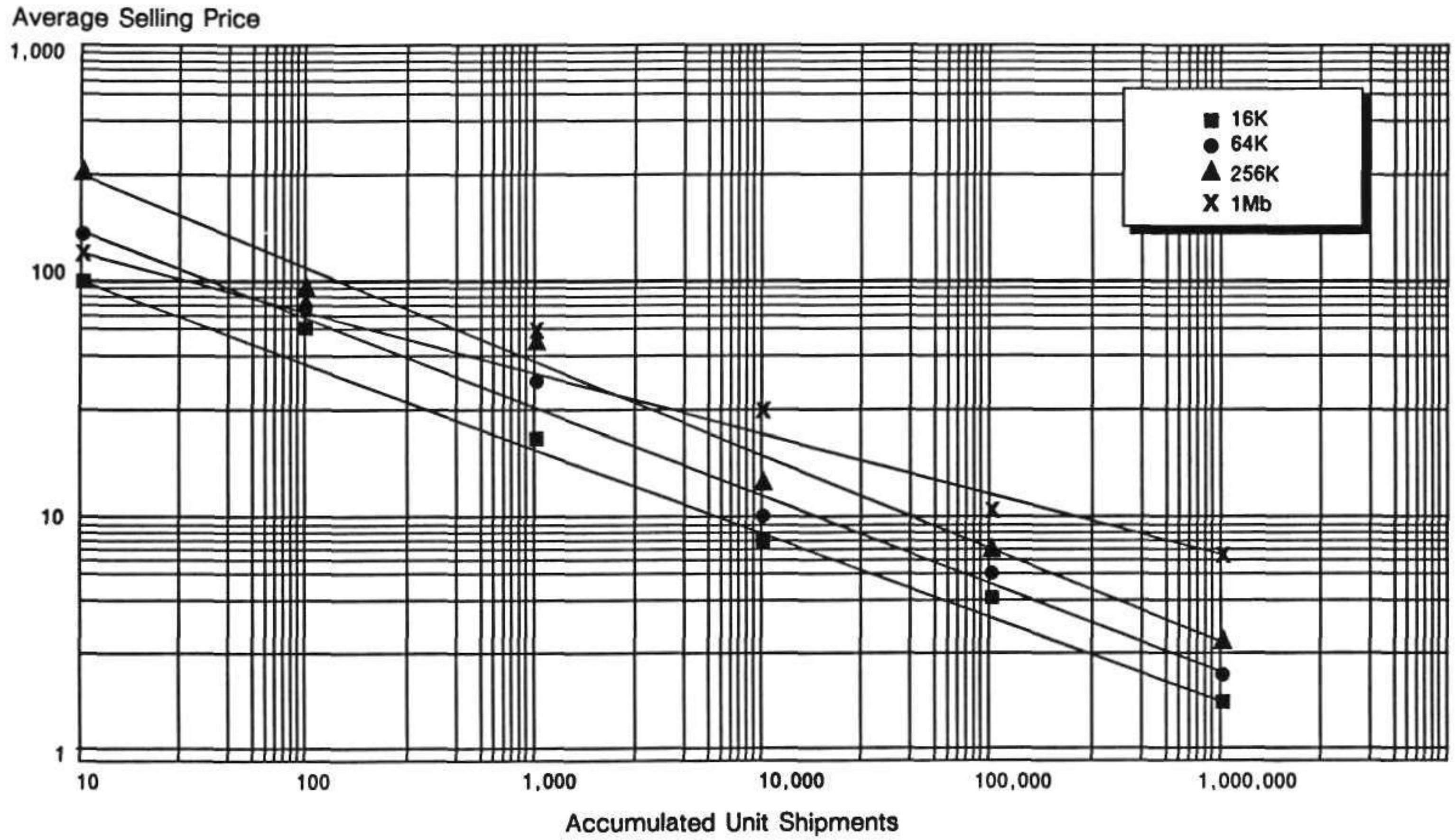


* The 1Mb DRAM price learning curve is based on actual quarterly data from 1985 through 1987 and on forecast quarterly data from 1988 through 1992.

Source: Dataquest May 1988

Figure 6

Price Learning Curve Comparison



Source: Dataquest
May 1988

Table 1

Price Learning Curves of DRAM Generations

DRAM	Learning Curve
16K	77%
64K	77%
256K	76%
1Mb	83%

Source: Dataquest
May 1988

DATAQUEST ANALYSIS

The difference in the 1Mb DRAM price slope raises several burning questions. Will the 1Mb DRAM price drop dramatically in the next downturn to make the curve approximate the slopes of the 16K to 256K DRAMs? Or, does the new 1Mb DRAM slope signal a change in the fundamental structure of the DRAM industry?

Dataquest believes that several factors will cause fundamental changes in DRAM pricing:

- Historically, DRAMs have fluctuated around a steeper learning curve, and there were even times when prices made profits prohibitive. Dataquest believes that the political safety nets have now been installed to catch any future DRAM price free-fall. These nets are the MITI demand forecasting system and the FMV determination. These nets will ensure that DRAM manufacturers will generally make a profit, however small, which is a radical departure from past patterns.

- Technological hurdles in DRAM manufacturing exist that still need to be mastered. Most manufacturers have planned on a trench transistor cell 4Mb DRAM. Eight-inch wafer fabrication technology needs to be economical and in place to allow for the more significant cost reductions of the 4Mb DRAM.

- The cost of submicron, larger wafer lines is increasing dramatically. These capital investments need to be paid back through the sale of their output. DRAM prices, therefore, will be affected, especially since investment payback is included in the FMV calculation.

- The overall attitude of DRAM manufacturers has changed. Capacity buildup is more cautious, and concern for profits is more prevalent.

DRAM--Vendor Base Analysis

THE DRAM VENDOR BASE

Two trends are prevalent in the dynamic RAM (DRAM) market: The market is becoming increasingly competitive, and memory buyers are limiting their supplier base in search of long-term strategic partnerships. More people are trying to get through a narrower door. For both memory manufacturer and purchaser, an understanding of the changes and trends in the vendor base is vital.

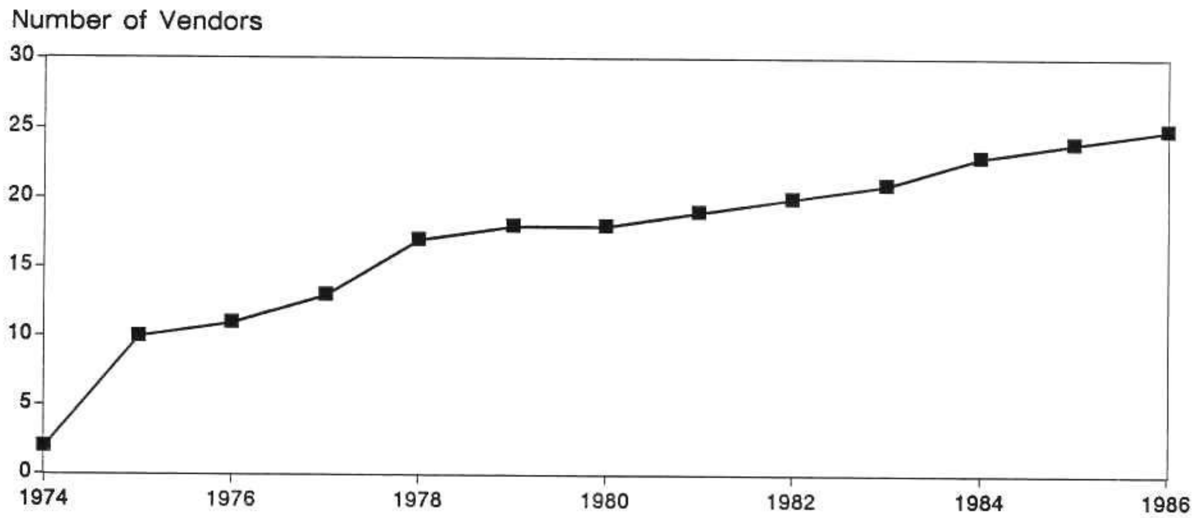
The highlights of this analysis are as follows:

- Growth in vendor number
  - The number of DRAM vendors has been steadily increasing, as shown in Figure 1. The total number in 1986 was 25, up from 19 in 1981 and 11 in 1976. Dataquest expects the vendor base to continue its growth, as more Korean and Japanese companies enter the market in 1987. These potential entrants are Goldstar, Hyundai, and Sony.
  - Historically, the number of market entrances as well as departures has been decreasing, as illustrated in Figure 2. All the companies that have left the DRAM market are based in the United States. As the lower-density markets erode, many other departures are expected in the next five years.
- Market concentration on the top 5 and 10 vendors
  - The DRAM vendor base growth is due largely to the attractive size of the market. In 1986, in a field of 25 competitors, the average revenue per vendor was $84 million, which is about four times more than for most other memory products, as shown in Table 1.
  - The DRAM market is also very competitive, however. The distribution of market share shows a heavy concentration on the top 10 manufacturers. Since 1981, the top 10 companies have held an average 90 percent share of the market, despite the fact that the companies in the top 10 have changed.
  - A study of the top 5 vendors and their market share shows further concentration. Market share of the top 5 vendors has been constantly increasing, reaching 73 percent in 1986 from 62 percent in 1981.

DRAM--Vendor Base Analysis

Figure 1

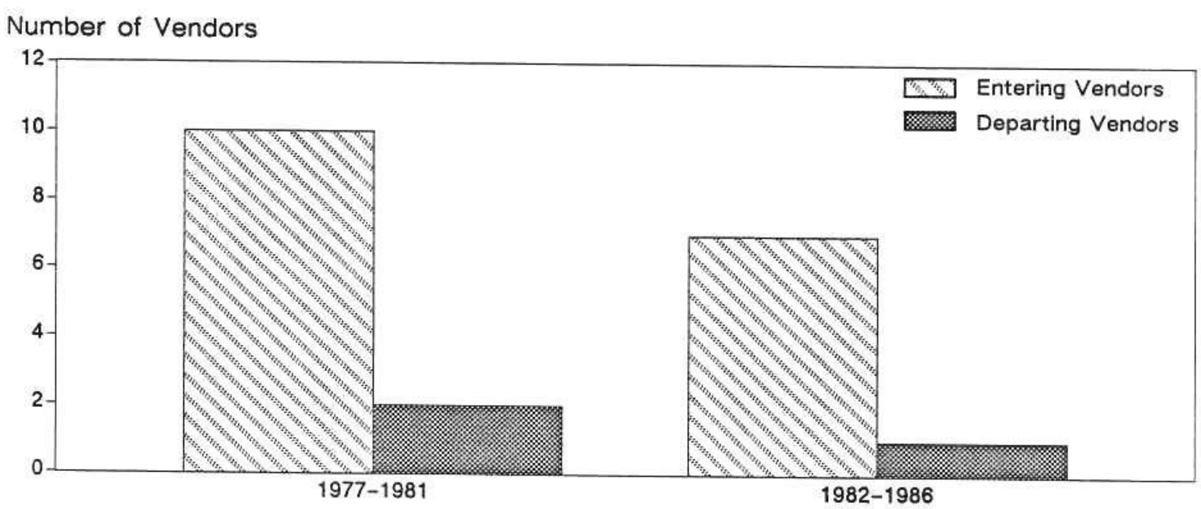
TOTAL DRAM VENDOR BASE



Source: Dataquest
April 1987

Figure 2

DRAM ENTERING AND DEPARTING VENDORS



Source: Dataquest
April 1987

DRAM--Vendor Base Analysis

Table 1

DRAM TOP 5/10 VENDOR CONCENTRATION

Top 5/10 Concentration	1981	1982	1983	1984	1985	1986
No. of Vendors	19	20	21	23	24	25
Average Revenue per Vendor	33	48	86	154	66	84
Top 10 Share	90%	90%	90%	89%	87%	93%
Top 5 Share	62%	62%	64%	61%	66%	73%

Source: Dataquest
April 1987

- Vendors by region
  - The Japanese vendor base has grown since 1976 to almost equal that of the U.S. base, as shown in Figure 3. Future vendors are expected to come primarily from Korea and Japan.
  - The Japanese vendors have focused primarily on high-density DRAMs, while many U.S. vendors are main suppliers of lower-density devices. Figures 4 through 7 present the regional breakdown of vendors for the 16K to 1Mb densities.
  - The DRAM market is dominated by Japanese vendors, as shown in Table 2. The average revenue per Japanese vendor is more than five times that of the U.S. vendor and has increased significantly through the years. The Korean average, coming primarily from Samsung sales, is growing rapidly.
  - Japanese vendors--Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba--have controlled the top 5 slots since 1985. As mentioned earlier, their share amounted to 73 percent in 1986. Among the top 10 vendors, 82 percent of the 93 percent market share in 1986 was held by Japanese companies.

DRAM--Vendor Base Analysis

Figure 3

TOTAL VENDOR BASE BY REGION

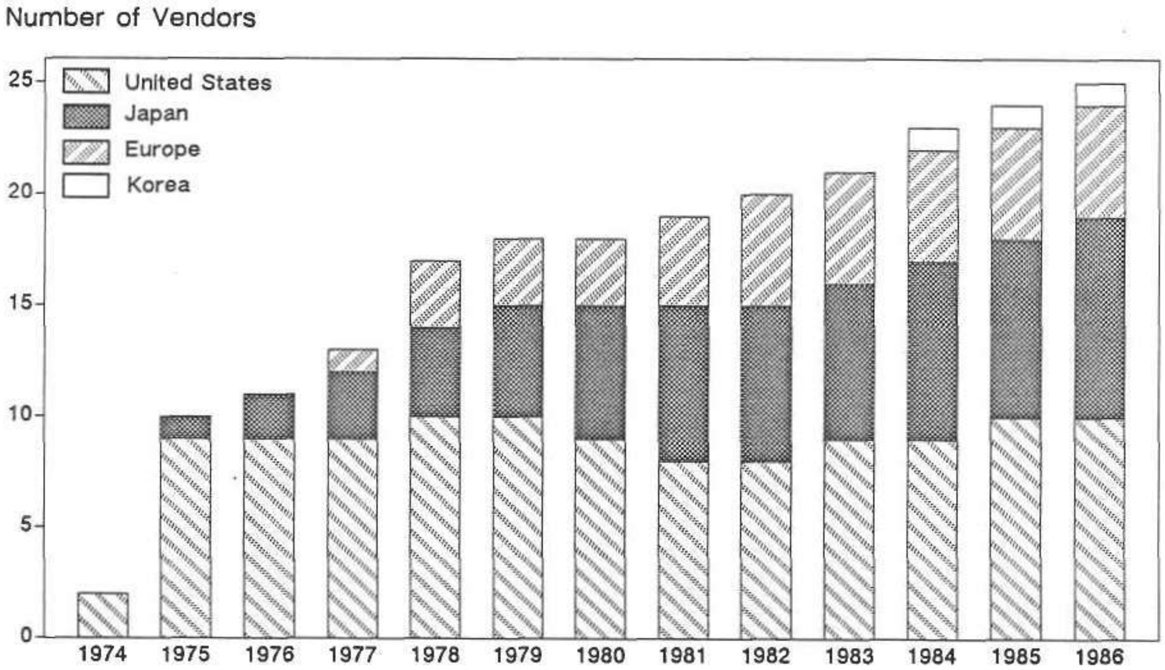
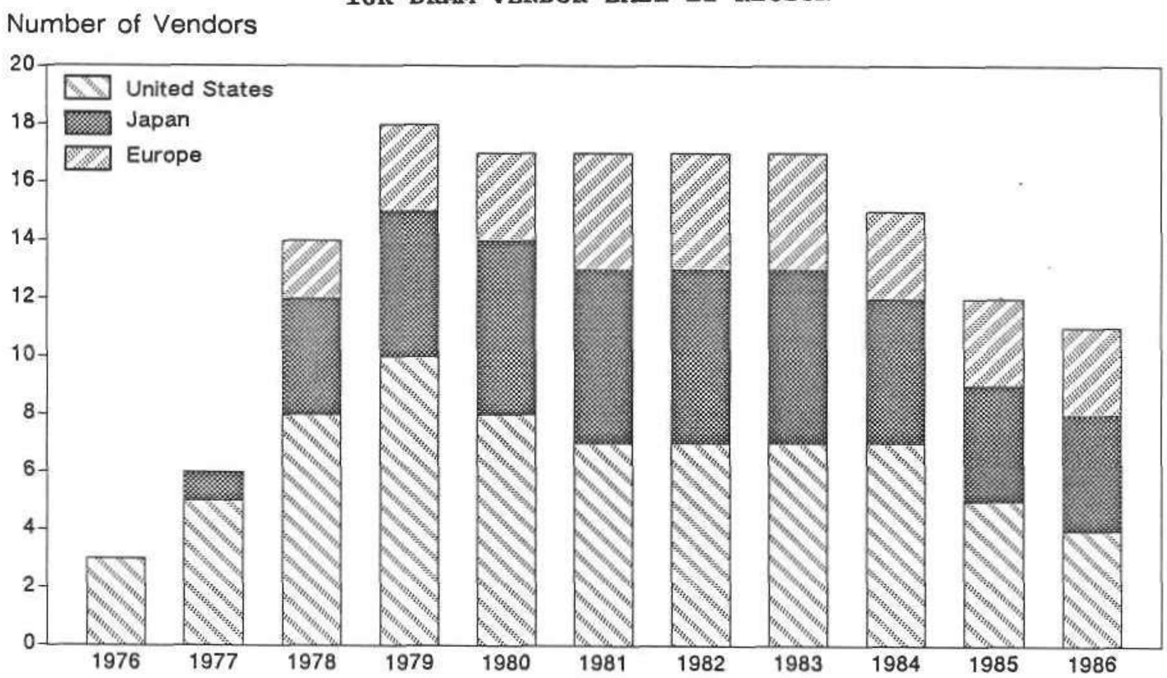


Figure 4

16K DRAM VENDOR BASE BY REGION



Source: Dataquest
April 1987

DRAM--Vendor Base Analysis

Figure 5

64K DRAM VENDOR BASE BY REGION

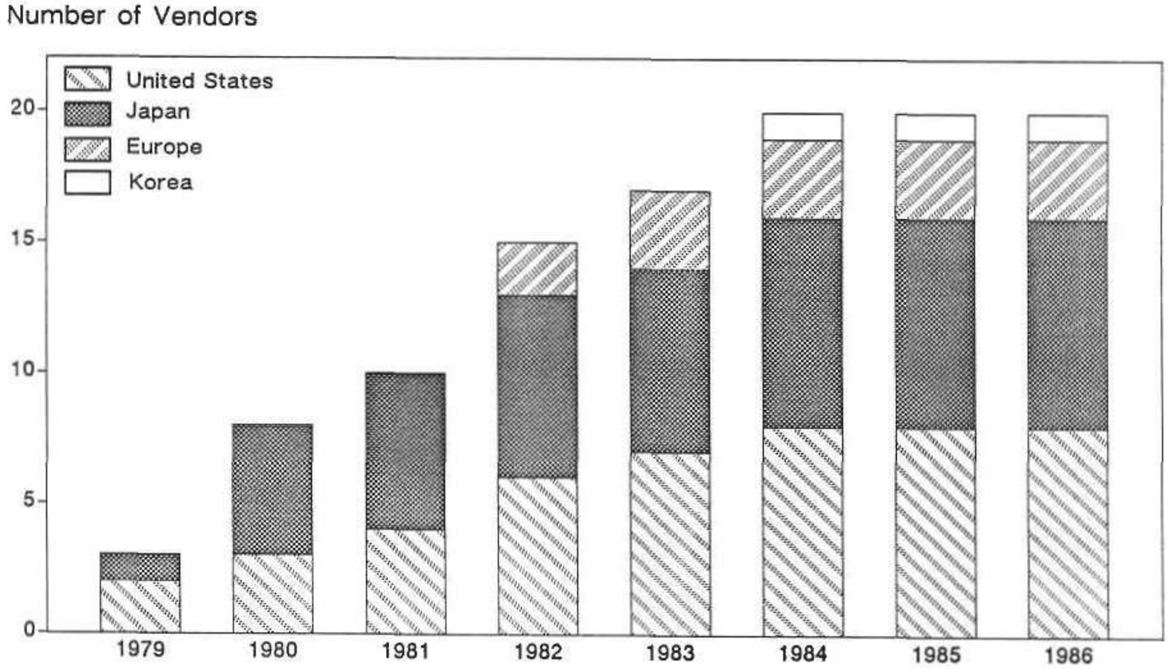
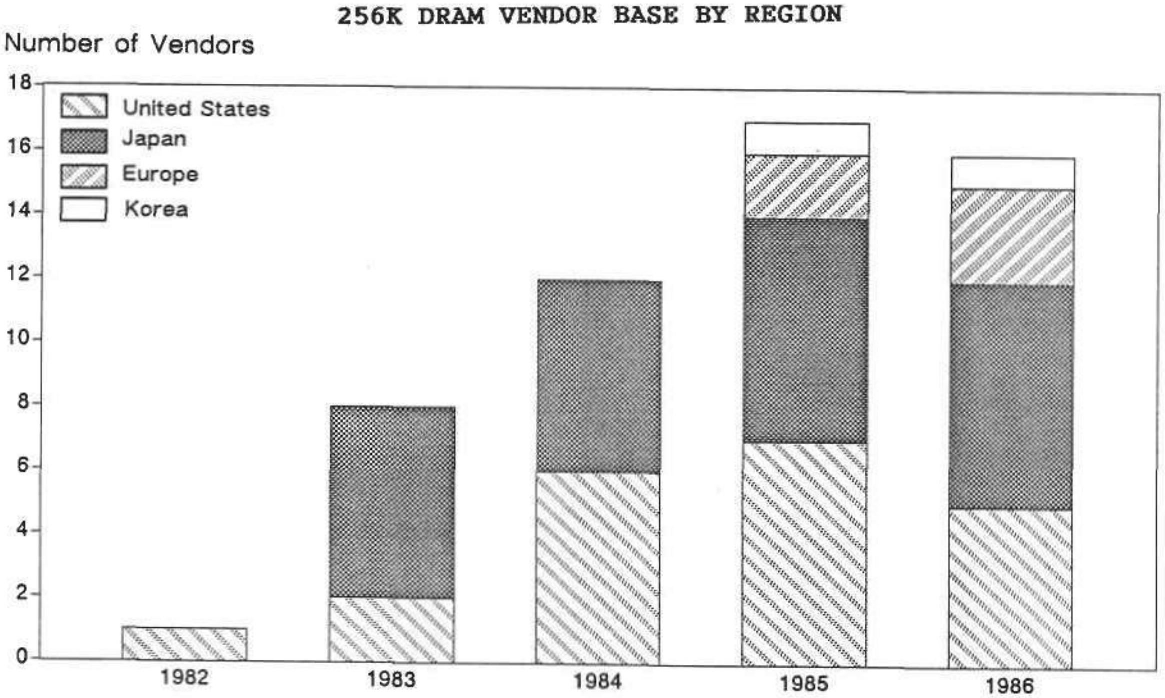


Figure 6

256K DRAM VENDOR BASE BY REGION

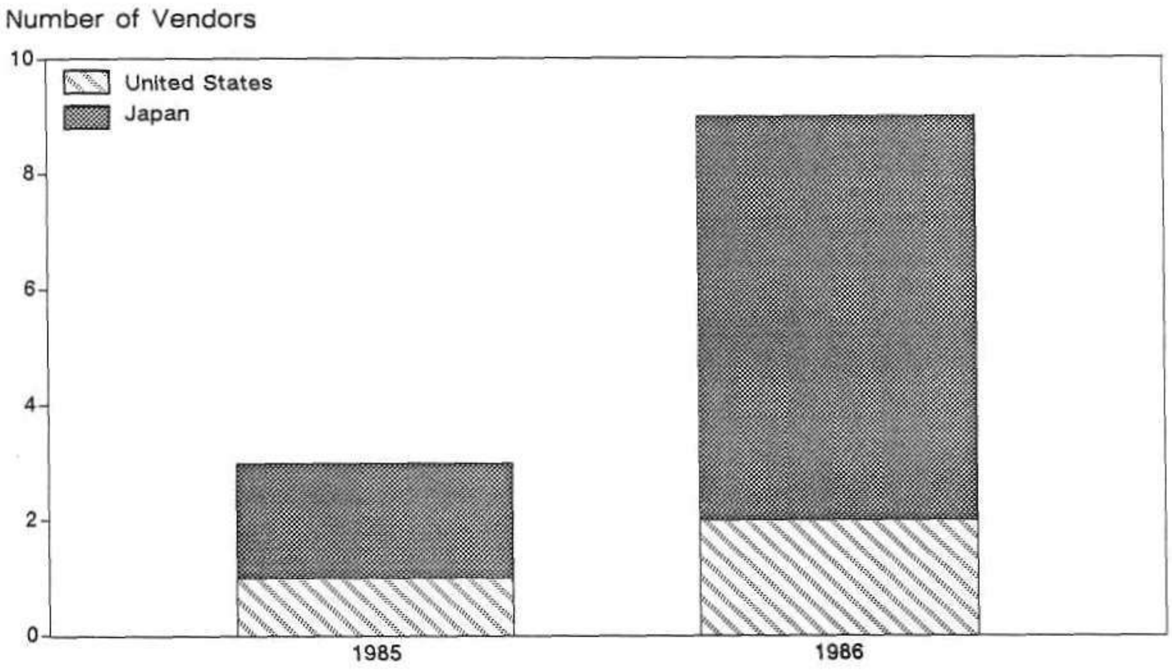


Source: Dataquest
April 1987

DRAM--Vendor Base Analysis

Figure 7

1MB DRAM VENDOR BASE BY REGION



Source: Dataquest
April 1987

DRAM--Vendor Base Analysis

Table 2

DRAM REGIONAL VENDOR CONCENTRATION

	1981	1982	1983	1984	1985	1986
Regional Concentration						
No. of U.S. Vendors	8	8	9	9	10	10
U.S. Market Share	50%	42%	40%	33%	20%	16%
Average Revenue per Vendor	40	50	79	129	32	34
No. of Japanese Vendors	7	7	7	8	8	9
Japanese Market Share	45%	53%	56%	63%	71%	78%
Average Revenue per Vendor	40	73	145	280	141	182
No. of European Vendors	6	7	7	7	7	7
European Market Share	5%	5%	4%	4%	7%	3%
Average Revenue per Vendor	6	6	11	19	16	9
No. of ROW Vendors	-	-	-	1	1	1
ROW Market Share	-	-	-	0%	2%	3%
Average Revenue per Vendor	-	-	-	4	25	69

Source: Dataquest
April 1987

DATAQUEST ANALYSIS

Dataquest believes that strategic partnering between DRAM manufacturers and users is a key trend and will prevail because of the high market share concentration on a few suppliers. Despite possible changes in the composition of the top 10 vendors, the top 10 share is expected to remain high.

DRAM--Vendor Base Analysis

There are signs that changes in the makeup of the DRAM market leadership is probable. Despite the market share concentration, Dataquest expects more companies to enter the market. Other Korean companies besides Samsung--Hyundai and Goldstar--are still slated to enter and are reputed to have manufacturing costs that are competitive with the Japanese. European companies--such as Philips and Siemens--are forming alliances to bridge the technology gap in DRAMs. In addition, many U.S. manufacturers are expected to make a comeback in this market because of the DRAM's value as a technology driver. IBM's advances in 4Mb DRAMs and the contemplated Sematech, if properly implemented, may enable U.S. manufacturers to once more increase their market share.

Dataquest expects the same competitive intensity to continue in the coming years as all these factors come into play.

DRAM Vendor Base Analysis

THE DRAM VENDOR BASE

The prevailing trend in the dynamic RAM (DRAM) market is toward more complex technology. The current availability of 4Mb DRAMs, announcements of presampling of the 16Mb DRAM device, and prototypes of the 64Mb DRAM being developed and tested complicate the market even further.

This analysis will highlight changes in the number of DRAM vendors and the market concentration on the top five and ten vendors.

CHANGES IN VENDOR NUMBER

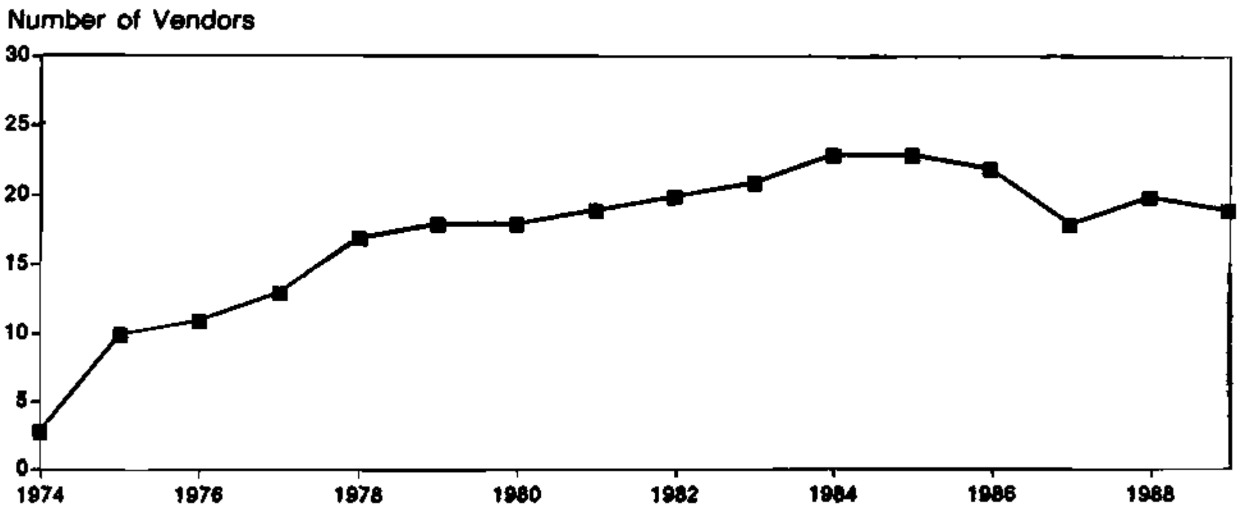
The number of DRAM vendors steadily increased until 1986 (see Figure 1). The total number of vendors in 1989 was down to 19 vendors from a peak of 23 in both 1984 and 1985. Dataquest expects the shrinking vendor base to reverse itself and once again grow; however, this growth will be in the form of joint ventures and of potential new entrants such as Sony.

Figure 2 shows a dramatic number of 12 companies leaving the DRAM market between 1981 and 1989. This trend may slow; many companies may elect to reenter or to remain in the DRAM market.

MARKET CONCENTRATION ON THE TOP FIVE AND TEN VENDORS

Figure 1

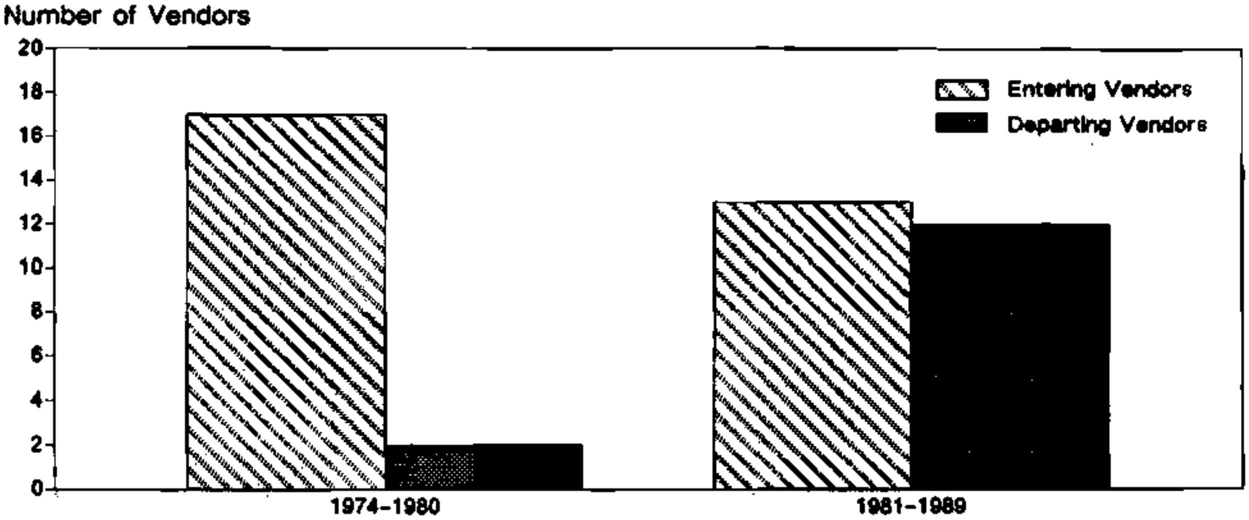
Total DRAM Vendor Base



Source: Dataquest (August 1990)

Figure 2

Vendors Entering and Departing DRAM



Source: Dataquest (August 1990)

In 1989, the average revenue per DRAM vendor was $512 million, which is about 15.5 times more than in 1981 (see Table 1).

The DRAM market is very competitive. The distribution of market share shows a heavy concentration on the top ten manufacturers. Since 1981, the top ten companies have held an average of just below 90 percent share of the market, despite the fact that the companies represented in the top ten have changed over the past nine-year period.

A study of the top five vendors and their market share shows further concentration. Market share of the top five vendors peaked at 73 percent in 1986 and slipped to 60 percent in 1989.

Table 1

Concentration of Top Five and Ten DRAM Vendors

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Number of Vendors	19	20	21	23	23	22	18	20	19
Average Revenue per Vendor ($M)	33	48	90	156	69	93	146	335	512
Top Ten Share (%)	90	90	90	89	87	93	93	89	87
Top Five Share (%)	62	62	64	61	66	73	65	62	60

Source: Dataquest (August 1990)

VENDORS BY REGION

Analysis of vendor activity by region shows the following:

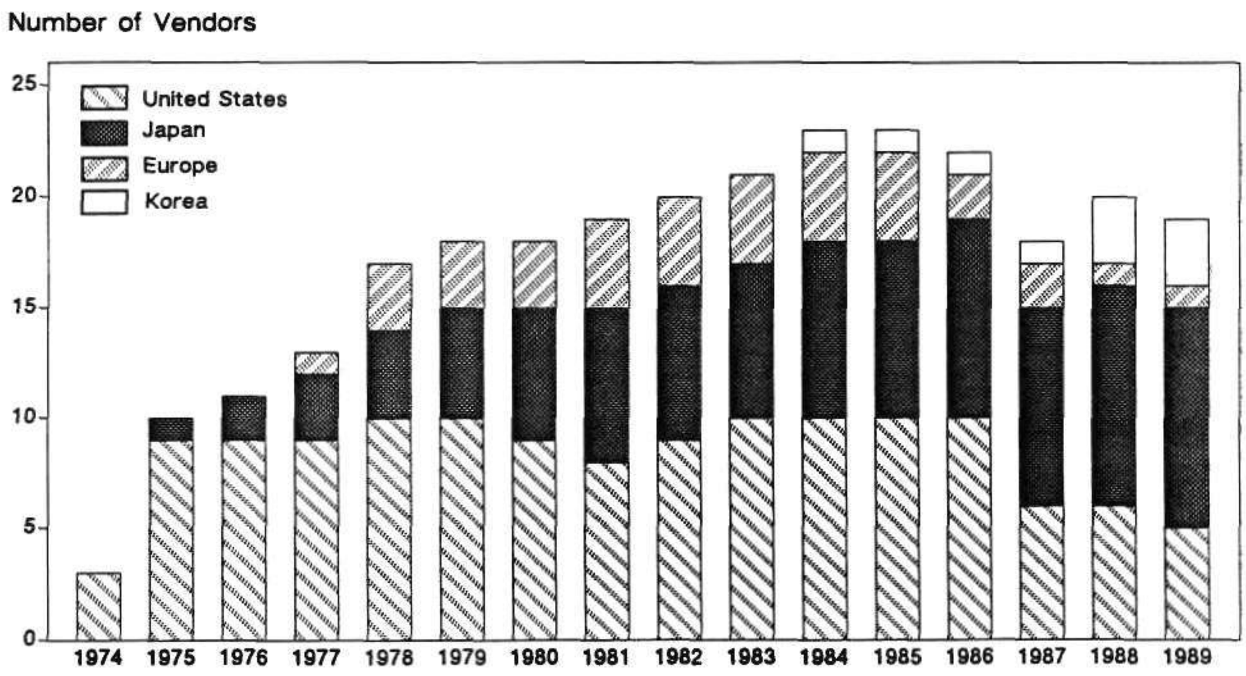
- The Japanese vendor base has exceeded that of the US base as shown (see Figure 3). Future vendors are expected to come primarily from Japan and joint venture activities.
- The Japanese vendors have focused primarily on high-density DRAMs. Figures 4 through 8 present the regional breakdown of vendors for 16K through 4Mb densities.
- The DRAM market is dominated by Japanese vendors (see Table 2). The average revenue per Japanese vendor is more than twice that of the US vendor and since 1982 has increased significantly through the years. The South Korean average, coming primarily from Samsung sales, is growing rapidly and exceeds the US average by 33 percent.
- Japanese vendors Fujitsu, Hitachi, Mitsubishi, NEC, Oki, and Toshiba are on the top ten list for 1989. Samsung, Texas Instruments, Motorola, and Siemens also are ranked in the top ten.

DATAQUEST ANALYSIS

Dataquest believes that strategic partnering between DRAM manufacturers and users is a key trend that will prevail because of the high market share concentration on a few suppliers. Despite possible changes in the composition of the top ten vendors, the share held by the top ten is expected to remain high.

Figure 3

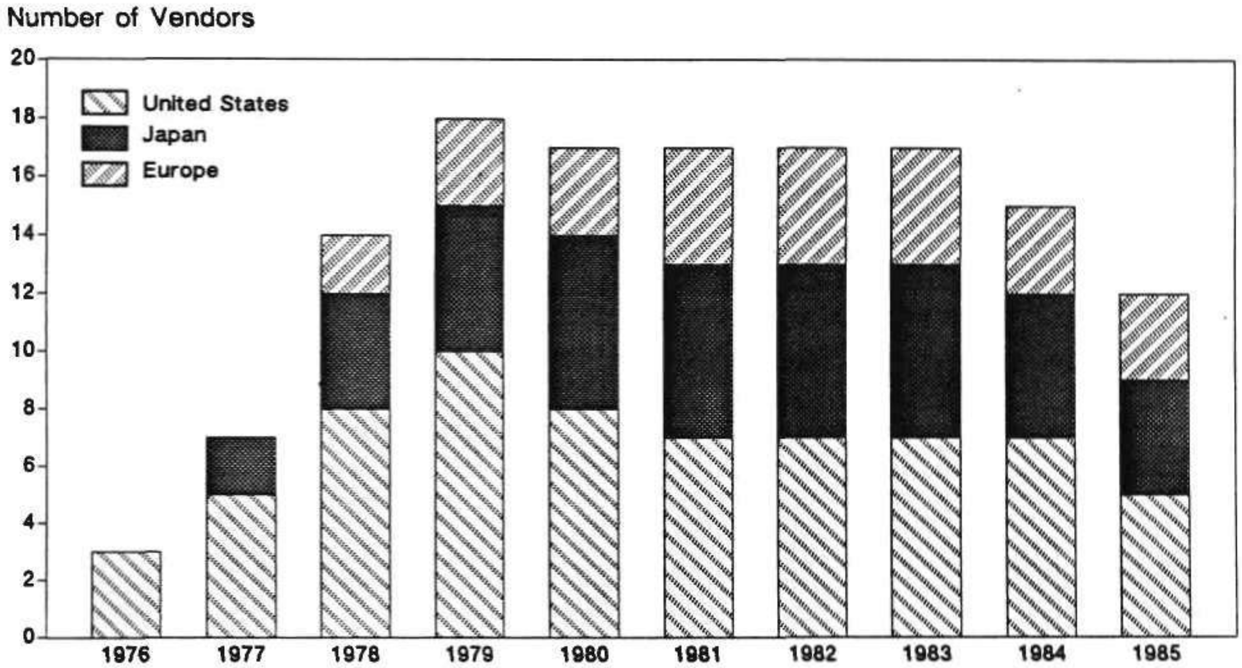
Total Vendor Base by Region



Source: Dataquest (August 1990)

Figure 4

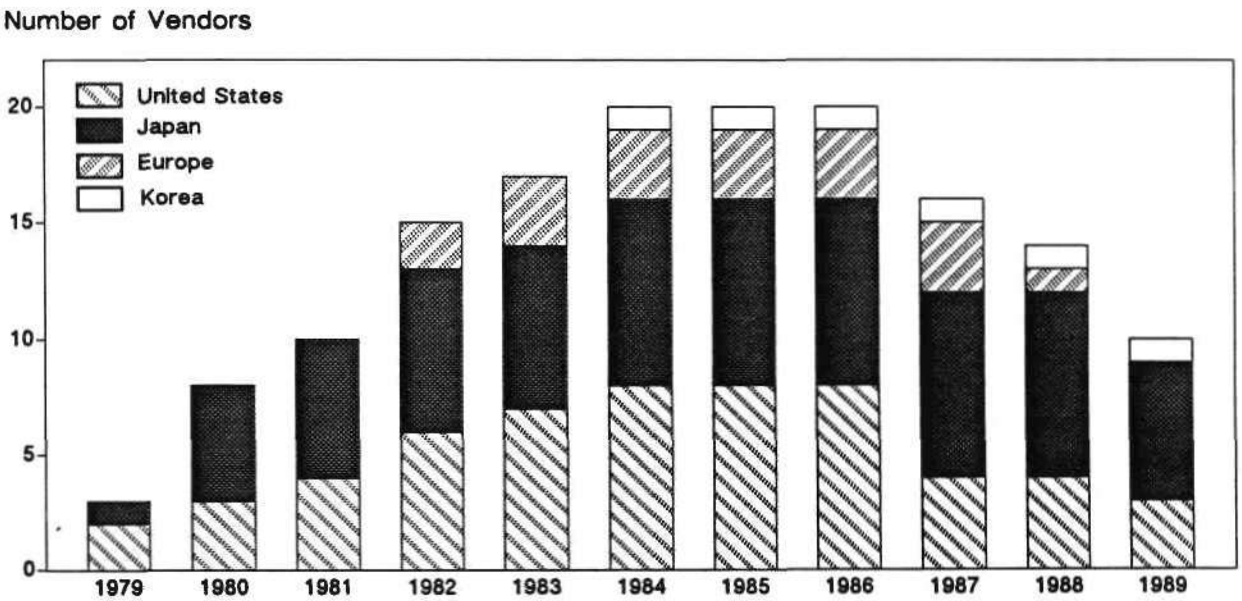
16K DRAM Vendor Base by Region



Source: Dataquest (August 1990)

Figure 5

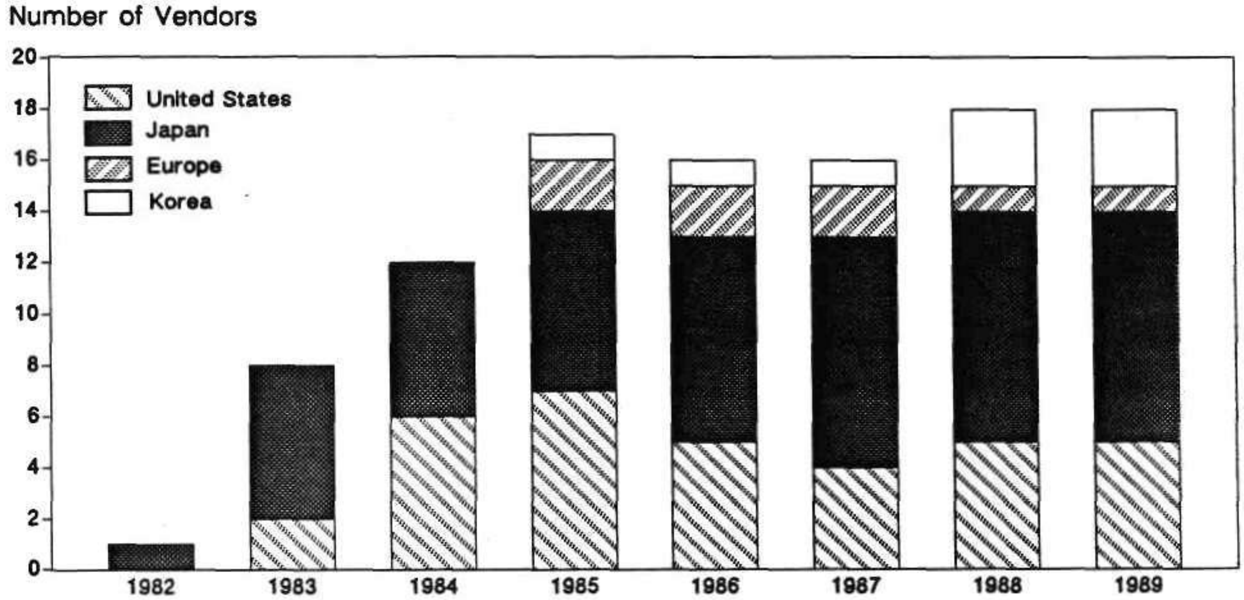
64K DRAM Vendor Base by Region



Source: Dataquest (August 1990)

Figure 6

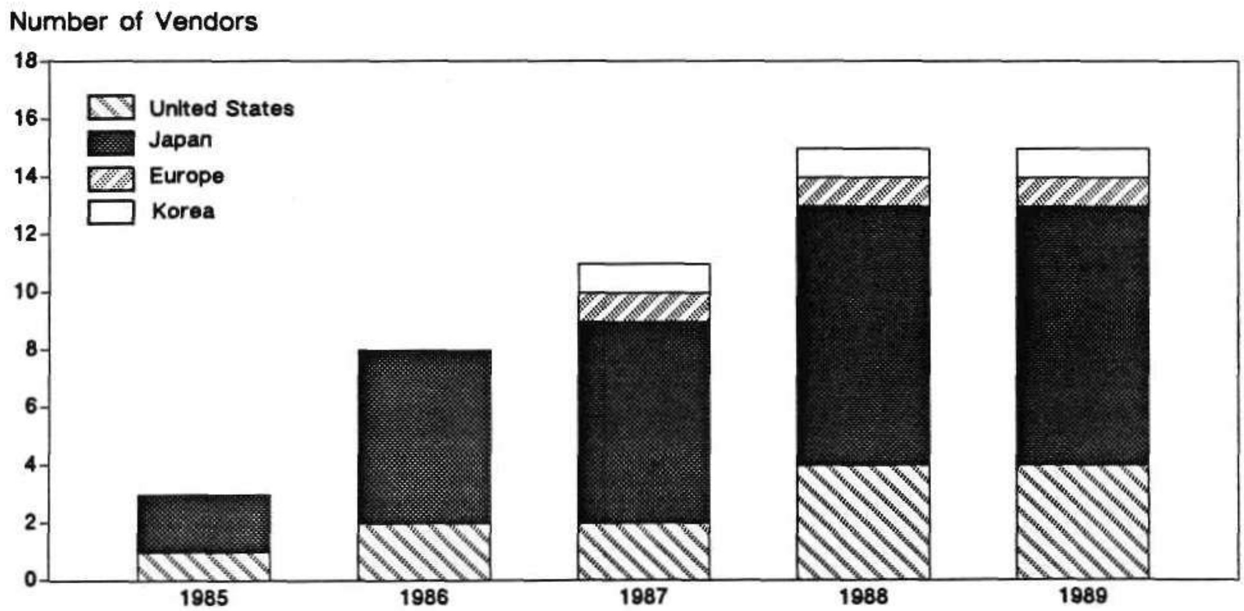
256K DRAM Vendor Base by Region



Source: Dataquest (August 1990)

Figure 7

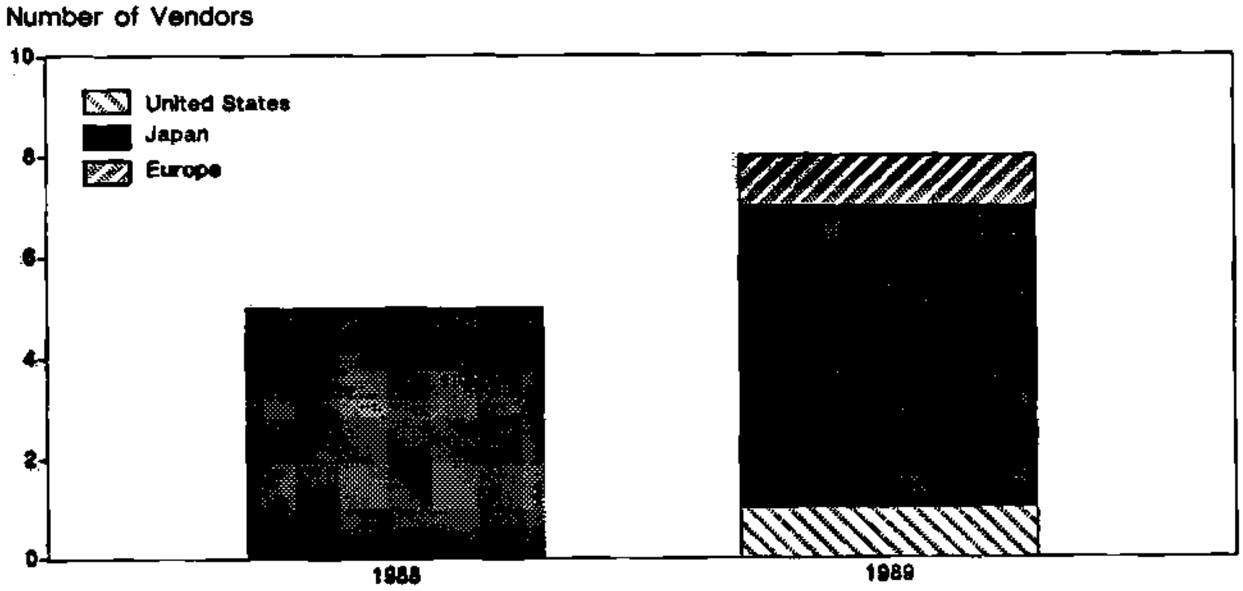
1Mb DRAM Vendor Base by Region



Source: Dataquest (August 1990)

Figure 8

4Mb DRAM Vendor Base by Region



Source: Dataquest (August 1990)

Table 2

DRAM Regional Vendor Concentration

Description	1981	1982	1983	1984	1985	1986	1987	1988	1989
Regional Concentration									
Number of US Vendors	8	9	10	10	10	10	6	6	5
US Market Share (%)	50	50	42	40	33	20	18	18	15
Average Revenue per Vendor ($M)	39	53	79	144	53	41	79	201	292
Number of Japanese Vendors	7	7	7	8	8	9	9	10	10
Japanese Market Share (%)	45	45	53	56	63	71	73	73	70
Average Revenue per Vendor ($M)	40	61	143	252	125	161	213	490	682
Number of European Vendors	4	4	4	4	4	2	2	1	1
European Market Share (%)	5	5	5	4	4	7	2	2	3
Average Revenue per Vendor ($M)	8	12	24	36	16	72	26	134	292
Number of ROW Vendors	0	0	0	1	1	1	1	3	3
ROW Market Share (%)	0	0	0	0	0	2	7	7	12
Average Revenue per Vendor ($M)	0	0	0	4	2	33	187	157	389
Total Vendors	19	20	21	23	23	22	18	20	19
Market Share (%)	100	100	100	100	100	100	100	100	100
Total Average Revenue per Vendor ($M)	33	48	90	156	69	93	146	335	512

Source: Dataquest (August 1990)

Samsung, because of its quick and sharp gain in market share, currently ranks third in the 1989 total DRAM market. Dataquest believes that other changes in the DRAM leadership are probable. Within the past year a number of joint ventures have been announced that involve DRAM technology. Some of these are the following:

- Hitachi and Goldstar
- NMB and Intel
- Oki and SGS-Thomson
- NMB and RAMTRON

Many US manufacturers are making a comeback in this market because of the DRAM's value as a technology driver. With IBM's advances in 4Mb DRAMs and its use of 8-inch wafers, Sematech, once properly implemented, may enable US manufacturers to once again increase their market share.

Dataquest expects the same competitive intensity to continue in the coming years as all of these factors come into play.

DRAM--Market Shares

OVERVIEW OF MARKET SHARES

This section presents an analysis of dynamic RAM (DRAM) market shares by company, region, and the top 5 and top 10 vendors for total DRAMs and for each of the present and past densities. In order to interpret our data correctly, the reader should understand our definition of market shares:

- All the market share percentages in this section are based on individual company or regional unit shares. On a product basis, Dataquest believes that the unit share is a better measure of overall competitiveness. It encompasses a company's ability to compete on a cost and manufacturing basis, which, in DRAMs, is critical to success.

- The overall DRAM market shares are based on "dollarized" units. Dollarized units represent the sum of all the units sold by a company weighted by each density's average selling price for that year. Although the resulting numbers are in dollars, they have no relation to the true revenue dollars of a company. They are still units expressed in weighted form in order to have a standard summary for overall DRAM market shares.

OVERALL DRAM MARKET SHARES

DRAM market share data are presented in the following tables:

- Table 1--DRAM Market Shares (Percentages)
- Table 2--DRAM Market Shares (Dollarized Unit Shares in Thousands)
- Table 3--DRAM Regional Shares (Percentages)
- Table 4--DRAM Regional Shares (Dollarized Unit Shares in Thousands)
- Table 5--DRAM Top 10 Shares (Percentages)
- Table 6--4K DRAM Market Shares (Percentages)
- Table 7--16K 3PS DRAM Market Shares (Percentages)
- Table 8--16K 5V DRAM Market Shares (Percentages)
- Table 9--64K DRAM Market Shares (Percentages)
- Table 10--256K DRAM Market Shares (Percentages)
- Table 11--1Mb DRAM Market Shares (Percentages)

DRAM—Market Shares

Highlights of the overall DRAM market include the following:

- Market share leaders have changed through the years, as shown in the tables. In 1976, the market was primarily dominated by Intel, Mostek, and Texas Instruments. By 1986, the top 5 vendors were all Japanese.

- Japanese companies have established their dominance of the DRAM market, capturing 78 percent of the market in 1986 from 44 percent in 1981 and a humble 16 percent in 1976. The turning point was 1982 when they broke away in the 256K DRAM market.

- The DRAM market has always been heavily concentrated in the top 10 vendors. Despite the fact that the companies in the top 10 have changed through the years, their shares have consistently held an average of about 90 percent of the market.

  - The DRAM market shows signs of increasing concentration, with the share of the top 5 vendors growing from 62 percent in 1981 to 73 percent in 1986.

  - In the 1986 field of competition, 5 vendors held 73 percent, 5 held 20 percent, and 15 held 7 percent.

- The nature of the top vendors has also changed through the years.

  - Japanese companies have had all five top slots since 1985. Of the total share of the top 10 vendors, 82 percent is held by Japanese manufacturers, an increase from 42 percent in 1981.

  - U.S. vendors have lost ground, achieving only 15 percent in 1986, down from 54 percent five years ago.

- Each density has had a different set of early leaders.

  - Intel was first in the 4K and 5-volt 16K markets.

  - In the 16K (3-power supply), Mostek led.

  - Fujitsu was first in the 64K market, and Hitachi gained an early lead in the 256K.

  - Now Toshiba has the advantage in the 1Mb DRAM market.

DRAM--Market Shares

- There are clear signs of potential market share changes in the future.
  - The Korean companies offer a significant threat to the Japanese. In 1986, their share went from obscure to material with Samsung's penetration of the 256K DRAM market.
  - Toshiba and Mitsubishi have gained market share and upgraded ranking at an impressive rate compared with more established vendors such as: Fujitsu, Hitachi, and NEC.

DATAQUEST ANALYSIS

The Japanese dominance of the DRAM market did not happen overnight. The Japanese established a technology lead in 64K DRAMs in 1979. They surpassed the U.S. market share in 1982 and in 1985, captured the top five DRAM vendor positions. What they gained has been achieved in the past ten years. Constant breast beating and lamenting the loss of share will not change that fact. It is clear that there are aspects of the Japanese economic system that have allowed them to progress.

The market share tables presented here tell us much more than the story of how Japan has successfully dominated the DRAM market. They tell us that the market share leaders have changed through the years and will continue to change in the future. They show us that market share leadership is gained from an early lead in technology, in being first at the next density. They show us a potential for change in the future market share profile.

Judging by history, Dataquest believes that the opportunities for success in the DRAM market are not closed. The dominance of certain Japanese companies still the threat of several other manufacturers. Toshiba and Mitsubishi have gained prominence and market share in the past two years and are challenging the positions of the stalwart leaders, Hitachi and NEC. Toshiba gained a clear advantage in the 1Mb DRAM market, while Mitsubishi is being successful with its popular ZIP package. The Korean manufacturers are slowly gaining market share and are reputed to have the ability to compete with the top Japanese vendors on a manufacturing cost basis. The U.S. companies are certainly not out of the picture. IBM's announcement of an early 4Mb DRAM production and the proposed manufacturing effort of Sematech may propel U.S. DRAM technology to the forefront in the coming years.

DRAM--Market Shares

Table 1

DRAM MARKET SHARES
(Percentages)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	0.1%	1.6%	3.3%	3.8%	3.6%	2.2%
AMI	0	0.9	0	0	0	0	0
AT&T	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	0
Fairchild	0	2.9	5.2	3.2	1.9	2.0	1.8
Fujitsu	0	0	2.5	6.6	6.5	7.7	11.9
Hitachi	0	0	0	1.3	4.3	7.9	7.7
Inmos	0	0	0	0	0	0	0
Intel	82.9%	45.6	19.0	20.0	12.7	5.9	2.9
Intersil	0	1.2	1.8	1.3	0.3	0.4	0.2
Matsushita	0	0	0	0	0	0	0.2
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	0	1.3	2.1
Mostek	4.1	13.8	18.7	24.0	22.9	22.8	19.2
Motorola	0	3.3	4.2	4.3	8.0	7.4	7.2
National	0	2.9	7.4	5.1	4.0	6.1	10.9
NEC	0	4.2	13.1	11.6	13.9	14.0	13.3
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	0
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	0	0.2	0.3	0.3
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	0	0.2	0.9	1.5
Signetics	0	0	0.8	1.2	1.0	0.3	0
STC (ITT)	0	0	0	0.4	1.5	3.6	3.2
Texas Instruments	13.0	25.1	25.7	17.8	18.0	13.3	11.0
Toshiba	0	0	0	0	0.8	2.1	4.3
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	0	0.2	0.2	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

DRAM--Market Shares

Table 1 (Continued)

DRAM MARKET SHARES
(Percentages)

Company	1981	1982	1983	1984	1985	1986
AMD	4.4%	2.5%	1.2%	0.8%	0.8%	0.2%
AMI	0	0	0	0	0	0
AT&T	0	0	0.3	1.5	3.1	3.0
Eurotechnique	0.2	0.6	0.5	0.2	0.4	0.1
Fairchild	1.1	0.4	0.1	0	0	0
Fujitsu	13.1	13.0	11.3	13.0	13.0	10.7
Hitachi	11.9	14.3	16.2	15.2	19.0	16.9
Inmos	0	0.1	0.7	1.4	0.9	0.9
Intel	4.1	3.5	3.6	1.6	1.2	0.1
Intersil	0	0	0	0	0	0
Matsushita	0.2	0.1	1.1	2.3	1.2	1.8
Micron Technology	0	0.7	1.8	4.3	3.1	4.2
Mitsubishi	3.1	7.0	7.1	8.0	7.6	13.9
Mostek	13.7	9.4	11.0	7.2	3.4	0.7
Motorola	7.5	8.7	8.6	6.2	3.8	1.7
National	8.8	4.9	1.2	0.9	0.9	0.3
NEC	12.6	13.7	14.0	14.9	17.0	17.0
NMB	0	0	0	0	0	0
Oki	1.3	3.8	4.3	5.7	3.2	3.2
Samsung	0	0	0	0.1	1.6	3.3
SGS-Ates	0.2	0.1	0.1	0	0	0
Sharp	0	0	0	0.1	0.1	0.1
Siemens	1.3	1.4	1.5	1.6	1.5	1.0
Signetics	0	0	0	0	0	0
STC (ITT)	3.4	2.4	1.5	0.6	0.8	0.2
Texas Instruments	10.8	12.0	11.8	10.3	7.4	6.5
Toshiba	2.3	1.4	2.4	4.0	9.8	14.2
Vitelic	0	0	0	0	0	0
Zilog	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 2

DRAM MARKET SHARES
(Dollarized Unit Shares in Thousands)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	31	2,036	6,201	12,012	19,976	21,435
AMI	0	281	0	0	0	0	0
AT&T	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	0
Fairchild	0	967	6,460	5,978	6,150	11,457	17,172
Fujitsu	0	0	3,110	12,529	20,518	43,278	114,600
Hitachi	0	0	0	2,412	13,561	44,445	73,788
Inmos	0	0	0	0	0	0	0
Intel	8,670	15,038	23,657	37,993	40,492	33,056	27,954
Intersil	0	406	2,227	2,385	819	1,980	2,377
Matsushita	0	0	0	0	0	0	1,455
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	0	7,538	19,866
Mostek	425	4,555	23,250	45,429	72,737	128,376	185,017
Motorola	0	1,092	5,242	8,193	25,302	41,826	69,354
National	0	967	9,200	9,739	12,640	34,464	104,704
NEC	0	1,373	16,269	21,940	44,034	78,795	128,028
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	0
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	0	655	1,458	3,044
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	0	725	5,276	14,072
Signetics	0	0	957	2,306	3,287	1,938	0
STC (ITT)	0	0	0	795	4,644	20,235	31,165
Texas Instruments	1,360	8,299	31,941	33,661	57,264	75,034	106,171
Toshiba	0	0	0	0	2,431	12,060	41,346
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	0	512	1,146	239
Total	10,455	33,010	124,349	189,559	317,782	562,339	961,785

(Continued)

Table 2 (Continued)

DRAM MARKET SHARES
(Dollarized Unit Shares in Thousands)

Company	1981	1982	1983	1984	1985	1986
AMD	27,418	23,725	22,495	28,225	11,806	3,616
AMI	0	0	0	0	0	0
AT&T	0	0	5,719	53,700	45,980	61,536
Eurotechnique	1,442	5,952	9,240	6,758	6,336	1,350
Fairchild	6,798	4,111	1,680	438	0	0
Fujitsu	82,331	123,302	212,300	466,756	191,617	217,833
Hitachi	74,555	136,185	304,889	546,150	278,469	346,587
Inmos	0	596	13,703	49,770	12,906	17,808
Intel	25,634	33,039	67,785	57,529	17,882	1,443
Intersil	255	0	0	0	0	0
Matsushita	1,483	1,031	20,591	81,165	17,363	37,358
Micron Tech.	0	6,612	34,547	154,250	45,920	86,022
Mitsubishi	19,760	66,746	133,209	287,976	111,310	284,120
Mostek	86,242	89,248	206,756	258,795	50,121	14,253
Motorola	46,944	82,897	161,748	224,155	56,429	35,051
National	55,046	46,167	22,298	33,667	13,624	1,095
NEC	78,931	130,358	263,123	534,947	250,237	348,517
NMB	0	0	0	0	0	752
Oki	8,085	35,880	80,617	204,340	47,318	64,941
Samsung	0	0	0	4,740	23,256	68,015
SGS-Ates	1,326	615	1,492	750	187	0
Sharp	0	0	0	5,372	1,450	2,266
Siemens	8,343	13,433	27,461	58,463	22,720	21,280
Signetics	0	0	0	0	0	0
STC (ITT)	21,651	23,228	27,426	20,360	12,048	3,776
Texas Inst.	67,677	113,767	223,459	371,450	108,159	132,005
Toshiba	14,373	13,612	45,207	144,706	143,361	289,373
Vitelic	0	0	0	0	0	947
Zilog	0	0	0	0	0	0
Total	628,295	950,506	1,885,745	3,594,460	1,468,497	2,044,943

Source: Dataquest
April 1987

DRAM--Market Shares

Table 3

DRAM REGIONAL SHARES
(Percentages)

Regional Shares	1974	1975	1976	1977	1978	1979	1980
U.S.	100.0%	95.8%	84.4%	80.1%	72.8%	62.1%	55.6%
Japan	0	4.2	15.6	19.5	25.3	33.1	39.4
Europe	0	0	0	0.4	1.9	4.8	5.0
Korea	0	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regional Shares	1981	1982	1983	1984	1985	1986
U.S.	50.3%	42.0%	39.6%	32.9%	20.4%	16.0%
Japan	44.5	53.4	56.2	63.2	70.9	77.8
Europe	5.2	4.6	4.2	3.8	7.1	2.9
Korea	0	0	0	0.1	1.6	3.3
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

DRAM--Market Shares

Table 4

DRAM REGIONAL SHARES
(Dollarized Unit Shares in Thousands)

Regional Shares	1974	1975	1976	1977	1978	1979	1980
U.S.	10,455	31,637	104,969	151,883	231,215	349,254	534,422
Japan	0	1,373	19,379	36,881	80,543	186,116	379,083
Europe	0	0	0	795	6,024	26,969	48,280
Korea	0	0	0	0	0	0	0
Total	10,455	33,010	124,349	189,559	317,782	562,339	961,785

Regional Shares	1981	1982	1983	1984	1985	1986
U.S.	316,014	399,567	746,487	1,182,208	299,799	326,715
Japan	279,518	507,114	1,059,936	2,271,411	1,041,124	1,591,747
Europe	32,763	43,825	79,322	136,101	104,317	58,466
Korea	0	0	0	4,740	23,256	68,015
Total	628,295	950,506	1,885,745	3,594,460	1,468,497	2,044,943

Source: Dataquest
April 1987

1987* (preliminary).
U.S. 472.5
Japan 1,899.0
total 2,609.0

DRAM--Market Shares

Table 5

DRAM TOP 10 SHARES
(Percentages)

Top 5 and 10 Shares	1981	1982	1983	1984	1985	1986
Top 5	62.0%	62.4%	64.2%	61.4%	66.4%	72.7%
U.S.	39.5%	34.2%	35.5%	16.8%	0	0
Japan	60.5%	65.8%	64.5%	83.2%	100.0%	100.0%
Europe	-	-	-	-	-	-
Korea	-	-	-	-	-	-
ROW	-	-	-	-	-	-
Next 5	28.1%	27.9%	25.9%	27.4%	21.0%	20.2%
U.S.	87.7%	61.2%	47.0%	64.6%	84.6%	67.8%
Japan	0	38.8%	53.0%	35.4%	15.4%	15.7%
Europe	12.3%	0	0	0	0	0
Korea	0	0	0	0	0	16.5%
ROW	-	-	-	-	-	-
Top 10	90.2%	90.2%	90.1%	88.8%	87.4%	92.9%
U.S.	54.5%	42.6%	38.8%	31.6%	20.3%	14.7%
Japan	41.6%	57.4%	61.2%	68.4%	79.7%	81.7%
Europe	3.8%	0	0	0	0	0
Korea	0	0	0	0	0	3.6%

Source: Dataquest
April 1987

Table 6

4K DRAM MARKET SHARES
(Percentages)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	0.1%	1.7%	4.1%	8.6%	14.6%	9.4%
AMI	0	0.9	0	0	0	0	0
Fairchild	0	2.9	5.3	3.6	1.6	0	0
Fujitsu	0	0	2.6	5.1	2.5	1.1	2.1
Hitachi	0	0	0	1.6	2.3	1.2	0.6
Intel	82.9%	45.6	18.7	18.1	14.3	8.7	3.2
Intersil	0	1.2	1.8	1.6	0.6	1.4	3.9
Mostek	4.1	13.8	17.9	20.6	22.0	20.1	22.8
Motorola	0	3.3	4.3	4.8	7.4	9.2	16.2
National	0	2.9	7.6	6.4	7.3	11.3	14.6
NEC	0	4.2	13.4	10.6	8.0	7.9	4.7
SGS-Ates	0	0	0	0	0.5	1.1	3.9
Signetics	0	0	0.8	1.5	1.5	0.7	0
STC (ITT)	0	0	0	0.5	2.1	7.4	16.0
Texas Instruments	13.0	25.1	26.1	21.6	21.6	15.3	2.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Company	1981	1982	1983	1984	1985
AMD	12.7%	5.5%	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	1.5	0.3	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	1.1	0	0	0	0
Mostek	17.3	19.4	34.4%	66.7%	80.9%
Motorola	24.9	31.7	12.5	4.4	0
National	16.1	15.3	10.4	0	0
NEC	2.5	0	0	0	0
SGS-Ates	5.1	5.7	17.7	11.1	2.1
Signetics	0	0	0	0	0
STC (ITT)	18.9	22.0	25.0	17.8	17.0
Texas Instruments	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 7

16K 3PS DRAM MARKET SHARES
(Percentages)

Company	1976	1977	1978	1979	1980
AMD	0	0	0	0.1%	1.8%
Eurotechnique	0	0	0	0	0
Fairchild	0	1.2%	2.2%	2.7	2.0
Fujitsu	0	12.9	9.6	9.3	12.3
Hitachi	0	0	5.8	10.2	7.8
Intel	37.0%	27.9	11.5	4.4	2.1
Intersil	0	0	0	0	0
Matsushita	0	0	0	0	0.2
Mitsubishi	0	0	0	1.8	2.2
Mostek	55.6	37.8	23.6	24.0	19.6
Motorola	0	2.5	8.4	6.7	6.0
National	0	0	1.4	4.6	11.0
NEC	0	15.4	18.5	16.2	14.3
SGS-Ates	0	0	0	0	0.1
Siemens	0	0	0.4	1.3	1.6
Signetics	0	0	0.7	0.3	0
STC (ITT)	0	0	1.0	2.4	2.5
Texas Instruments	7.4	2.1	15.2	12.9	11.9
Toshiba	0	0	1.4	2.9	4.7
Zilog	0	0	0.3	0.3	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 7 (Continued)

16K 3PS DRAM MARKET SHARES
(Percentages)

Company	1981	1982	1983	1984	1985	1986
AMD	5.5%	7.1%	8.4%	7.0%	9.1%	8.3%
Eurotechnique	0.3	1.8	3.7	5.1	9.6	8.3
Fairchild	1.5	1.2	0.7	0.2	0	0
Fujitsu	13.5	8.8	5.2	4.6	2.7	0
Hitachi	6.0	5.9	5.4	6.6	3.0	0
Intel	2.4	2.3	1.9	1.4	0	0
Intersil	0	0	0	0	0	0
Matsushita	0.3	0.3	0.1	0	0	0
Mitsubishi	1.8	0.9	0.4	0.3	0	0
Mostek	18.1	13.8	7.4	5.0	5.0	8.3
Motorola	4.2	5.5	6.3	6.9	5.6	8.3
National	11.5	13.8	8.4	7.0	10.2	5.8
NEC	14.0	15.2	16.8	17.2	12.0	16.7
SGS-Ates	0	0.1	0.1	0	0	0
Siemens	1.9	3.6	5.0	7.2	16.0	25.0
Signetics	0	0	0	0	0	0
STC (ITT)	3.9	6.6	9.8	9.3	13.0	12.5
Texas Instruments	11.9	10.5	16.1	17.4	8.4	4.2
Toshiba	3.0	2.7	4.2	4.8	5.3	2.5
Zilog	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 8

16K 5V DRAM MARKET SHARES
(Percentages)

Company	1979	1980	1981	1982	1983	1984	1985	1986
Fujitsu	0	0	4.2%	9.7%	16.6%	22.2%	10.5%	6.3%
Hitachi	0	4.0%	23.6	31.4	23.5	20.9	21.5	12.5
Intel	100.0%	94.2	66.5	33.1	11.7	12.3	6.9	6.3
Mostek	0	0	1.9	19.8	24.0	15.0	10.0	12.5
Motorola	0	1.8	3.2	4.9	21.8	26.6	51.1	62.5
National	0	0	0.4	0	0	0	0	0
Texas Inst.	0	0	0.2	1.0	2.4	3.0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 9

64K DRAM MARKET SHARES
(Percentages)

Company	1979	1980	1981	1982	1983	1984	1985	1986
AMD	0	0	0	0	0.1%	0.7%	1.0%	0.5%
Fairchild	0	0	0	0	0	0	0	0
Fujitsu	66.7%	29.5%	15.2%	15.9%	11.0	11.2	12.1	7.5
Hitachi	0	23.8	30.9	17.6	16.3	12.2	13.4	10.1
Inmos	0	0	0	0.1	1.0	1.8	2.2	2.5
Intel	0	0.7	0.2	1.5	3.5	1.7	0.3	0.1
Matsushita	0	0	0	0	1.4	3.0	1.8	2.9
Micron Tech.	0	0	0	1.2	2.4	5.7	6.5	4.4
Mitsubishi	0	3.9	8.4	11.3	9.0	9.9	11.6	18.2
Mostek	0	0	1.1	5.8	11.0	8.6	6.0	1.7
Motorola	27.8	34.0	15.6	10.7	8.4	7.1	6.0	4.9
National	0	0	0	0	.0	0.9	1.1	1.2
NEC	0	1.1	11.5	14.3	14.4	12.2	13.3	14.0
Oki	0	0	5.8	6.4	5.6	6.9	5.1	4.9
Samsung	0	0	0	0	0	0.2	3.9	9.4
Sharp	0	0	0	0	0	0.2	0.2	0.5
Siemens	0	0	0	0.3	1.0	1.8	2.0	2.5
STC (ITT)	0	0	0	0	0.1	0.3	0.3	0.4
Texas Inst.	5.6	5.4	10.6	14.0	12.6	12.8	9.7	8.4
Toshiba	0	1.6	0.6	0.9	2.2	2.7	3.5	5.6
Vitelic	0	0	0	0	0	0	0	0.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 10

256K DRAM MARKET SHARES
(Percentages)

Company	1982	1983	1984	1985	1986
AMD	0	0	0	0	0
ATT Technologies	0	7.1%	7.9%	6.1%	3.2%
Fujitsu	0	28.2	20.8	15.3	12.6
Hitachi	100.0%	38.2	28.2	25.2	19.6
Inmos	0	0	0	0	0.5
Intel	0	0	0.1	1.9	0
Matsushita	0	0	0	0.9	1.8
Micron Technology	0	0	0.1	1.0	4.7
Mitsubishi	0	3.5	3.0	5.7	12.8
Mostek	0	0.3	0.4	0.1	0.3
Motorola	0	0	0	0	0.3
National	0	0	0	0	0
NEC	0	17.6	27.0	21.8	20.1
Oki Electric	0	0.9	2.6	2.3	3.1
Samsung	0	0	0	0	2.0
Siemens	0	0	0	0.1	0.5
Texas Instruments	0	0	0.4	6.1	6.7
Toshiba	0	4.1	9.5	13.6	11.7
Vitelic	0	0	0	0	0.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

Table 11

1Mb DRAM MARKET SHARE
(Percentages)

Company	1985	1986
AT&T	0.6%	9.0%
Fujitsu	0	3.2
Hitachi	1.2	13.8
Matsushita	0	0
Micron Technology	0	0
Mitsubishi	0	14.6
NEC	0	0.1
NMB	0	0.4
Oki	0	0.3
Texas Instruments	0	0.6
Toshiba	98.2	58.0
Vitelic	0	0
Total	100.0%	100.0%

Source: Dataquest
April 1987

DRAM—Market Shares

OVERVIEW OF MARKET SHARES

This section presents an analysis of dynamic RAM (DRAM) market shares by company, region, and the top 5 and top 10 vendors for total DRAMs and for each of the present and past densities. In order to interpret our data correctly, the reader should understand our definition of market shares:

- All the market share percentages in this section are based on individual company or regional unit shares. On a product basis, Dataquest believes that the unit share is a better measure of overall competitiveness. It encompasses a company's ability to compete on a cost and manufacturing basis, which, in DRAMs, is critical to success.

- The overall DRAM market shares are based on "dollarized" units. Dollarized units represent the sum of all the units sold by a company weighted by each density's average selling price for that year. Although the resulting numbers are in dollars, they have no relation to the true revenue dollars of a company. They are still units expressed in weighted form in order to have a standard summary for overall DRAM market shares.

OVERALL DRAM MARKET SHARES

DRAM market share data are presented in the following tables:

- Table 1—DRAM Market Shares (Percentages)
- Table 2—DRAM Market Shares (Dollarized Unit Shares in Thousands)
- Table 3—DRAM Regional Shares (Percentages)
- Table 4—DRAM Regional Shares (Dollarized Unit Shares in Thousands)
- Table 5—DRAM Top 10 Shares (Percentages)
- Table 6—4K DRAM Market Shares (Percentages)
- Table 7—16K 3PS DRAM Market Shares (Percentages)
- Table 8—16K 5V DRAM Market Shares (Percentages)
- Table 9—64K DRAM Market Shares (Percentages)
- Table 10—256K DRAM Market Shares (Percentages)
- Table 11—1Mb DRAM Market Shares (Percentages)

DRAM--Market Shares

Dramatic shifts in market share occurred in 1987, primarily sparked by the series of political events of that year.

- The foreign market value system allowed non-Japanese manufacturers to price 256K DRAMs below Japanese FMV levels and fill their factories with orders.
- MITI imposed DRAM production cuts for two consecutive quarters in anticipation of a perceived poor demand for 1987.
- Japanese manufacturers delayed capacity buildup decisions in the face of the political uncertainty and missed the opportunity to meet the explosive demand in the second half of 1987.
- U.S. manufacturers boosted their capacity. Texas Instruments brought up its Dallas fab and signed up Hyundai as a DRAM foundry. Micron Technology underwent a major die shrink and process revision that significantly increased its capacity by the fourth quarter of 1987.

Besides the political influences, the yen appreciated rapidly versus the dollar, precipitating concerns by Japanese manufacturers for their profits. The strong yen effectively reduced the pricing and competitive flexibility of Japanese vendors.

A second nonpolitical influence is the emergence of Korean manufacturers, most notably, Samsung. Samsung's DRAM revenue increased by 174 percent in 1987, the highest growth among DRAM vendors.

The highlights of the 1987 DRAM market shares were as follows:

- Japanese vendors lost market share in 1987. This is unprecedented. Japanese manufacturers have been gaining market share consistently since they entered the market in 1975. Japan's market share dropped from 78 percent in 1986 to 73 percent in 1987. Despite the drop, Japan still enjoys market leadership, which it has held since 1982.
- U.S. vendors, on the other hand, increased their market share in DRAMs for the first time since 1974. The 1987 U.S. share rose to 18 percent in 1987 from 16 percent in 1986.
- Korea, or more specifically Samsung, also gained substantially, increasing its share to 7 percent in 1987 from 3 percent in 1986.
- European vendors decreased their market share, from 3 percent in 1986 to 2 percent in 1987. Inmos and Thomson Mostek have been slowly exiting the DRAM market. Siemens has remained in the market but has suffered production delays of its 1Mb DRAM.

DRAM--Market Shares

- The ranking of companies has also changed. Hitachi dropped from the top slot to fifth position. Fujitsu dropped to sixth rank. The big gainers are Toshiba, Mitsubishi, Texas Instruments, and Samsung. Toshiba took first position followed by NEC. Texas Instruments reentered the top five.

- The top 10 DRAM vendors continue to dominate, holding 93 percent of the market. However, in 1987, the top 5 companies performed poorer than the next 5. The top 5 companies now hold only 65 percent of the market versus their 73 percent share in 1986.

- In 64K DRAMs, Samsung leads the pack followed by NEC, Mitsubishi, and Texas Instruments. Together, these four companies account for 57 percent of the worldwide supply of 64K DRAMs. In 1988, the 64K DRAM supply has worsened, and users are extremely concerned about long-term availability and their dependence on a few manufacturers.

- In 256K DRAMs, NEC still commands a substantial lead, followed by Texas Instruments, Fujitsu, Mitsubishi, and Hitachi. However, in 1988, only NEC among the four 1987 top vendors has remained a staunch supplier of 256K DRAMs. Samsung and Micron Technology have since improved their shares.

- In 1Mb DRAMs, Toshiba supplied more than half of the world's demand, followed by Hitachi and Mitsubishi.

DATAQUEST ANALYSIS

The effect of exchange rates in market share dynamics should not be underplayed. Japanese manufacturers gained substantial market share in DRAMs, not only because of their technology lead in 64K and 256K DRAMs, but also because of the strong dollar. Today, we have shifted from an era of a strong dollar to the age of a strong yen. This shift will sap some competitive fervor from the Japanese. Already, Dataquest hears more concern for profits than for market share.

Politics has also played a key role. The foreign market value (FMV) system helped move the market toward U.S. vendors. Dataquest does not yet see the end of the road. As long as the trade deficit between Japan and the United States remains large, the system will exist. These two influences should more than ever encourage the U.S. and European manufacturers to reenter the market.

DRAM--Market Shares

Table 1

DRAM Market Shares
(Percentages)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	0.1%	1.6%	3.3%	3.8%	3.6%	2.2%
AMI	0	0.9	0	0	0	0	0
AT&T	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	0
Fairchild	0	2.9	5.2	3.2	1.9	2.0	1.8
Fujitsu	0	0	2.5	6.6	6.5	7.7	11.9
Hitachi	0	0	0	1.3	4.3	7.9	7.7
Inmos	0	0	0	0	0	0	0
Intel	82.9%	45.6	19.0	20.0	12.7	5.9	2.9
Intersil	0	1.2	1.8	1.3	0.3	0.4	0.2
Matsushita	0	0	0	0	0	0	0.2
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	0	1.3	2.1
Mostek	4.1	13.8	18.7	24.0	22.9	22.8	19.2
Motorola	0	3.3	4.2	4.3	8.0	7.4	7.2
National	0	2.9	7.4	5.1	4.0	6.1	10.9
NEC	0	4.2	13.1	11.6	13.9	14.0	13.3
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	0
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	0	0.2	0.3	0.3
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	0	0.2	0.9	1.5
Signetics	0	0	0.8	1.2	1.0	0.3	0
STC (ITT)	0	0	0	0.4	1.5	3.6	3.2
Texas Instruments	13.0	25.1	25.7	17.8	18.0	13.3	11.0
Toshiba	0	0	0	0	0.8	2.1	4.3
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	0	0.2	0.2	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

DRAM Market Shares
(Percentages)

Company	1981	1982	1983	1984	1985	1986	1987
AMD	4.4%	2.5%	1.2%	0.8%	0.8%	0.2%	0
AMI	0	0	0	0	0	0	0
AT&T	0	0	0.3	1.5	3.1	3.0	0
Eurotechnique	0.2	0.6	0.5	0.2	0.4	0.1	0
Fairchild	1.1	0.4	0.1	0	0	0	0
Fujitsu	13.1	13.0	11.3	13.0	13.0	10.7	9.1%
Hitachi	11.9	14.3	16.2	15.2	19.0	16.9	10.7
Inmos	0	0.1	0.7	1.4	0.9	0.9	0.6
Intel	4.1	3.5	3.6	1.6	1.2	0.1	0.2
Intersil	0	0	0	0	0	0	0
Matsushita	0.2	0.1	1.1	2.3	1.2	1.8	1.7
Micron Technology	0	0.7	1.8	4.3	3.1	4.2	4.2
Mitsubishi	3.1	7.0	7.1	8.0	7.6	13.9	12.1
Mostek	13.7	9.4	11.0	7.2	3.4	0.7	0.1
Motorola	7.5	8.7	8.6	6.2	3.8	1.7	2.3
National	8.8	4.9	1.2	0.9	0.9	0.3	0
NEC	12.6	13.7	14.0	14.9	17.0	17.0	14.1
NMB	0	0	0	0	0	0	1.5
Oki	1.3	3.8	4.3	5.7	3.2	3.2	4.6
Samsung	0	0	0	0.1	1.6	3.3	7.2
SGS-Ates	0.2	0.1	0.1	0	0	0	0
Sharp	0	0	0	0.1	0.1	0.1	1.8
Siemens	1.3	1.4	1.5	1.6	1.5	1.0	1.3
Signetics	0	0	0	0	0	0	0
STC (ITT)	3.4	2.4	1.5	0.6	0.8	0.2	0
Texas Instruments	10.8	12.0	11.8	10.3	7.4	6.5	11.0
Toshiba	2.3	1.4	2.4	4.0	9.8	14.2	17.4
Vitelic	0	0	0	0	0	0	0.2
Zilog	0	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM--Market Shares

Table 2

DRAM Market Shares
(Dollarized Unit Shares in Thousands)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	31	2,036	6,201	12,012	19,976	21,435
AMI	0	281	0	0	0	0	0
AT&T	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	0
Fairchild	0	967	6,460	5,978	6,150	11,457	17,172
Fujitsu	0	0	3,110	12,529	20,518	43,278	114,600
Hitachi	0	0	0	2,412	13,561	44,445	73,788
Inmos	0	0	0	0	0	0	0
Intel	8,670	15,038	23,657	37,993	40,492	33,056	27,954
Intersil	0	406	2,227	2,385	819	1,980	2,377
Matsushita	0	0	0	0	0	0	1,455
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	0	7,538	19,866
Mostek	425	4,555	23,250	45,429	72,737	128,376	185,017
Motorola	0	1,092	5,242	8,193	25,302	41,826	69,354
National	0	967	9,200	9,739	12,640	34,464	104,704
NEC	0	1,373	16,269	21,940	44,034	78,795	128,028
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	0
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	0	655	1,458	3,044
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	0	725	5,276	14,072
Signetics	0	0	957	2,306	3,287	1,938	0
STC (ITT)	0	0	0	795	4,644	20,235	31,165
Texas Instruments	1,360	8,299	31,941	33,661	57,264	75,034	106,171
Toshiba	0	0	0	0	2,431	12,060	41,346
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	0	512	1,146	239
Total	10,455	33,010	124,349	189,559	317,782	562,339	961,785

(Continued)

DRAM—Market Shares

Table 2 (Continued)

DRAM Market Shares
(Dollarized Unit Shares in Thousands)

Company	1981	1982	1983	1984	1985	1986	1987
AMD	27,418	23,725	22,495	28,225	11,806	3,616	0
AMI	0	0	0	0	0	0	0
AT&T	0	0	5,719	53,700	45,980	61,536	0
Eurotech-nique	1,442	5,952	9,240	6,758	6,336	1,350	0
Fairchild	6,798	4,111	1,680	438	0	0	0
Fujitsu	82,331	123,302	212,300	466,756	191,617	217,833	240,431
Hitachi	74,555	136,185	304,889	546,150	278,469	346,587	278,662
Inmos	0	596	13,703	49,770	12,906	17,808	15,780
Intel	25,634	33,039	67,785	57,529	17,882	1,443	4,720
Intersil	255	0	0	0	0	0	0
Matsushita	1,483	1,031	20,591	81,165	17,363	37,358	43,532
Micron Tech.	0	6,612	34,547	154,250	45,920	86,022	109,743
Mitsubishi	19,760	66,746	133,209	287,976	111,310	284,120	313,780
Motorola	46,944	82,897	161,748	224,155	56,429	35,051	61,005
National	55,046	46,167	22,298	33,667	13,624	1,095	0
NEC	78,931	130,358	263,123	534,947	250,237	348,517	368,800
NMB	0	0	0	0	0	752	37,760
Oki	8,085	35,880	80,617	204,340	47,318	64,941	122,152
Samsung	0	0	0	4,740	23,256	68,015	186,275
SGS-Ates	1,326	615	1,492	750	187	0	0
Sharp	0	0	0	5,372	1,450	2,266	47,190
Siemens	8,343	13,433	27,461	58,463	22,720	21,280	33,595
Signetics	0	0	0	0	0	0	0
STC (ITT)	21,651	23,228	27,426	20,360	12,048	3,776	864
TCMC	86,242	89,248	206,756	258,795	50,121	14,253	2,160
Texas Inst.	67,677	113,767	223,459	371,450	108,159	132,005	286,575
Toshiba	14,373	13,612	45,207	144,706	143,361	289,373	452,755
Vitelic	0	0	0	0	0	947	4,071
Zilog	0	0	0	0	0	0	0
Total	628,295	950,506	1,885,745	3,594,460	1,468,497	2,044,943	2,609,849

Source: Dataquest
June 1988

DRAM--Market Shares

Table 3

DRAM Regional Shares
(Percentages)

Regional Shares	1974	1975	1976	1977	1978	1979	1980
U.S.	100.0%	95.8%	84.4%	80.1%	72.8%	62.1%	55.6%
Japan	0	4.2	15.6	19.5	25.3	33.1	39.4
Europe	0	0	0	0.4	1.9	4.8	5.0
Rest of World	0	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regional Shares	1981	1982	1983	1984	1985	1986	1987
U.S.	50.3%	42.0%	39.6%	32.9%	20.4%	16.0%	17.9%
Japan	44.5	53.4	56.2	63.2	70.9	77.8	73.0
Europe	5.2	4.6	4.2	3.8	7.1	2.9	2.0
Rest of World	0	0	0	0.1	1.6	3.3	7.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM--Market Shares

Table 4

DRAM Regional Shares
(Dollarized Unit Shares in Thousands)

Regional Shares	1974	1975	1976	1977	1978	1979	1980
U.S.	10,455	31,637	104,969	151,883	231,215	349,254	534,422
Japan	0	1,373	19,379	36,881	80,543	186,116	379,083
Europe	0	0	0	795	6,024	26,969	48,280
Rest of World	0	0	0	0	0	0	0
Total	10,455	33,010	124,349	189,559	317,782	562,339	961,785

Regional Shares	1981	1982	1983	1984	1985	1986	1987
U.S.	316,014	399,567	746,487	1,182,208	299,799	326,715	466,113
Japan	279,518	507,114	1,059,936	2,271,411	1,041,124	1,591,747	1,905,062
Europe	32,763	43,825	79,322	136,101	104,317	58,466	52,399
Rest of World	0	0	0	4,740	23,256	68,015	186,275
Total	628,295	950,506	1,885,745	3,594,460	1,468,497	2,044,943	2,609,849

Source: Dataquest
June 1988

DRAM--Market Shares

Table 5

DRAM Top 10 Shares
(Percentages)

Top 5 and 10 Shares	1981	1982	1983	1984	1985	1986	1987
Top 5	62.0%	62.4%	64.2%	61.4%	66.4%	72.7%	65.2%
U.S.	39.5%	34.2%	35.5%	16.8%	0	0	16.9%
Japan	60.5%	65.8%	64.5%	83.2%	100.0%	100.0%	83.1%
Europe	-	-	-	-	-	-	-
Korea	-	-	-	-	-	-	-
ROW	-	-	-	-	-	-	-
Next 5	28.1%	27.9%	25.9%	27.4%	21.0%	20.2%	27.6%
U.S.	87.7%	61.2%	47.0%	64.6%	84.6%	67.8%	23.7%
Japan	0	38.8%	53.0%	35.4%	15.4%	15.7%	50.4%
Europe	12.3%	0	0	0	0	0	0
Korea	0	0	0	0	0	16.5%	25.9%
ROW	-	-	-	-	-	-	-
Top 10	90.2%	90.2%	90.1%	88.8%	87.4%	92.9%	92.7%
U.S.	54.5%	42.6%	38.8%	31.6%	20.3%	14.7%	18.9%
Japan	41.6%	57.4%	61.2%	68.4%	79.7%	81.7%	73.4%
Europe	3.8%	0	0	0	0	0	0
Korea	0	0	0	0	0	3.6%	7.7%

Source: Dataquest
June 1988

Table 6

4K DRAM Market Shares
(Percentages)

Company	1974	1975	1976	1977	1978	1979	1980
AMD	0	0.1%	1.7%	4.1%	8.6%	14.6%	9.4%
AMI	0	0.9	0	0	0	0	0
Fairchild	0	2.9	5.3	3.6	1.6	0	0
Fujitsu	0	0	2.6	5.1	2.5	1.1	2.1
Hitachi	0	0	0	1.6	2.3	1.2	0.6
Intel	82.9%	45.6	18.7	18.1	14.3	8.7	3.2
Intersil	0	1.2	1.8	1.6	0.6	1.4	3.9
Mostek	4.1	13.8	17.9	20.6	22.0	20.1	22.8
Motorola	0	3.3	4.3	4.8	7.4	9.2	16.2
National	0	2.9	7.6	6.4	7.3	11.3	14.6
NEC	0	4.2	13.4	10.6	8.0	7.9	4.7
SGS-Ates	0	0	0	0	0.5	1.1	3.9
Signetics	0	0	0.8	1.5	1.5	0.7	0
STC (ITT)	0	0	0	0.5	2.1	7.4	16.0
Texas Instruments	13.0	25.1	26.1	21.6	21.6	15.3	2.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Company	1981	1982	1983	1984	1985
AMD	12.7%	5.5%	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	1.5	0.3	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	1.1	0	0	0	0
Mostek	17.3	19.4	34.4%	66.7%	80.9%
Motorola	24.9	31.7	12.5	4.4	0
National	16.1	15.3	10.4	0	0
NEC	2.5	0	0	0	0
SGS-Ates	5.1	5.7	17.7	11.1	2.1
Signetics	0	0	0	0	0
STC (ITT)	18.9	22.0	25.0	17.8	17.0
Texas Instruments	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

Table 7

16K 3PS DRAM Market Shares
(Percentages)

Company	1976	1977	1978	1979	1980
AMD	0	0	0	0.1%	1.8%
Eurotechnique	0	0	0	0	0
Fairchild	0	1.2%	2.2%	2.7	2.0
Fujitsu	0	12.9	9.6	9.3	12.3
Hitachi	0	0	5.8	10.2	7.8
Intel	37.0%	27.9	11.5	4.4	2.1
Intersil	0	0	0	0	0
Matsushita	0	0	0	0	0.2
Mitsubishi	0	0	0	1.8	2.2
Mostek	55.6	37.8	23.6	24.0	19.6
Motorola	0	2.5	8.4	6.7	6.0
National	0	0	1.4	4.6	11.0
NEC	0	15.4	18.5	16.2	14.3
SGS-Ates	0	0	0	0	0.1
Siemens	0	0	0.4	1.3	1.6
Signetics	0	0	0.7	0.3	0
STC (ITT)	0	0	1.0	2.4	2.5
Texas Instruments	7.4	2.1	15.2	12.9	11.9
Toshiba	0	0	1.4	2.9	4.7
Zilog	0	0	0.3	0.3	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 7 (Continued)

16K 3PS DRAM Market Shares
(Percentages)

Company	1981	1982	1983	1984	1985	1986
AMD	5.5%	7.1%	8.4%	7.0%	9.1%	8.3%
Eurotechnique	0.3	1.8	3.7	5.1	9.6	8.3
Fairchild	1.5	1.2	0.7	0.2	0	0
Fujitsu	13.5	8.8	5.2	4.6	2.7	0
Hitachi	6.0	5.9	5.4	6.6	3.0	0
Intel	2.4	2.3	1.9	1.4	0	0
Intersil	0	0	0	0	0	0
Matsushita	0.3	0.3	0.1	0	0	0
Mitsubishi	1.8	0.9	0.4	0.3	0	0
Mostek	18.1	13.8	7.4	5.0	5.0	8.3
Motorola	4.2	5.5	6.3	6.9	5.6	8.3
National	11.5	13.8	8.4	7.0	10.2	5.8
NEC	14.0	15.2	16.8	17.2	12.0	16.7
SGS-Ates	0	0.1	0.1	0	0	0
Siemens	1.9	3.6	5.0	7.2	16.0	25.0
Signetics	0	0	0	0	0	0
STC (ITT)	3.9	6.6	9.8	9.3	13.0	12.5
Texas Instruments	11.9	10.5	16.1	17.4	8.4	4.2
Toshiba	3.0	2.7	4.2	4.8	5.3	2.5
Zilog	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM--Market Shares

Table 8

16K 5V DRAM Market Shares
(Percentages)

Company	1979	1980	1981	1982	1983	1984	1985	1986
Fujitsu	0	0	4.2%	9.7%	16.6%	22.2%	10.5%	6.3%
Hitachi	0	4.0%	23.6	31.4	23.5	20.9	21.5	12.5
Intel	100.0%	94.2	66.5	33.1	11.7	12.3	6.9	6.3
Mostek	0	0	1.9	19.8	24.0	15.0	10.0	12.5
Motorola	0	1.8	3.2	4.9	21.8	26.6	51.1	62.5
National	0	0	0.4	0	0	0	0	0
Texas Inst.	0	0	0.2	1.0	2.4	3.0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM--Market Shares

Table 9

64K DRAM Market Shares
(Percentages)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987
AMD	0	0	0	0	0.1%	0.7%	1.0%	0.5%	0
Fairchild	0	0	0	0	0	0	0	0	0
Fujitsu	66.7%	29.5%	15.2%	15.9%	11.0	11.2	12.1	7.5	6.8%
Hitachi	0	23.8	30.9	17.6	16.3	12.2	13.4	10.1	4.7
Inmos	0	0	0	0.1	1.0	1.8	2.2	2.5	1.0
Intel	0	0.7	0.2	1.5	3.5	1.7	0.3	0.1	0
Matsushita	0	0	0	0	1.4	3.0	1.8	2.9	3.9
Micron Tech.	0	0	0	1.2	2.4	5.7	6.5	4.4	5.2
Mitsubishi	0	3.9	8.4	11.3	9.0	9.9	11.6	18.2	14.8
Motorola	27.8	34.0	15.6	10.7	8.4	7.1	6.0	4.9	2.1
National	0	0	0	0	.0	0.9	1.1	1.2	0
NEC	0	1.1	11.5	14.3	14.4	12.2	13.3	14.0	15.2
Oki	0	0	5.8	6.4	5.6	6.9	5.1	4.9	8.0
Samsung	0	0	0	0	0	0.2	3.9	9.4	17.4
Sharp	0	0	0	0	0	0.2	0.2	0.5	1.3
Siemens	0	0	0	0.3	1.0	1.8	2.0	2.5	4.7
STC (ITT)	0	0	0	0	0.1	0.3	0.3	0.4	0.5
TCMC	0	0	1.1	5.8	11.0	8.6	6.0	1.7	1.3
Texas Inst.	5.6	5.4	10.6	14.0	12.6	12.8	9.7	8.4	9.4
Toshiba	0	1.6	0.6	0.9	2.2	2.7	3.5	5.6	3.7
Vitelic	0	0	0	0	0	0	0	0.1	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

Table 10

256K DRAM Market Shares
(Percentages)

Company	1982	1983	1984	1985	1986	1987
AMD	0	0	0	0	0	0
ATT Technologies	0	7.1%	7.9%	6.1%	3.2%	0
Fujitsu	0	28.2	20.8	15.3	12.6	11.3%
Hitachi	100.0%	38.2	28.2	25.2	19.6	10.1
Inmos	0	0	0	0	0.5	0.8
Intel	0	0	0.1	1.9	0	0.3
Matsushita	0	0	0	0.9	1.8	1.7
Micron Technology	0	0	0.1	1.0	4.7	5.6
Mitsubishi	0	3.5	3.0	5.7	12.8	11.3
Motorola	0	0	0	0	0.3	3.2
National	0	0	0	0	0	0
NEC	0	17.6	27.0	21.8	20.1	16.3
NMB	0	0	0	0	0	2.1
Oki Electric	0	0.9	2.6	2.3	3.1	4.2
Samsung	0	0	0	0	2.0	8.8
Sharp	0	0	0	0	0	2.5
Siemens	0	0	0	0.1	0.5	1.4
TCMC	0	0.3	0.4	0.1	0.3	0
Texas Instruments	0	0	0.4	6.1	6.7	14.5
Toshiba	0	4.1	9.5	13.6	11.7	5.6
Vitelic	0	0	0	0	0.1	0.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM--Market Shares

Table 11

1Mb DRAM Market Share
(Percentages)

Company	1985	1986	1987
AT&T	0.6%	9.0%	0
Fujitsu	0	3.2	3.7
Hitachi	1.2	13.8	13.9
Matsushita	0	0	1.0
Micron Technology	0	0	0
Mitsubishi	0	14.6	13.5
NEC	0	0.1	7.9
NMB	0	0.4	0
Oki	0	0.3	4.7
Texas Instruments	0	0.6	1.5
Toshiba	98.2	58.0	53.9
Vitelic	0	0	0
Total	100.0%	100.0%	100.0%

Source: Dataquest
June 1988

DRAM—Market Shares

OVERVIEW OF MARKET SHARES

This section presents an analysis of dynamic RAM (DRAM) market share by company, region, and the top five and ten vendors for total DRAMs and for each of the past and present densities. In order to interpret our data correctly, the reader should understand our definition of market shares, as follows:

- All market share percentages in this section are based on individual company or regional *unit shares*. On a product basis, Dataquest believes that the unit share is an accurate measure of overall competitiveness. It encompasses a company's ability to compete on a cost and manufacturing basis, which, in DRAMs, is critical to success.
- The overall DRAM market shares are based on *dollarized* units, which represent the sum of all the units sold by a company weighted by each density's average selling price (ASP) for that year. Although the resulting numbers are in dollars, they have no relation to the true revenue dollars of a company. They are still units expressed in weighted form in order to have a standard summary for overall DRAM market shares.

OVERALL DRAM MARKET SHARES

- DRAM market share data are presented in the following tables:
- Table 1—DRAM Market Shares (Percentage)
- Table 2—DRAM Market Shares (Dollarized Unit Shares in Thousands)
- Table 3—DRAM Regional Shares (Percentage)
- Table 4—DRAM Regional Shares (Dollarized Unit Shares in Thousands)
- Table 5—DRAM Top Ten Shares (Percentage)
- Table 6—64K DRAM Market Shares (Percentage)
- Table 7—256K DRAM Market Shares (Percentage)
- Table 8—1Mb DRAM Market Shares (Percentage)
- Table 9—4Mb DRAM Market Shares (Percentage)

Shifts in market share occurred in 1989. Some of the reasons are as follows:

- Prices declined in all DRAM densities.
- To halt further price erosion, Japanese companies announced DRAM production cuts starting during the third quarter of 1989.
- Appreciation of the dollar against the Japanese yen contributed to the manufacturers' profits.
- Competition increased from the Korean manufacturers, primarily Samsung.
- Starting in the middle of 1989, 4Mb DRAMs were available for sampling; production began to ramp up.

Highlights of company shifts that occurred in the 1989 DRAM dollarized unit market shares are as follows:

- Toshiba remained in first place and grew nearly 46 percent in terms of dollarized units over 1988. Toshiba has had an increase in its market share for the past eight consecutive years, a feat unmatched by any other manufacturer in this product area.
- NEC's market share declined in 1989 when compared with 1988. However, NEC remained solidly ranked in the second position.
- Samsung's 1988 market share nearly doubled in 1989, moving the company to the third position, up from the eighth position in 1988.
- Texas Instruments declined in market share for the second year in a row and dropped to the sixth position in the 1989 market share, down from third place in 1988.
- Siemens increased in market share for the third year in a row, up to 3.7 percent, which placed it at the tenth position, up from the thirteenth position in 1988.
- Motorola's 1989 growth of about 124 percent in dollarized units placed it ninth, compared with its ranking of eleventh in 1988.
- The top 20 companies grew 45 percent in 1989 over 1988.

Figure 1 depicts the changes in DRAM regional market share that have occurred over the past 15 years (1974 through 1989). The chart has been prepared in a three-year moving average to smooth the curve and more clearly illustrate the changes in regional market share.

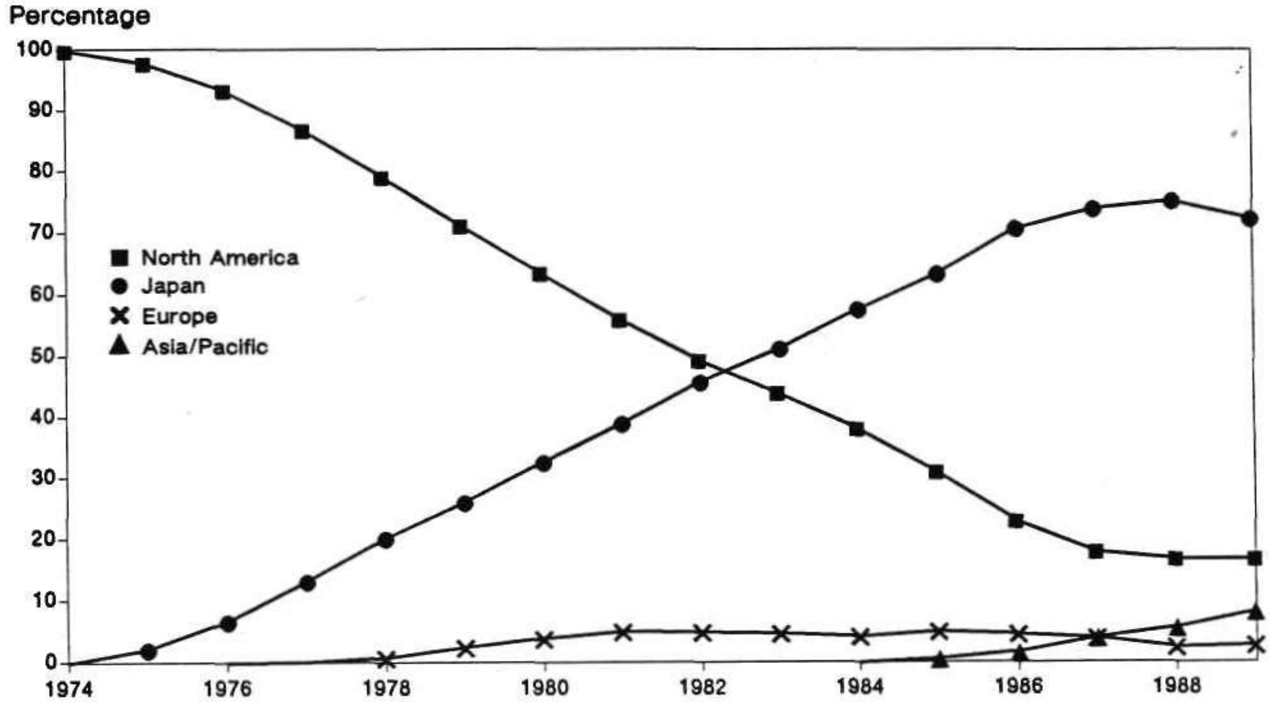
DATAQUEST ANALYSIS

The current issue with the strongest impact on the DRAM market clearly is pricing. The prices for all densities of DRAMs have remained unstable for the past nine months with no immediate signs of improving, and current fab capacity levels for this product are running at 75 percent. The continued threat of oversupply and overcapacity in the fabs in turn will drive prices down further.

The foreign market value (FMV) system has aided South Korean, European, and US vendors in penetrating the Japanese market. However, the system is only to remain in effect for another year. The U.S.-Japan Semiconductor Trade Arrangement between the United States and Japan will conclude in July 1991, and currently the possibility of renewal is slim. Dataquest believes that joint efforts between Japanese and foreign manufacturers should continue after the trade agreement concludes, thereby jointly benefiting all participating parties.

Figure 1

DRAM Regional Market Share



Source: Dataquest (September 1990)

Table 1

DRAM Market Shares
(Percentage)

Company	1975	1976	1977	1978	1979	1980	1981
AMD	0.1%	1.6%	3.3%	3.8%	3.6%	2.2%	4.4%
AMI	0.9	0	0	0	0	0	0
AT&T Technologies	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	0.2
Fairchild	2.9	5.2	3.2	1.9	2.0	1.8	1.1
Fujitsu	0	2.5	6.6	6.5	7.7	11.9	13.1
Hitachi	0	0	1.3	4.3	7.9	7.7	11.9
Hyundai	0	0	0	0	0	0	0
Inmos	0	0	0	0	0	0	0
Intel	45.6	19.0	20.0	12.7	5.9	2.9	4.1
Intersil	1.2	1.8	1.3	0.3	0.4	0.2	0
Matsushita	0	0	0	0	0	0.2	0.2
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	1.3	2.1	3.1
Mostek	13.8	18.7	24.0	22.9	22.8	19.2	0
Motorola	3.3	4.2	4.3	8.0	7.4	7.2	7.5
National	2.9	7.4	5.1	4.0	6.1	10.9	8.8
NEC	4.2	13.1	11.6	13.9	14.0	13.3	12.6
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	1.3
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	0.2	0.3	0.3	0.2
SGS-Thomson	0	0	0	0	0	0	0
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	0.2	0.9	1.5	1.3
Signetics	0	0.8	1.2	1.0	0.3	0	0
STC (ITT)	0	0	0.4	1.5	3.6	3.2	3.4
TCMC	0	0	0	0	0	0	13.7
Texas Instruments	25.1	25.7	17.8	18.0	13.3	11.0	10.8
Toshiba	0	0	0	0.8	2.1	4.3	2.3
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	0.2	0.2	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

DRAM Market Shares
(Percentage)

Company	1982	1983	1984	1985	1986	1987	1988	1989
AMD	0	1.2%	0.8%	0.8%	0.2%	0	0	0
AMI	0	0	0	0	0	0	0	0
AT&T Technologies	0	0.3	1.5	3.1	3.0	0	0	0
Eurotechnique	0.6%	0.5	0.2	0.4	0.1	0	0	0
Fairchild	0.4	0.1	0	0	0	0	0	0
Fujitsu	13.3	11.3	13.0	13.0	10.7	9.2%	9.6%	8.8%
Goldstar	0	0	0	0	0	0	0	0.3
Hitachi	14.7	16.2	15.2	19.0	17.0	10.7	9.5	9.4
Hyundai	0	0	0	0	0	0	0.4	0.8
Inmos	0.1	0.7	1.4	0.9	0.9	0.6	0	0
Intel	3.6	3.6	1.6	1.2	0.1	0.2	0.6	0.8
Intersil	0	0	0	0	0	0	0	0
Matsushita	0.1	1.1	2.3	1.2	1.8	1.7	2.6	3.0
Micron Technology	0.7	1.8	4.3	3.1	4.2	4.2	3.8	2.8
Mitsubishi	7.2	7.1	8.0	7.6	13.9	12.0	9.6	6.7
Mostek	0	0	0	0	0	0	0	0
Motorola	8.9	8.6	6.2	3.8	1.7	2.3	2.4	3.7
National	5.0	1.2	0.9	0.9	0.1	0	0	0
NEC	14.1	14.0	14.9	17.0	17.1	14.1	14.1	12.8
NMB	0	0	0	0	0	1.4	2.1	2.7
Oki	3.9	4.3	5.7	3.2	3.2	4.7	6.1	5.7
Samsung	0	0	0.1	1.6	3.3	7.1	5.8	10.2
Sanyo	0	0	0	0	0	0	0.2	0.3
SGS-Ates	0.1	0.1	0	0	0	0	0	0
SGS-Thomson	0	0	0	0	0	0	0	0
Sharp	0	0	0.1	0.1	0.1	1.8	2.4	1.4
Siemens	1.4	1.5	1.6	1.5	1.0	1.3	2.4	3.7
Signetics	0	0	0	0	0	0	0	0
STC (ITT)	2.5	1.5	0.6	0.8	0.2	0	0	0
TCMC	9.6	11.0	7.2	3.4	0.7	0.1	0	0
Texas Instruments	12.3	11.8	10.3	7.4	6.5	11.0	9.8	7.8
Toshiba	1.5	2.4	4.0	9.8	14.2	17.3	18.4	18.5
Vitelic	0	0	0	0	0	0.2	0.3	0.6
Zilog	0	0	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (September 1990)

Table 2

DRAM Market Shares
(Dollarized Unit Shares in Thousands)

Company	1975	1976	1977	1978	1979	1980	1981
AMD	31	2,036	6,201	12,012	19,976	21,435	27,418
AMI	281	0	0	0	0	0	0
AT&T Technologies	0	0	0	0	0	0	0
Eurotechnique	0	0	0	0	0	0	1,442
Fairchild	967	6,460	5,978	6,150	11,457	17,172	6,798
Fujitsu	0	3,110	12,529	20,518	43,278	114,660	82,331
Goldstar	0	0	0	0	0	0	0
Hitachi	0	0	2,412	13,561	44,445	73,788	74,555
Hyundai	0	0	0	0	0	0	0
Inmos	0	0	0	0	0	0	0
Intel	15,038	23,657	37,993	40,492	33,056	27,954	25,634
Intersil	406	2,227	2,385	819	1,980	2,377	255
Matsushita	0	0	0	0	0	1,455	1,483
Micron Technology	0	0	0	0	0	0	0
Mitsubishi	0	0	0	0	7,538	19,866	19,760
Mostek	4,555	23,250	45,429	72,737	128,376	185,017	0
Motorola	1,092	5,242	8,193	25,302	41,826	69,354	46,944
National	967	9,200	9,739	12,640	34,464	104,704	55,046
NEC	1,373	16,269	21,940	44,034	78,795	128,028	78,931
NMB	0	0	0	0	0	0	0
Oki	0	0	0	0	0	0	8,085
Samsung	0	0	0	0	0	0	0
SGS-Ates	0	0	0	655	1,458	3,044	1,326
SGS-Thomson	0	0	0	0	0	0	0
Sharp	0	0	0	0	0	0	0
Siemens	0	0	0	725	5,276	14,072	8,343
Signetics	0	957	2,306	3,287	1,938	0	0
STC (ITT)	0	0	795	4,644	20,235	31,165	21,651
TCMC	0	0	0	0	0	0	86,242
Texas Instruments	8,299	31,941	33,661	57,264	75,034	106,171	67,677
Toshiba	0	0	0	2,431	12,060	41,346	14,373
Vitelic	0	0	0	0	0	0	0
Zilog	0	0	0	512	1,146	239	0
Total	33,010	124,349	189,559	317,782	562,339	961,785	628,295

(Continued)

Table 2 (Continued)

DRAM Market Shares
(Dollarized Unit Shares in Thousands)

Company	1982	1983	1984	1985	1986	1987	1988	1989
AMD	23,725	22,495	28,225	11,806	3,616	0	0	0
AMI	0	0	0	0	0	0	0	0
AT&T Technologies	0	5,719	53,700	45,980	61,536	0	0	0
Eurotechnique	5,952	9,240	6,758	6,336	1,350	0	0	0
Fairchild	4,111	1,680	438	0	0	0	0	0
Fujitsu	123,302	212,300	466,756	191,617	217,833	240,431	646,474	859,888
Goldstar	0	0	0	0	0	0	2,745	30,992
Hitachi	136,185	304,889	546,150	278,469	346,587	278,662	634,158	916,547
Hyundai	0	0	0	0	0	0	29,675	74,259
Inmos	596	13,703	49,770	12,906	17,808	15,780	2,307	0
Intel	33,039	67,785	57,529	17,882	1,443	4,720	37,429	81,360
Intersil	0	0	0	0	0	0	0	0
Matsushita	1,031	20,591	81,165	17,363	37,358	43,532	171,950	294,076
Micron Technology	6,612	34,547	154,250	45,920	86,022	109,743	252,546	269,541
Mitsubishi	66,746	133,209	287,976	111,310	284,120	313,780	646,206	652,211
Mostek	0	0	0	0	0	0	0	0
Motorola	82,897	161,748	224,155	56,429	35,051	61,005	161,804	361,829
National	46,167	22,298	33,667	13,624	1,095	0	0	0
NEC	130,358	263,123	534,947	250,237	348,517	368,800	943,993	1,245,660
NMB	0	0	0	0	752	37,760	138,257	258,765
Oki	35,880	80,617	204,340	47,318	64,941	122,152	405,645	553,783
Samsung	0	0	4,740	23,256	68,015	186,275	386,134	996,198
Sanyo	0	0	0	0	0	0	11,590	33,748
SGS-Ates	615	1,492	750	187	0	0	0	0
SGS-Thomson	0	0	0	0	14,253	2,160	0	0
Sharp	0	0	5,372	1,450	2,266	47,190	161,032	132,208
Siemens	13,433	27,461	58,463	22,720	21,280	33,595	160,169	357,437
Signetics	0	0	0	0	0	0	0	0
STC (ITT)	23,228	27,426	20,360	12,048	3,776	864	0	0
TCMC	89,248	206,756	258,795	50,121	0	0	0	0
Texas Instruments	113,767	223,459	371,450	108,159	132,005	286,575	655,034	762,725
Toshiba	13,612	45,207	144,706	143,361	289,373	452,755	1,234,079	1,798,944
Vitelic	0	0	0	0	947	4,071	22,418	56,109
Zilog	0	0	0	0	0	0	0	0
Total	950,506	1,885,745	3,594,460	1,468,497	2,039,943	2,609,849	6,703,645	9,736,280

Source: Dataquest (September 1990)

Table 3

DRAM Regional Shares
(Percentage)

Regional Shares	1974	1975	1976	1977	1978	1979
North America	100.0%	95.8%	84.4%	80.1%	72.8%	62.1%
Japan	0	4.2	15.6	19.5	25.3	33.1
Europe	0	0	0	0.4	1.9	4.8
Asia/Pacific	0	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regional Shares	1980	1981	1982	1983	1984	1985
North America	55.6%	50.3%	42.0%	39.6%	32.9%	20.4%
Japan	39.4	44.5	53.4	56.2	63.2	70.9
Europe	5.0	5.2	4.6	4.2	3.8	7.1
Asia/Pacific	0	0	0	0	0.1	1.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Regional Shares	1986	1987	1988	1989
North America	15.8%	17.9%	16.8%	15.7%
Japan	78.0	73.0	74.5	69.3
Europe	2.9	2.0	2.4	3.7
Asia/Pacific	3.3	7.1	6.2	11.3
Total	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (September 1990)

Table 4

DRAM Regional Shares
(Dollarized Unit Shares in Thousands)

Regional Shares	1974	1975	1976	1977	1978	1979
North America	10,455	31,637	104,970	151,884	231,215	349,253
Japan	0	1,373	19,379	36,881	80,544	186,116
Europe	0	0	0	795	6,024	26,969
Asia/Pacific	0	0	0	0	0	0
Total	10,455	33,010	124,349	189,559	317,782	562,339

Regional Shares	1980	1981	1982	1983	1984	1985
North America	534,419	316,014	399,567	746,487	1,182,208	299,800
Japan	379,140	279,518	507,114	1,059,936	2,271,412	1,041,124
Europe	48,280	32,762	43,824	79,322	136,101	104,318
Asia/Pacific	0	0	0	0	4,740	23,256
Total	961,785	628,295	950,506	1,885,745	3,594,460	1,468,497

Regional Shares	1986	1987	1988	1989
North America	321,715	466,114	1,129,256	1,531,546
Japan	1,591,747	1,905,062	4,994,381	6,745,099
Europe	58,467	52,399	162,476	357,433
Asia/Pacific	68,015	186,275	418,602	1,101,449
Total	2,039,943	2,609,849	6,704,715	9,735,527

Source: Dataquest (September 1990)

Table 5

DRAM Top Ten Shares
(Percentage)

Top Five and Ten Shares	1981	1982	1983	1984	1985	1986	1987	1988	1989
Top Five	62.0%	62.4%	64.2%	61.4%	66.4%	72.7%	65.2%	61.5%	59.8%
Europe	0	0	0	0	0	0	0	0	0
Japan	60.5	65.8	64.5	83.2	100.0	100.0	83.1	84.1	82.9
Korea	0	0	0	0	0	0	0	0	17.1
North America	39.5	34.2	35.5	16.8	0	0	16.9	15.9	0
ROW	0	0	0	0	0	0	0	0	0
Next Five	28.1%	27.9%	25.9%	27.4%	21.0%	20.2%	27.6%	27.6%	27.6%
Europe	12.3	0	0	0	0	0	0	0	13.3
Japan	0	38.8	53.0	35.4	15.4	15.7	50.4	65.5	44.9
Korea	0	0	0	0	0	16.5	25.9	20.9	0
North America	87.7	61.2	47.0	64.6	84.6	67.8	23.7	13.6	41.8
ROW	0	0	0	0	0	0	0	0	0
Top Ten	90.2%	90.2%	90.1%	88.8%	87.4%	92.9%	92.7%	89.1%	87.4%
Europe	3.8	0	0	0	0	0	0	0	4.2
Japan	41.6	57.4	61.2	68.4	79.7	81.7	73.4	78.4	70.9
Korea	0	0	0	0	0	3.6	7.7	6.5	11.7
North America	54.5	42.6	38.8	31.6	20.3	14.7	18.9	15.2	13.2
ROW	0	0	0	0	0	0	0	0	0

Source: Dataquest (September 1990)

Table 6

64K DRAM Market Shares
(Percentage)

Company	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
AMD	0	0	0	0.1%	0.7%	1.0%	0.5%	0	0	0
Fujitsu	29.5%	15.2%	15.9%	11.0	11.2	12.1	7.5	6.8%	1.5%	1.8%
Hitachi	23.8	30.9	17.6	16.3	12.2	13.4	10.1	4.7	0.3	0
Hyundai	0	0	0	0	0	0	0	0	2.0	0.2
Inmos	0	0	0.1	1.0	1.8	2.2	2.5	1.0	1.2	0
Intel	0.7	0.2	1.5	3.5	1.7	0.3	0.1	0	3.7	2.5
Matsushita	0	0	0	1.4	3.0	1.8	2.9	3.9	8.4	9.2
Micron Technology	0	0	1.2	2.4	5.7	6.5	4.4	5.2	7.5	9.4
Mitsubishi	3.9	8.4	11.3	9.0	9.9	11.6	18.2	14.8	5.9	2.5
Motorola	34.0	15.6	10.7	8.4	7.1	6.0	4.9	2.1	0.7	0
National	0	0	0	0	0.9	1.1	1.2	0	0	0
NEC	1.1	11.5	14.3	14.4	12.2	13.3	14.0	15.2	9.4	0
Oki	0	5.8	6.4	5.6	6.9	5.1	4.9	8.0	6.3	7.2
Samsung	0	0	0	0	0.2	3.9	9.4	17.4	35.4	44.8
SGS-Thomson	0	0	0	0	0	0	0	0	0	0
Sharp	0	0	0	0	0.2	0.2	0.5	1.3	7.3	1.0
Siemens	0	0	0.3	1.0	1.8	2.0	2.5	4.7	0	0
STC (ITT)	0	0	0	0.1	0.3	0.3	0.4	0.5	0	0
TCMC	0	1.1	5.8	11.0	8.6	6.0	1.7	1.3	0	0
Texas Instruments	5.4	10.6	14.0	12.6	12.8	9.7	8.4	9.4	8.7	21.5
Toshiba	1.6	0.6	0.9	2.2	2.7	3.5	5.6	3.7	1.8	0
Vitelic	0	0	0	0	0	0	0.1	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (September 1990)

Table 7

256K DRAM Market Shares
(Percentage)

Company	1982	1983	1984	1985	1986	1987	1988	1989
AT&T Technologies	0	7.1%	7.9%	6.1%	3.2%	0	0	0
Fujitsu	0	28.2	20.8	15.3	12.6	11.3%	9.8%	7.9%
Goldstar	0	0	0	0	0	0	0.1	1.2
Hitachi	100.0%	38.2	28.2	25.2	19.6	10.1	8.9	8.8
Hyundai	0	0	0	0	0	0	0.9	2.7
Inmos	0	0	0	0	0.5	0.8	0	0
Intel	0	0	0.1	1.9	0	0.3	0.9	0.8
Matsushita	0	0	0	0.9	1.8	1.7	2.2	2.3
Micron Technology	0	0	0.1	1.0	4.7	5.6	7.6	7.8
Mitsubishi	0	3.5	3.0	5.7	12.8	11.3	7.2	6.4
Motorola	0	0	0	0	0.3	3.2	2.8	1.8
NEC	0	17.6	27.0	21.8	20.1	16.3	14.9	13.2
NMB	0	0	0	0	0	2.1	4.2	5.5
Oki	0	0.9	2.6	2.3	3.1	4.2	6.5	7.1
Samsung	0	0	0	0	2.0	8.8	5.5	6.2
Sanyo	0	0	0	0	0	0	0.4	0.5
Sharp	0	0	0	0	0	2.5	4.2	3.6
Siemens	0	0	0	0.1	0.5	1.4	2.2	2.9
TCMC	0	0.3	0.4	0.1	0.3	0	0	0
Texas Instruments	0	0	0.4	6.1	6.7	14.5	15.5	12.9
Toshiba	0	4.1	9.5	13.6	11.7	5.6	5.5	6.2
Vitelic	0	0	0	0	0.1	0.2	0.8	2.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (September 1990)

Table 8

1Mb DRAM Market Shares
(Percentage)

Company	1985	1986	1987	1988	1989
AT&T Technologies	0.6%	9.0%	0	0	0
Fujitsu	0	3.2	3.7%	10.0%	9.4%
Hitachi	1.2	13.8	13.9	10.3	9.0
Hyundai	0	0	0	0	0.1
Intel	0	0	0	0.1	0.8
Matsushita	0	0	1.0	2.6	3.3
Micron Technology	0	0	0	0.4	0.9
Mitsubishi	0	14.6	13.5	11.8	7.1
Motorola	0	0	0	2.2	4.6
NEC	0	0.1	7.9	13.7	12.6
NMB	0	0.4	0	0.4	1.7
Oki	0	0.3	4.7	5.6	5.2
Samsung	0	0	0	4.4	11.5
Sanyo	0	0	0	0	0.3
Sharp	0	0	0	0.7	0.6
Siemens	0	0	0	2.7	4.1
Texas Instruments	0	0.6	1.5	5.2	6.0
Toshiba	98.2	58.0	53.9	29.8	22.8
Vitelic	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (September 1990)

Table 9

4Mb DRAM Market Shares
(Percentage)

Company	1988	1989
Fujitsu	6.3%	6.6%
Hitachi	25.0	31.9
Matsushita	0	0.9
Mitsubishi	18.8	0.5
Motorola	0	0.8
NEC	0	19.8
Oki	6.3	3.1
Siemens	0	0.3
Texas Instruments	0	0.8
Toshiba	43.8	35.4
Total	100.0%	100.0%

Source: Dataquest (September 1990)

DRAM--Data

MOS DYNAMIC RAMs--DATA

This section presents historical unit shipments of the more significant densities of dynamic RAMs (DRAMs) from 1974 to the third quarter of 1986 and an estimate of shipments in the fourth quarter of 1986. The 1986 estimated shipments are for the 64K to 1Mb densities. Included in the tables are estimated worldwide billing prices for each density and market share data (in units) for U.S.-based, Japan-based, Europe-based, and Asia-Pacific-based companies. These data are subject to review at a later date due to the qualifications discussed below. The tables are as follows:

- Table 1--4K DRAM (1974-1985)
- Table 2--16K 3ps DRAM (1976-1985)
- Table 3--16K 5V DRAM (1979-1985)
- Table 4--64K DRAM (1978-1986)
- Table 5--256K DRAM (1982-1986)
- Table 6--1Mb DRAM (1985-1986)

DEFINITIONS

Prices

Average selling price is the Dataquest estimate of the average worldwide billing price for that quarter. It incorporates prices for all package types and access times for both commercial and military markets.

Unit Shipments

Shipment data are factory revenue shipments as published in earlier newsletters, with occasional revisions based on the availability of more recent information. The unit shipments in the fourth quarter of 1986 are forecast numbers.

Quarterly Revenue

Revenue is calculated as total units shipped in the quarter multiplied by the average billing price of that quarter.

Table 1

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1974 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD					
AMI					
Fairchild					
Fujitsu					
Hitachi					
Intel	40	100	150	220	510
Intersil					
Mostek			5	20	25
Motorola					
National					
NEC					
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	5	10	20	50	80
Total	40	110	175	290	615
Percentage Change from Previous Quarter		175%	59%	66%	
Cumulative Total	40	150	325	615	
Average Selling Price	$40.00	$25.00	$15.00	$12.00	$17.00
Revenue ($M)	1.6	2.8	2.6	3.5	10.5

	1974 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1975 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD				5	5
AMI			15	30	45
Fairchild		15	40	100	155
Fujitsu					
Hitachi					
Intel	260	425	675	1,050	2,410
Intersil			20	45	65
Mostek	35	95	210	390	730
Motorola		5	25	145	175
National		10	35	110	155
NEC	10	25	65	120	220
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	75	175	340	740	1,330
Total	380	750	1,425	2,735	5,290
Percentage Change from Previous Quarter	31%	97%	90%	92%	
Cumulative Total	995	1,745	3,170	5,905	
Average Selling Price	$10.00	$7.50	$6.00	$5.50	$6.24
Revenue ($M)	3.8	5.6	8.6	15.0	33.0

	1975 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	97.4%	96.7%	95.4%	95.6%	95.8%
Japan	2.6	3.3	4.6	4.4	4.2
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1976 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	23	105	165	175	468
AMI	0	0	0	0	0
Fairchild	290	430	435	330	1,485
Fujitsu	95	155	205	260	715
Hitachi			S	S	S
Intel	900	1,325	1,500	1,500	5,225
Intersil	42	85	190	195	512
Mostek	600	1,400	1,600	1,425	5,025
Motorola	190	180	360	475	1,205
National	300	480	560	775	2,115
NEC	575	790	1,100	1,275	3,740
SGS-Ates					
Signetics	S	35	65	120	220
STC (ITT)				S	S
Texas Instruments	1,400	1,800	2,000	2,100	7,300
Total	4,415	6,785	8,180	8,630	28,010
Percentage Change from Previous Quarter	61%	54%	21%	6%	
Cumulative Total	4,415	11,200	19,380	28,010	
Average Selling Price	$5.00	$4.50	$4.25	$4.00	$4.35
Revenue ($M)	22.1	30.5	34.8	34.5	121.9

	1976 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	84.8%	86.1%	84.0%	82.2%	84.1%
Japan	15.2	13.9	16.0	17.8	15.9
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1977 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	290	450	600	1,000	2,340
AMI	0	0	0	0	0
Fairchild	380	450	550	700	2,080
Fujitsu	550	750	800	800	2,900
Hitachi	50	100	300	460	910
Intel	2,000	2,300	3,000	3,100	10,400
Intersil	240	220	220	220	900
Mostek	2,150	2,600	3,300	3,750	11,800
Motorola	540	700	750	750	2,740
National	825	925	925	1,000	3,675
NEC	1,400	1,500	1,600	1,600	6,100
SGS-Ates				S	S
Signetics	180	210	230	250	870
STC (ITT)	20	50	80	150	300
Texas Instruments	2,300	3,000	3,200	3,900	12,400
Total	10,925	13,255	15,555	17,680	57,415
Percentage Change from Previous Quarter	27%	21%	17%	14%	
Cumulative Total	38,935	52,190	67,745	85,425	
Average Selling Price	$3.50	$3.00	$2.50	$2.00	$2.65
Revenue ($M)	38.2	39.8	38.9	35.4	152.3

	1977 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	81.7%	82.3%	82.6%	83.8%	82.7%
Japan	18.3	17.7	17.4	16.2	17.3
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1978 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	1,100	1,500	1,800	2,200	6,600
AMI	0	0	0	0	0
Fairchild	500	400	200	100	1,200
Fujitsu	600	600	400	300	1,900
Hitachi	330	500	500	450	1,780
Intel	3,000	3,000	2,700	2,300	11,000
Intersil	150	100	100	100	450
Mostek	4,000	4,000	4,800	4,200	17,000
Motorola	1,000	1,300	1,500	1,900	5,700
National	1,200	1,200	1,500	1,700	5,600
NEC	1,600	1,600	1,600	1,350	6,150
SGS-Ates	60	75	100	125	360
Signetics	250	300	300	300	1,150
STC (ITT)	200	300	300	800	1,600
Texas Instruments	4,200	4,700	4,000	3,800	16,700
Total	18,190	19,575	19,800	19,625	77,190
Percentage Change from Previous Quarter	3%	8%	1%	(1%)	
Cumulative Total	103,615	123,190	142,990	162,615	
Average Selling Price	$2.00	$1.90	$1.80	$1.60	$1.82
Revenue ($M)	36.4	37.2	35.6	31.4	140.6

	1978 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	85.8%	85.8%	86.9%	88.7%	86.8%
Japan	13.9	13.8	12.6	10.7	12.7
Europe	0.3	0.4	0.5	0.6	0.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	2,600	3,000	3,000	1,600	10,200
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	200	200	200	150	750
Hitachi	350	200	200	100	850
Intel	1,700	1,700	1,500	1,200	6,100
Intersil	100	100	300	500	1,000
Mostek	3,800	3,300	3,400	3,600	14,100
Motorola	1,500	1,150	1,800	2,000	6,450
National	2,000	2,400	2,000	1,500	7,900
NEC	1,350	1,900	1,300	1,000	5,550
SGS-Ates	150	175	200	225	750
Signetics	300	100	50	10	460
STC (ITT)	1,100	1,300	1,300	1,500	5,200
Texas Instruments	3,600	3,200	2,700	1,200	10,700
Total	18,750	18,725	17,950	14,585	70,010
Percentage Change from Previous Quarter	(4%)	0%	(4%)	(19%)	
Cumulative Total	181,365	200,090	218,040	232,625	
Average Selling Price	$1.50	$2.00	$2.00	$2.25	$1.92
Revenue ($M)	28.1	37.5	35.9	32.8	134.3

	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	89.1%	86.8%	89.4%	89.9%	88.7%
Japan	10.1	12.3	9.5	8.6	10.2
Europe	0.8	0.9	1.1	1.5	1.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1980 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	1,300	750	450	435	2,935
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	200	200	150	650
Hitachi	100	100	0	0	200
Intel	900	100	0	0	1,000
Intersil	600	300	225	100	1,225
Mostek	2,500	2,000	1,400	1,200	7,100
Motorola	1,700	1,000	850	1,500	5,050
National	1,500	1,300	1,000	750	4,550
NEC	400	275	360	420	1,455
SGS-Ates	300	350	300	250	1,200
Signetics	0	0	0	0	0
STC (ITT)	1,400	600	1,500	1,500	5,000
Texas Instruments	700	100	0	0	800
Total	11,500	7,075	6,285	6,305	31,165
Percentage Change from Previous Quarter	(21%)	(38%)	(11%)	0%	
Cumulative Total	244,125	251,200	257,485	263,790	
Average Selling Price	$2.00	$1.90	$1.90	$1.90	$1.94
Revenue ($M)	23.0	13.4	11.9	12.0	60.4

	1980 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	92.2%	86.9%	86.3%	87.0%	88.8%
Japan	5.2	8.1	8.9	9.0	7.4
Europe	2.6	4.9	4.8	4.0	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1981 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	550	450	350	300	1,650
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	50	25	20	195
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	35	50	30	30	145
Mostek	800	650	500	300	2,250
Motorola	900	1,000	800	550	3,250
National	600	600	500	400	2,100
NEC	150	100	50	20	320
SGS-Ates	220	200	150	90	660
Signetics	0	0	0	0	0
STC (ITT)	1,100	570	450	350	2,470
Texas Instruments	0	0	0	0	0
Total	4,455	3,670	2,855	2,060	13,040
Percentage Change from Previous Quarter	(29%)	(18%)	(22%)	(28%)	
Cumulative Total	268,245	271,915	274,770	276,830	
Average Selling Price	$2.00	$1.75	$1.60	$1.50	$1.76
Revenue ($M)	8.9	6.4	4.6	3.1	23.0

	1981 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	89.5%	90.5%	92.1%	93.7%	91.0%
Japan	5.6	4.1	2.6	1.9	3.9
Europe	4.9	5.4	5.3	4.4	5.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1982 1st Qtr	1982 2nd Qtr	1982 3rd Qtr	1982 4th Qtr	1982 Year
AMD	200	40	15	0	255
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	10	5	0	0	15
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	250	250	200	200	900
Motorola	475	475	250	270	1,470
National	250	180	180	100	710
NEC	0	0	0	0	0
SGS-Ates	60	70	60	75	265
Signetics	0	0	0	0	0
STC (ITT)	400	200	200	220	1,020
Texas Instruments	0	0	0	0	0
Total	1,645	1,220	905	865	4,635
Percentage Change from Previous Quarter	(20%)	(26%)	(26%)	(4%)	
Cumulative Total	278,475	279,695	280,600	281,465	
Average Selling Price	$1.35	$1.60	$1.75	$2.00	$1.62
Revenue ($M)	2.2	2.0	1.6	1.7	7.5

	1982 1st Qtr	1982 2nd Qtr	1982 3rd Qtr	1982 4th Qtr	1982 Year
Market Share					
U.S.	95.7%	93.9%	93.4%	91.3%	94.0%
Japan	0.6	0.4	0.0	0.0	0.3
Europe	3.6	5.7	6.6	8.7	5.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	200	200	200	225	825
Motorola	175	50	50	25	300
National	100	100	50	0	250
NEC	0	0	0	0	0
SGS-Ates	75	100	200	50	425
Signetics	0	0	0	0	0
STC (ITT)	200	200	150	50	600
Texas Instruments	0	0	0	0	0
Total	750	650	650	350	2,400
Percentage Change from Previous Quarter	(13%)	(13%)	0%	(46%)	
Cumulative Total	282,215	282,865	283,515	283,865	
Average Selling Price	$2.75	$2.50	$2.75	$3.00	$2.72
Revenue ($M)	2.1	1.6	1.8	1.1	6.5

	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	90.0%	84.6%	69.2%	85.7%	82.3%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	10.0	15.4	30.8	14.3	17.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	300	350	350	500	1,500
Motorola	25	25	25	25	100
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	100	50	50	50	250
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	525	525	525	675	2,250
Percentage Change from Previous Quarter	(78%)	0%	0%	29%	
Cumulative Total	284,390	284,915	285,440	286,115	
Average Selling Price	$3.00	$3.00	$3.00	$3.00	$3.00
Revenue ($M)	1.6	1.6	1.6	2.0	6.8

	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	81.0%	90.5%	90.5%	92.6%	88.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	19.0	9.5	9.5	7.4	11.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

ESTIMATED WORLDWIDE MOS 4K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1985 1st Qtr	1985 2nd Qtr	1985 3rd Qtr	1985 4th Qtr	1985 Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	500	400	500	500	1,900
Motorola	0	0	0	0	0
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	50	0	0	0	50
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	650	500	600	600	2,350
Percentage Change from Previous Quarter	(4%)	(23%)	20%	0%	
Cumulative Total	286,765	287,265	287,865	288,465	
Average Selling Price	$3.00	$3.50	$4.00	$4.50	$3.74
Revenue ($M)	2.0	1.8	2.4	2.7	8.8

	1985 1st Qtr	1985 2nd Qtr	1985 3rd Qtr	1985 4th Qtr	1985 Year
Market Share					
U.S.	92.3%	100.0%	100.0%	100.0%	97.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	7.7	0.0	0.0	0.0	2.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

Table 2

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1976 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD					
Eurotechnique					
Fairchild					
Fujitsu					
Hitachi					
Intel			[illegible]	20	20
Intersil					
Matsushita					
Mitsubishi					
Mostek			5	25	30
Motorola					
National					
NEC					
SGS-Ates					
Siemens					
Signetics					
STC (ITT)					
Texas Instruments				4	4
Toshiba					
Zilog	—	—	—	—	—
Total	0	0	5	49	59
Percent Change from Previous Quarter				880%	
Cumulative Total	0	0	5	54	
Average Selling Price			$60.00	$45.00	$46.39
Revenue ($M)	0.0	0.0	0.3	2.2	2.5

	1976 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.			100.0%	100.0%	100.0%
Japan			0.0	0.0	0.0
Europe			0.0	0.0	0.0
Total			100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1977 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD					
Eurotechnique					
Fairchild				25	25
Fujitsu		15	70	175	260
Hitachi				S	S
Intel	55	120	160	225	560
Intersil					
Matsushita					
Mitsubishi				S	S
Mostek	80	160	170	350	760
Motorola			S	50	50
National				S	S
NEC		15	70	225	310
SGS-Ates					
Siemens					
Signetics				S	S
STC (ITT)				S	S
Texas Instruments	3	0	0	40	43
Toshiba					
Zilog				S	S
Total	138	310	470	1,090	2,008
Percent Change from Previous Quarter	182%	125%	52%	132%	
Cumulative Total	192	502	972	2,062	
Average Selling Price	$35.00	$22.00	$20.00	$15.00	$18.63
Revenue ($M)	4.8	6.8	9.4	16.4	37.4

	1977 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	100.0%	90.3%	70.2%	63.3%	71.6%
Japan	0.0	9.7	29.8	36.7	28.4
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1978 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD				S	S
Eurotechnique					
Fairchild	25	40	200	200	465
Fujitsu	250	350	500	900	2,000
Hitachi	120	240	350	500	1,210
Intel	400	500	600	900	2,400
Intersil				S	S
Matsushita	0	0	0	0	0
Mitsubishi					
Mostek	700	1,000	1,400	1,800	4,900
Motorola	200	500	550	500	1,750
National	12	50	75	150	287
NEC	650	800	1,100	1,300	3,850
SGS-Ates					
Siemens	5	15	25	40	85
Signetics	S	30	30	80	140
STC (ITT)	3	25	75	100	203
Texas Instruments	300	500	950	1,400	3,150
Toshiba	20	35	80	150	285
Zilog	10	15	15	20	60
Total	2,695	4,100	5,950	8,040	20,785
Percent Change from Previous Quarter	147%	52%	45%	35%	
Cumulative Total	4,757	8,857	14,807	22,847	
Average Selling Price	$12.00	$10.00	$8.00	$7.00	$8.53
Revenue ($M)	32.3	41.0	47.6	56.3	177.2

	1978 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	61.2%	64.9%	65.5%	64.1%	64.3%
Japan	38.6	34.8	34.1	35.4	35.3
Europe	0.2	0.4	0.4	0.5	0.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

DRAM--Data

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	5	5	10	50	65
Eurotechnique					
Fairchild	300	400	500	700	1,900
Fujitsu	1,100	1,300	1,600	2,500	6,500
Hitachi	800	1,400	2,200	2,700	7,100
Intel	600	700	900	900	3,100
Intersil	5	5	5	0	10
Matsushita	0	0	0	0	0
Mitsubishi	100	200	400	550	1,250
Mostek	2,400	3,600	4,800	6,000	16,800
Motorola	700	1,200	1,000	1,800	4,700
National	250	450	1,000	1,500	3,200
NEC	1,700	2,200	3,200	4,200	11,300
SGS-Ates				3	3
Siemens	100	150	250	375	875
Signetics	75	40	50	10	175
STC (ITT)	200	300	600	600	1,700
Texas Instruments	1,800	2,200	1,800	3,200	9,000
Toshiba	150	350	450	1,050	2,000
Zilog	20	50	50	70	190
Total	10,295	14,550	18,815	26,208	69,868
Percent Change from Previous Quarter	28%	41%	29%	39%	
Cumulative Total	33,142	47,692	66,507	92,715	
Average Selling Price	$6.50	$6.25	$6.00	$5.75	$6.03
Revenue ($M)	66.9	90.9	112.9	150.7	421.4

	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	61.6%	61.5%	56.9%	56.6%	58.5%
Japan	37.4	37.5	41.7	42.0	40.3
Europe	1.0	1.0	1.3	1.4	1.3
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

DRAM--Data

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1980				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	300	700	700	1,600	3,300
Eurotechnique					
Fairchild	800	1,000	1,000	800	3,600
Fujitsu	4,500	6,000	5,800	6,200	22,500
Hitachi	3,200	3,700	3,700	3,700	14,300
Intel	1,000	1,000	700	1,100	3,800
Intersil	0	0	0	0	0
Matsushita	5	100	100	100	305
Mitsubishi	700	1,100	1,100	1,100	4,000
Mostek	7,400	10,500	9,500	8,500	35,900
Motorola	3,000	3,000	2,500	2,500	11,000
National	3,500	4,800	5,800	6,000	20,100
NEC	6,100	7,500	6,700	5,900	26,200
SGS-Ates	10	30	50	60	150
Siemens	600	750	800	800	2,950
Signetics	0	0	0	0	0
STC (ITT)	750	1,050	1,200	1,500	4,500
Texas Instruments	4,200	5,200	5,700	6,600	21,700
Toshiba	1,700	2,000	2,300	2,600	8,600
Zilog	0	0	0	50	50
Total	37,765	48,430	47,650	49,110	182,955
Percent Change from Previous Quarter	44%	28%	(2%)	3%	
Cumulative Total	130,480	178,910	226,560	275,670	
Average Selling Price	$5.50	$5.25	$4.50	$4.00	$4.77
Revenue ($M)	207.7	254.3	214.4	196.4	872.8

	1980				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	55.5%	56.3%	56.9%	58.3%	56.8%
Japan	42.9	42.1	41.3	39.9	41.5
Europe	1.6	1.6	1.8	1.8	1.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1981				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	1,900	2,200	3,000	4,800	11,900
Eurotechnique		S	100	600	700
Fairchild	800	800	800	900	3,300
Fujitsu	6,800	7,300	7,600	7,400	29,100
Hitachi	3,600	3,750	3,600	1,900	12,850
Intel	900	1,400	1,400	1,500	5,200
Intersil	0	0	0	0	0
Matsushita	120	100	250	250	720
Mitsubishi	500	900	1,250	1,250	3,900
Mostek	8,900	11,100	9,990	9,000	38,990
Motorola	1,970	2,160	2,350	2,650	9,130
National	5,500	5,990	6,400	7,000	24,890
NEC	6,300	7,100	7,900	9,000	30,300
SGS-Ates	20	20	15	25	80
Siemens	800	850	900	1,500	4,050
Signetics	0	0	0	0	0
STC (ITT)	1,600	1,800	2,000	3,000	8,400
Texas Instruments	6,300	6,600	6,800	6,000	25,700
Toshiba	1,750	1,650	1,550	1,600	6,550
Zilog	0	0	0	0	0
Total	47,760	53,720	55,905	58,375	215,760
Percent Change from Previous Quarter	(3%)	12%	4%	4%	
Cumulative Total	323,430	377,150	433,055	491,430	
Average Selling Price	$3.15	$2.25	$1.65	$1.40	$2.06
Revenue ($M)	150.4	120.9	92.2	81.7	445.3

	1981				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	58.4%	59.7%	58.6%	59.7%	59.1%
Japan	39.9	38.7	39.6	36.7	38.7
Europe	1.7	1.6	1.8	3.6	2.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	4,400	4,700	4,700	5,000	18,800
Eurotechnique	900	1,200	1,300	1,400	4,800
Fairchild	900	900	750	700	3,250
Fujitsu	6,800	6,250	5,400	4,800	23,250
Hitachi	4,000	4,000	4,000	3,500	15,500
Intel	1,500	1,500	1,500	1,500	6,000
Intersil	0	0	0	0	0
Matsushita	250	250	100	100	700
Mitsubishi	500	450	800	500	2,250
Mostek	9,000	9,000	9,400	8,900	36,300
Motorola	3,015	3,190	4,550	3,600	14,355
National	8,995	9,500	9,500	8,300	36,295
NEC	10,000	10,000	10,000	10,000	40,000
SGS-Ates	50	50	35	15	150
Siemens	1,700	2,200	2,800	2,800	9,500
Signetics	0	0	0	0	0
STC (ITT)	2,800	3,200	5,100	6,300	17,400
Texas Instruments	6,500	7,000	7,000	7,000	27,500
Toshiba	1,500	1,700	1,800	2,000	7,000
Zilog	0	0	0	0	0
Total	62,810	65,090	68,735	66,415	263,050
Percent Change from Previous Quarter	8%	4%	6%	(3%)	
Cumulative Total	554,240	619,330	688,065	754,480	
Average Selling Price	$1.35	$1.30	$1.20	$1.10	$1.24
Revenue ($M)	84.8	84.6	82.5	73.1	324.9

	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	59.1%	59.9%	61.8%	62.2%	60.8%
Japan	36.7	34.8	32.2	31.5	33.7
Europe	4.2	5.3	6.0	6.3	5.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	5,100	5,800	5,200	4,000	20,100
Eurotechnique	1,800	2,000	2,500	2,500	8,800
Fairchild	600	400	300	300	1,600
Fujitsu	4,000	3,500	2,500	2,500	12,500
Hitachi	3,000	3,000	3,500	3,500	13,000
Intel	1,500	1,000	1,000	1,000	4,500
Intersil	0	0	0	0	0
Matsushita	100	50	50	0	200
Mitsubishi	400	240	200	150	990
Mostek	4,300	5,500	4,500	3,500	17,800
Motorola	3,800	3,600	4,100	3,500	15,000
National	4,500	6,000	5,000	4,500	20,000
NEC	9,800	9,500	11,000	10,000	40,300
SGS-Ates	20	100	150	50	320
Siemens	3,000	3,000	3,000	3,000	12,000
Signetics	0	0	0	0	0
STC (ITT)	5,600	6,200	6,200	5,500	23,500
Texas Instruments	7,000	12,000	10,000	9,500	38,500
Toshiba	2,400	3,000	2,500	2,200	10,100
Zilog	0	0	0	0	0
Total	56,920	64,890	61,700	55,700	239,210
Percent Change from Previous Quarter	(14%)	14%	(5%)	(10%)	
Cumulative Total	811,400	876,290	937,990	993,690	
Average Selling Price	$1.15	$1.10	$1.00	$0.95	$1.05
Revenue ($M)	65.5	71.4	61.7	52.9	251.5

	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	56.9%	62.4%	58.8%	57.1%	58.9%
Japan	34.6	29.7	32.0	32.9	32.2
Europe	8.5	7.9	9.2	10.0	8.8
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1984				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	2,500	2,500	2,000	1,500	8,500
Eurotechnique	2,000	2,000	1,200	1,000	6,200
Fairchild	200	100	0	0	300
Fujitsu	2,000	1,800	1,000	800	5,600
Hitachi	3,000	3,000	1,200	800	8,000
Intel	800	500	350	0	1,650
Intersil	0	0	0	0	0
Matsushita	0	0	0	0	0
Mitsubishi	170	170	0	0	340
Mostek	2,500	1,500	1,000	1,000	6,000
Motorola	3,000	2,500	1,600	1,200	8,300
National	3,500	2,500	1,200	1,200	8,400
NEC	8,000	6,000	4,200	2,500	20,700
SGS-Ates	0	0	0	0	0
Siemens	3,000	3,000	1,500	1,200	8,700
Signetics	0	0	0	0	0
STC (ITT)	4,000	3,500	2,200	1,500	11,200
Texas Instruments	8,000	6,500	4,000	2,500	21,000
Toshiba	1,800	1,600	1,200	1,200	5,800
Zilog	0	0	0	0	0
Total	44,470	37,170	22,650	16,400	120,690
Percent Change from Previous Quarter	(81%)	(16%)	(39%)	(28%)	
Cumulative Total	1,038,160	1,075,330	1,097,980	1,114,380	
Average Selling Price	$1.00	$1.10	$1.15	$1.20	$1.09
Revenue ($M)	44.5	40.9	26.0	19.7	131.1

	1984				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	46.1%	43.3%	44.8%	45.1%	44.9%
Japan	33.7	33.8	33.6	32.3	33.5
Europe	20.2	22.9	21.6	22.6	21.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

ESTIMATED WORLDWIDE 3-POWER-SUPPLY MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1985				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	1,250	1,100	1,100	1,100	4,550
Eurotechnique	1,200	1,200	1,200	1,200	4,800
Fairchild					
Fujitsu	500	250	300	300	1,350
Hitachi	500	200	400	400	1,500
Intel					
Intersil					
Matsushita					
Mitsubishi					
Mostek	800	700	600	400	2,500
Motorola	1,000	800	600	400	2,800
National	1,200	1,200	1,500	1,200	5,100
NEC	2,100	1,800	1,500	620	6,020
SGS-Ates					
Siemens	2,500	2,000	2,000	1,500	8,000
Signetics					
STC (ITT)	1,800	2,000	1,500	1,200	6,500
Texas Instruments	2,200	2,000	0	0	4,200
Toshiba	1,000	800	600	250	2,650
Zilog					
Total	16,050	14,050	11,300	8,570	49,970
Percent Change from Previous Quarter	(2%)	(12%)	(20%)	(24%)	
Cumulative Total	1,130,430	1,144,480	1,155,780	1,164,350	
Average Selling Price	$1.25	$1.30	$1.35	$1.45	$1.32
Revenue ($M)	20.1	18.3	15.3	12.4	66.0

	1985				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	40.2%	41.3%	33.6%	36.2%	38.3%
Japan	25.5	21.7	24.8	18.3	23.1
Europe	34.3	37.0	41.6	45.5	38.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

Table 3

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1979				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitsu					
Hitachi					
Intel	S	10	50	90	150
Mostek					
Motorola					
National					
Texas Instruments	—	—	—	—	—
Total	0	10	50	90	150
Percentage Change from Previous Quarter			400%	80%	
Cumulative Total	0	10	60	150	
Average Selling Price	$40.00	$30.00	$20.00	$15.00	$17.67
Revenue ($M)	0.0	0.3	1.0	1.4	2.7

	1979				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1980				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitsu				S	S
Hitachi			15	30	45
Intel	150	200	300	400	1,050
Mostek				S	S
Motorola			5	15	20
National				S	S
Texas Instruments				S	S
Total	150	200	320	445	1,115
Percentage Change from Previous Quarter	67%	33%	60%	39%	
Cumulative Total	300	500	820	1,265	
Average Selling Price	$10.00	$8.00	$7.00	$6.50	$7.38
Revenue ($M)	1.5	1.6	2.2	2.9	8.2

	1980				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	100.0%	100.0%	95.3%	93.3%	96.0%
Japan	0.0	0.0	4.7	6.7	4.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1981				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitsu	S	10	80	150	240
Hitachi	100	250	400	600	1,350
Intel	600	800	1,100	1,300	3,800
Mostek	0	S	10	100	110
Motorola	30	40	50	60	180
National	S	10	5	5	20
Texas Instruments	0	S	3	10	13
Total	730	1,110	1,648	2,225	5,713
Percentage Change from Previous Quarter	64%	52%	48%	35%	
Cumulative Total	1,995	3,105	4,753	6,978	
Average Selling Price	$5.00	$4.50	$4.00	$3.00	$3.84
Revenue ($M)	3.7	5.0	6.6	6.7	21.9

	1981				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	86.3%	76.6%	70.9%	66.3%	72.2%
Japan	13.7	23.4	29.1	33.7	27.8
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitsu	200	250	600	1,200	2,250
Hitachi	1,000	1,500	2,400	2,400	7,300
Intel	1,500	2,000	2,200	2,000	7,700
Mostek	500	1,200	1,200	1,700	4,600
Motorola	85	110	150	800	1,145
National	5	0	0	0	5
Texas Instruments	20	20	50	150	240
Total	3,310	5,080	6,600	8,250	23,240
Precentage Change from Previous Quarter	49%	53%	30%	25%	
Cumulative Total	10,288	15,368	21,968	30,218	
Average Selling Price	$2.70	$2.50	$2.25	$1.85	$2.23
Revenue ($M)	8.9	12.7	14.9	15.3	51.7

	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	63.7%	65.6%	54.5%	56.4%	58.9%
Japan	36.3	34.4	45.5	43.6	41.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1983				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitsu	1,500	2,000	3,000	3,000	9,500
Hitachi	3,000	3,500	3,500	3,500	13,500
Intel	2,000	1,700	1,500	1,500	6,700
Mostek	3,000	2,800	3,500	4,500	13,800
Motorola	2,200	3,300	4,000	3,000	12,500
National	0	0	0	0	0
Texas Instruments	250	350	400	400	1,400
Total	11,950	13,650	15,900	15,900	57,400
Percentage Change from Previous Quarter	45%	14%	16%	0%	
Cumulative Total	42,168	55,818	71,718	87,618	
Average Selling Price	$1.75	$1.85	$2.00	$2.25	$1.98
Revenue ($M)	20.9	25.3	31.8	35.8	113.7

	1983				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	62.3%	59.7%	59.1%	59.1%	59.9%
Japan	37.7	40.3	40.9	40.9	40.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitu	3,000	2,500	2,000	1,500	9,000
Hitachi	3,000	2,000	2,000	1,500	8,500
Intel	1,500	1,500	1,200	800	5,000
Mostek	2,000	1,500	1,700	900	6,100
Motorola	1,600	2,500	3,200	3,500	10,800
National	0	0	0	0	0
Texas Instruments	500	500	200	0	1,200
Total	11,600	10,500	10,300	8,200	40,600
Percentage Change from Previous Quarter	(27%)	(9%)	(2%)	(20%)	
Cumulative Total	99,218	109,718	120,018	128,218	
Average Selling Price	$2.10	$2.10	$2.10	$1.95	$2.07
Revenue ($M)	24.4	22.1	21.6	16.0	84.0

	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	48.3%	57.1%	61.2%	63.4%	56.9%
Japan	51.7	42.9	38.8	36.6	43.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

ESTIMATED WORLDWIDE 5-VOLT MOS 16K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

	1985				
Company	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Fujitu	800	500	500	400	2,200
Hitachi	1,500	1,200	1,000	800	4,500
Intel	600	500	250	100	1,450
Mostek	600	500	500	500	2,100
Motorola	3,200	3,000	2,500	2,000	10,700
National	0	0	0	0	0
Texas Instruments	0	0	0	0	0
Total	6,700	5,700	4,750	3,800	20,950
Percentage Change from Previous Quarter	(18%)	(15%)	(17%)	(20%)	
Cumulative Total	134,918	140,618	145,368	149,168	
Average Selling Price	$1.65	$1.55	$1.60	$1.70	$1.62
Revenue ($M)	11.1	8.8	7.6	6.5	34.0

	1985				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	65.7%	70.2%	68.4%	68.4%	68.0%
Japan	34.3	29.8	31.6	31.6	32.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

Table 4

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1978 1st Qtr	1978 2nd Qtr	1978 3rd Qtr	1978 4th Qtr	1978 Year
AMD							
Fairchild							
Fujitsu		64Kx1		S	S	S	S
		16Kx4					
	C	8Kx8					
Hitachi		64Kx1					
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1					
	C	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1					
		16Kx4					
Mostek							
Motorola							
National							
NEC		64Kx1					
	C	64Kx1					
		16Kx4					
Oki Electric							
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1				S	S
		16Kx4					
Toshiba							
Vitelic	C	64Kx1	-	-	-	-	-
Total			0	0	0	0	0
Percent Change from Previous Quarter							
Cumulative Total			0	0	0	0	
Average Selling Price				$200.00	$175.00	$150.00	$150.00
Revenue ($M)			0.0	0.0	0.0	0.0	0.0

	1978 1st Qtr	1978 2nd Qtr	1978 3rd Qtr	1978 4th Qtr	1978 Year
Market Share					
U.S.		0.0	0.0	0.0	0.0
Japan		100.0%	100.0%	100.0%	100.0%
Europe		0.0	0.0	0.0	0.0
Asia Pacific		0.0	0.0	0.0	0.0
Total		100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/	Organization	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD							
Fairchild							
Fujitsu		64Kx1	3	5	7	9	24
		16Kx4					
	C	8Kx8					
Hitachi		64Kx1				S	S
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1					
	C	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1				S	S
		16Kx4					
Mostek							
Motorola			S	1	3	6	10
National							
NEC		64Kx1					
	C	64Kx1					
		16Kx4					
Oki Electric							
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1	S	S	1	1	2
		16Kx4					
Toshiba							
Vitelic	X	64Kx1	-	-	-	-	-
Total			3	6	11	16	36
Percent Change from Previous Quarter				100%	83%	45%	
Cumulative Total			3	9	20	36	
Average Selling Price			$135.00	$125.00	$110.00	$100.00	$110.14
Revenue ($M)			0.4	0.8	1.2	1.6	4.0

	1979 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	0.0	16.7%	36.4%	43.8%	33.3%
Japan	100.0%	83.3	63.6	56.3	66.7
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.1%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization	1980 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD						
Fairchild						
Fujitsu	64Kx1	10	25	30	65	130
	16Kx4					
	C 8Kx8					
Hitachi	64Kx1	S	10	35	60	105
	16Kx4					
Inmos	64Kx1					
	16Kx4					
	8Kx8					
Intel	64Kx1		S	S	3	3
	C 64Kx1					
Matsushita	64Kx1					
	16Kx4					
	8Kx8					
Micron Technology						
Mitsubishi	64Kx1	S	S	2	15	17
	16Kx4					
Mostek						
Motorola		10	30	40	70	150
National					S	S
NEC	64Kx1			S	5	5
	C 64Kx1					
	16Kx4					
Oki Electric					S	S
Samsung						
Sharp						
Siemens						
STC (ITT)						
Texas Instruments	64Kx1	1	3	5	15	24
	16Kx4					
Toshiba		S	S	2	5	7
Vitelic	C 64Kx1	—	—	—	—	—
Total		21	68	114	238	441
Percent Change from Previous Quarter		31%	224%	68%	109%	
Cumulative Total		57	125	239	477	
Average Selling Price		$90.00	$75.00	$55.00	$30.00	$46.26
Revenue ($M)		1.9	5.1	6.3	7.1	20.4

	1980 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	52.4%	48.5%	39.5%	37.0%	40.1%
Japan	47.6	51.5	60.5	63.0	59.9
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

DRAM--Data

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization	1981 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD						
Fairchild					S	S
Fujitsu	64Kx1	110	360	550	900	1,920
	16Kx4					
	C 8Kx8					
Hitachi	64Kx1	200	700	1,[illegible]00	1,900	3,900
	16Kx4					
Inmos	64Kx1				S	S
	16Kx4					
	8Kx8					
Intel	64Kx1	5	10	10	5	30
	C 64Kx1					
Matsushita	64Kx1				S	S
	16Kx4					
	8Kx8					
Micron Technology					S	S
Mitsubishi	64Kx1	36	70	320	640	1,066
	16Kx4					
Mostek		S	10	30	100	140
Motorola		125	350	700	800	1,975
National		S	S	S	S	S
NEC	64Kx1	50	100	300	1,000	1,450
	C 64Kx1					
	16Kx4					
Oki Electric		5	30	100	600	735
Samsung						
Sharp						
Siemens					S	S
STC (ITT)						
Texas Instruments	64Kx1	35	130	370	800	1,335
	16Kx4					
Toshiba		10	20	20	30	80
Vitelic	C 64Kx1					
Total		576	1,780	3,500	6,775	12,631
Percent Change from Previous Quarter		142%	209%	97%	94%	
Cumulative Total		1,053	2,833	6,333	13,108	
Average Selling Price		$22.00	$15.00	$12.00	$8.50	$11.00
Revenue ($M)		12.7	26.7	42.0	57.6	139.0

	1981 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	28.6%	28.1%	31.7%	25.2%	27.6%
Japan	71.4	71.9	68.3	74.8	72.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD						S	S
Fairchild			S	S	10	5	15
Fujitsu		64Kx1	2,000	3,500	4,700	6,300	16,500
		16Kx4					
	C	8Kx8					
Hitachi		64Kx1	2,500	3,600	5,400	6,800	18,300
		16Kx4					
Inmos		64Kx1	5	10	20	75	110
		16Kx4					
		8Kx8					
Intel		64Kx1	5	100	350	1,100	1,555
	C	64Kx1					
Matsushita		64Kx1	S	S	10	20	30
		16Kx4					
		8Kx8					
Micron Technology			20	150	450	600	1,200
Mitsubishi		64Kx1	1,300	1,800	3,200	5,500	11,800
		16Kx4					
Mostek			450	650	1,700	3,200	6,000
Motorola			1,100	2,300	3,100	4,600	11,100
National			S	S	0	0	S
NEC		64Kx1	2,200	2,700	4,500	5,500	14,900
	C	64Kx1					
		16Kx4					
Oki Electric			1,150	1,770	2,500	1,200	6,620
Samsung							
Sharp							
Siemens			5	25	75	200	305
STC (ITT)						S	S
Texas Instruments		64Kx1	1,700	3,400	4,000	4,800	13,900
		16Kx4		S	200	500	700
Toshiba			30	80	200	600	910
Vitelic	C	64Kx1					
Total			12,465	20,085	30,415	41,000	103,965
Percent Change from Previous Quarter			84%	61%	51%	35%	
Cumulative Total			25,573	45,658	76,073	117,073	
Average Selling Price			$6.50	$6.00	$5.50	$4.75	$5.42
Revenue ($M)			81.0	120.5	167.3	194.8	563.6

	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	26.3%	32.9%	32.3%	36.1%	33.2%
Japan	73.6	67.0	67.4	63.2	66.4
Europe	0.1	0.2	0.3	0.7	0.4
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.1%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company		MOS Process/ Organization	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD			S	10	100	250	360
Fairchild			0	0	0	S	S
Fujitsu		64Kx1	7,500	9,200	11,200	11,500	39,400
		16Kx4	S	100	300	1,000	1,400
	C	8Kx8				S	S
Hitachi		64Kx1	11,000	14,500	16,500	18,500	60,500
		16Kx4			S	S	S
Inmos		64Kx1	150	350	625	1,400	2,525
		16Kx4	S	50	250	600	900
		8Kx8		S	25	100	125
Intel		64Kx1	1,800	2,600	3,500	5,000	12,900
	C	64Kx1			S	S	S
Matsushita		64Kx1	80	400	1,800	3,000	5,280
		16Kx4					
		8Kx8					
Micron Technology			950	1,500	2,500	4,000	8,950
Mitsubishi		64Kx1	6,800	7,000	8,900	10,800	33,500
		16Kx4					
Mostek			4,000	8,500	12,300	16,200	41,000
Motorola			4,000	6,300	8,900	12,000	31,200
National			0	S	10	150	160
NEC		64Kx1	8,500	12,000	15,000	18,000	53,500
	C	64Kx1				S	S
		16Kx4					
Oki Electric			2,200	4,000	6,500	8,000	20,700
Samsung							
Sharp						S	S
Siemens			350	500	1,000	2,000	3,850
STC (ITT)			15	75	100	100	290
Texas Instruments		64Kx1	7,400	8,500	9,000	13,700	38,600
		16Kx4	600	1,500	3,000	3,000	8,100
Toshiba			1,000	1,500	2,600	3,000	8,100
Vitelic	C	64Kx1					
Total			56,345	78,585	104,110	132,300	371,340
Percent Change from Previous Quarter			37%	39%	32%	27%	
Cumulative Total			173,418	252,003	356,113	488,413	
Average Selling Price			$4.00	$3.75	$3.80	$3.90	$3.86
Revenue ($M)			225.4	294.7	395.6	516.0	1,431.7

	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	33.3%	36.9%	37.9%	41.1%	38.1%
Japan	65.8	62.0	60.3	55.8	59.9
Europe	0.9	1.1	1.8	3.1	2.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD		500	1,000	1,500	3,000	6,000
Fairchild		10	25	0	0	35
Fujitsu	64Kx1	14,500	18,000	25,000	28,500	86,000
	16Kx4	1,500	2,000	2,500	3,000	9,000
	C 8Kx8	S	10	10	25	45
Hitachi	64Kx1	22,300	25,500	27,500	28,000	103,300
	16Kx4	10	25	150	300	485
Inmos	64Kx1	2,000	2,200	2,500	2,500	9,200
	16Kx4	800	1,200	1,800	1,500	5,300
	8Kx8	250	350	400	250	1,250
Intel	64Kx1	5,000	4,000	3,000	1,600	13,600
	C 64Kx1	50	150	200	200	600
Matsushita	64Kx1	4,200	6,000	8,000	7,000	25,200
	16Kx4	S	10	100	350	460
	8Kx8		S	5	20	25
Micron Technology		6,200	9,300	14,000	19,200	48,700
Mitsubishi	64Kx1	13,500	18,400	24,000	26,000	81,900
	16Kx4	S	100	1,000	1,500	2,600
Mostek		15,000	17,000	20,000	21,500	73,500
Motorola		11,000	13,100	18,000	18,700	60,800
National		500	1,200	2,500	3,500	7,700
NEC	64Kx1	21,100	23,600	27,000	30,000	101,700
	C 64Kx1	50	150	850	1,250	2,300
	16Kx4				S	S
Oki Electric		11,000	13,500	16,000	18,500	59,000
Samsung			S	S	1,500	1,500
Sharp		50	150	500	1,000	1,700
Siemens		3,000	4,000	4,000	4,500	15,500
STC (ITT)		200	400	600	1,000	2,200
Texas Instruments	64Kx1	17,000	22,000	25,500	24,000	88,500
	16Kx4	3,500	4,000	5,600	7,000	20,100
Toshiba		4,500	4,700	5,200	9,000	23,400
Vitelic	C 64Kx1				S	S
Total		157,720	192,070	237,415	264,395	851,600
Percent Change from Previous Quarter		19%	22%	24%	11%	
Cumulative Total		646,133	838,203	1,075,618	1,340,013	
Average Selling Price		$3.50	$3.40	$3.15	$2.80	$3.16
Revenue ($M)		552.0	653.0	747.9	740.3	2,693.2

	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	37.3%	37.4%	38.0%	37.3%	37.5%
Japan	58.8	58.4	58.0	58.4	58.4
Europe	4.0	4.2	3.9	3.7	3.9
Asia Pacific	0.0	0.0	0.0	0.6	0.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization	1985 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	NMOS 64Kx1	2,000	1,000	1,000	1,000	5,000
Fairchild		0	0	0	0	0
Fujitsu	NMOS 64Kx1	19,000	18,000	10,000	8,500	55,500
	NMOS 16Kx4	2,200	1,500	1,200	1,000	5,900
	CMOS 8Kx8	25	25	10	0	60
Hitachi	NMOS 64Kx1	20,000	17,500	14,000	13,500	65,000
	NMOS 16Kx4	500	700	1,000	1,250	3,450
Inmos	NMOS 64Kx1	2,500	2,200	2,000	2,100	8,800
	NMOS 16Kx4	800	500	400	500	2,200
	NMOS 8Kx8	50	40	20	0	110
Intel	NMOS 64Kx1	500	0	0	0	500
	CMOS 64Kx1	250	250	200	100	800
Matsushita	NMOS 64Kx1	3,000	2,000	1,500	1,200	7,700
	NMOS 16Kx4	400	300	200	150	1,050
	NMOS 8Kx8	100	150	100	80	430
Micron Technology	NMOS	12,500	12,000	6,000	2,800	33,300
Mitsubishi	NMOS 64Kx1	15,000	15,000	12,500	13,500	56,000
	NMOS 16Kx4	1,000	800	650	850	3,300
Mostek	NMOS	8,000	10,000	7,500	5,000	30,500
Motorola	NMOS	10,000	12,000	5,000	3,500	30,500
National	NMOS	2,500	1,500	1,200	500	5,700
NEC	NMOS 64Kx1	22,500	18,000	14,400	7,520	62,420
	CMOS 64Kx1	800	350	40	0	1,190
	NMOS 16Kx4	150	500	1,630	1,820	4,100
Oki Electric	NMOS	7,500	8,000	5,500	5,000	26,000
Samsung	NMOS	3,000	6,000	5,500	5,500	20,000
Sharp	NMOS	500	500	250	0	1,250
Siemens	NMOS	3,500	2,500	2,000	2,000	10,000
STC (ITT)	NMOS	500	400	400	400	1,700
Texas Instruments	NMOS 64Kx1	13,000	10,000	7,000	6,000	36,000
	NMOS 16Kx4	3,500	4,000	3,200	2,500	13,200
Toshiba	NMOS	6,000	4,000	4,000	4,000	18,000
Vitelic	CMOS 64Kx1	S	S	S	10	10
Total		161,275	149,715	108,400	90,280	509,670
Percent Change from Previous Quarter		(39%)	(7%)	(28%)	(17%)	
Cumulative Total		1,501,288	1,651,003	1,759,403	1,849,683	
Average Selling Price		$1.65	$1.10	$0.75	$0.85	$1.16
Revenue ($M)		266.1	164.7	81.3	76.7	588.8

	1985 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	32.4%	33.9%	28.7%	23.7%	30.5%
Japan	61.2	58.3	61.8	64.7	61.1
Europe	4.6	3.8	4.4	5.5	4.5
Asia Pacific	1.9	4.0	5.1	6.1	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

ESTIMATED WORLDWIDE MOS 64K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization	1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	NMOS 64Kx1	700	500	500	500	2,200
Fairchild		0	0	0	0	0
Fujitsu	NMOS 64Kx1	8,000	7,500	6,000	5,000	26,500
	NMOS 16Kx4	1,000	1,000	1,000	1,000	4,000
	CMOS 8Kx8	0	0	0	0	0
Hitachi	NMOS 64Kx1	14,000	10,000	8,000	5,000	37,000
	NMOS 16Kx4	1,250	1,000	1,000	500	3,750
Inmos	NMOS 64Kx1	2,000	2,000	2,000	2,000	8,000
	NMOS 16Kx4	500	500	500	500	2,000
	NMOS 8Kx8	0	0	0	0	0
Intel	NMOS 64Kx1	0	0	0	0	0
	CMOS 64Kx1	200	200	100	100	600
Matsushita	NMOS 64Kx1	1,500	1,500	1,400	1,400	5,800
	NMOS 16Kx4	200	200	200	200	800
	NMOS 8Kx8	500	1,000	1,500	2,000	5,000
Micron Technology	NMOS	4,000	4,500	5,000	4,500	18,000
Mitsubishi	NMOS 64Kx1	20,000	21,000	15,000	15,000	71,000
	NMOS 16Kx4	850	850	600	500	2,800
Mostek	NMOS	3,000	2,000	1,000	1,000	7,000
Motorola	NMOS	5,000	5,000	5,000	5,000	20,000
National	NMOS	1,250	1,250	1,250	1,250	5,000
NEC	NMOS 64Kx1	14,930	15,560	6,290	5,800	42,580
	CMOS 64Kx1	0	0	130	0	130
	NMOS 16Kx4	1,880	2,690	4,080	5,200	13,850
Oki Electric	NMOS	5,000	5,000	5,000	5,000	20,000
Samsung	NMOS	8,000	10,000	10,000	10,000	38,000
Sharp	NMOS	700	500	500	500	2,200
Siemens	NMOS	2,500	2,500	2,500	2,500	10,000
STC (ITT)	NMOS	500	400	400	400	1,700
Texas Instruments	NMOS 64Kx1	6,000	6,000	6,000	5,000	23,000
	NMOS 16Kx4	3,000	3,000	2,500	2,500	11,000
Toshiba	NMOS	6,000	6,000	6,500	4,000	22,500
Vitelic	CMOS 64Kx1	50	100	150	200	500
Total		112,510	111,750	94,100	86,550	404,910
Percent Change from Previous Quarter		25%	(1%)	(16%)	(8%)	
Cumulative Total		1,962,193	2,073,943	2,168,043	2,254,593	
Average Selling Price		$1.10	$1.05	$1.05	$0.90	$1.03
Revenue ($M)		123.8	117.3	98.8	77.9	417.8

	1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	20.6%	20.2%	22.8%	23.2%	21.6%
Japan	67.4	66.0	60.8	59.0	63.7
Europe	4.9	4.8	5.7	6.2	5.4
Asia Pacific	7.1	8.9	10.6	11.6	9.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

DRAM--Data

Table 5

ESTIMATED WORLDWIDE MOS 256K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1				S	S
Fujitsu	NMOS	256Kx1				S	S
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1			5	10	10
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron Technology	NMOS	256Kx1					
	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1					
	NMOS	64Kx4					
Mostek	NMOS	32Kx8					
	NMOS	256Kx1					
Motorola	NMOS	256Kx1					
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1					
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1				S	S
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					
Texas Instruments	NMOS	256Kx1					
	NMOS	64Kx4					
Toshiba	NMOS	256Kx1				S	S
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			0	0	0	10	10
Percent Change from Previous Quarter							
Cumulative Total			0	0	0	10	
Average Selling Price					$200.00	$150.00	$150.00
Revenue ($M)			0.0	0.0	0.0	1.5	1.5

	1982 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.				0.0	0.0
Japan				100.0%	100.0%
Europe				0.0	0.0
Asia Pacific				0.0	0.0
Total				100.0%	100.0%

(Continued)

Table 5 (Continued)

ESTIMATED WORLDWIDE MOS 256K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1	S	S	20	100	120
Fujitsu	NMOS	256Kx1	S	30	150	300	480
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1	25	50	175	400	650
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron Technology	NMOS	256Kx1					
	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1		S	10	50	60
	NMOS	64Kx4					
Mostek	NMOS	32Kx8			S	5	5
	NMOS	256Kx1					
Motorola	NMOS	256Kx1		S	S	0	S
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1	S	S	100	200	300
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1	S	S	5	10	15
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					
Texas Instruments	NMOS	256Kx1			S	S	S
	NMOS	64Kx4					
Toshiba	NMOS	256Kx1	S	S	20	50	70
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			25	80	480	1,115	1,700
Percent Change from Previous Quarter				220%	500%	132%	
Cumulative Total			25	105	585	1,700	
Average Selling Price			$100.00	$80.00	$55.00	$41.00	$47.66
Revenue ($M)			2.5	6.4	26.4	45.7	81.0

	1983 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	0.0	0.0	4.2%	9.4%	7.4%
Japan	100.0%	100.0%	95.8	90.6	92.6
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

ESTIMATED WORLDWIDE MOS 256K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1	200	500	800	1,500	3,000
Fujitsu	NMOS	256Kx1	600	1,500	2,500	3,300	7,900
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1	700	2,200	3,000	4,800	10,700
	CMOS	256Kx1					
	NMOS	64Kx4			S	5	5
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1		S	S	20	20
	CMOS	64Kx4				S	S
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron Technology	NMOS	256Kx1			S	20	20
	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1	50	50	300	750	1,150
	NMOS	64Kx4					
Mostek	NMOS	32Kx8	15	35	40	60	150
	NMOS	256Kx1				S	S
Motorola	NMOS	256Kx1				S	S
	CMOS	256Kx1					
National	NMOS	256Kx1		S	S	10	10
NEC	NMOS	256Kx1	800	1,500	3,500	4,100	9,900
	NMOS	64Kx4	S	150	90	120	360
	NMOS	32Kx8			S	5	5
Oki Electric	NMOS	256Kx1	50	100	350	500	1,000
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					
Texas Instruments	NMOS	256Kx1	10	25	50	75	160
	NMOS	64Kx4	S	S	S	S	S
Toshiba	NMOS	256Kx1	200	500	1,100	1,800	3,600
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			2,625	6,560	11,730	17,065	37,980
Percent Change from Previous Quarter			135%	150%	79%	45%	
Cumulative Total			4,325	10,885	22,615	39,680	
Average Selling Price			$31.00	$23.50	$17.50	$14.00	$17.90
Revenue ($M)			81.4	154.2	205.3	238.9	679.7

	1984 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	8.6%	8.5%	7.6%	9.9%	8.8%
Japan	91.4	91.5	92.4	90.1	91.2
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

ESTIMATED WORLDWIDE MOS 256K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

			1985				
Company	MOS Process/ Organization		1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	CMOS	256Kx1			S	S	S
AT&T Technologies	NMOS	256Kx1	1,600	2,200	3,500	5,000	12,300
Fujitsu	NMOS	256Kx1	3,700	5,600	8,500	13,000	30,800
	NMOS	64Kx1			S	25	25
	CMOS	256Kx1				S	S
	CMOS	64Kx4				S	S
Hitachi	NMOS	256Kx1	6,000	8,500	14,500	20,000	49,000
	CMOS	256Kx1	S	5	50	250	305
	NMOS	64Kx4	25	100	400	1,000	1,525
Inmos	CMOS	256Kx1	S	S	S	5	5
Intel	CMOS	256Kx1	200	400	600	750	1,950
	CMOS	64Kx4	10	100	600	1,100	1,810
Matsushita	NMOS	256Kx1	S	50	250	1,500	1,800
	NMOS	64Kx4					0
Micron Technology	NMOS	256Kx1	20	10	400	1,500	1,930
	NMOS	64Kx4		S	S	25	25
Mitsubishi	NMOS	256Kx1	900	1,800	3,200	5,500	11,400
	NMOS	64Kx4				S	S
Mostek	NMOS	32Kx8	50	50	50	25	175
	NMOS	256Kx1	S	25	25	25	75
Motorola	NMOS	256Kx1	S	5	0	0	5
	CMOS	256Kx1			S	S	S
National	NMOS	256Kx1	25	50	0	0	75
NEC	NMOS	256Kx1	4,650	6,500	13,750	16,780	41,680
	NMOS	64Kx4	420	600	260	80	1,360
	NMOS	32Kx8	10	150	250	450	860
Oki Electric	NMOS	256Kx1	600	800	1,200	2,000	4,600
	NMOS	64Kx4					
Samsung	NMOS	256Kx1	S	S	5	10	15
Sharp	NMOS	256Kx1			S	S	0
	NMOS	64Kx4			S	S	0
Siemens	NMOS	256Kx1			S	150	150
Texas Instruments	NMOS	256Kx1	500	1,200	4,000	6,000	11,700
	NMOS	64Kx4	10	15	150	300	510
Toshiba	NMOS	256Kx1	4,000	6,000	7,000	8,000	25,000
	NMOS	64Kx4	S	500	1,000	1,000	2,500
Vitelic	CMOS	256Kx1			S	S	S
	CMOS	64Kx4					S
Total			22,720	34,695	59,690	84,475	201,580
Percent Change from Previous Quarter			33%	53%	72%	42%	
Cumulative Total			62,400	97,095	156,785	241,260	
Average Selling Price			$9.50	$5.15	$3.00	$2.25	$3.79
Revenue ($M)			215.8	178.7	179.1	190.1	763.7

	1985				
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	10.6%	11.8%	15.6%	17.4%	15.2%
Japan	89.4	88.2	84.4	82.4	84.8
Europe	0.0	0.0	0.0	0.2	0.1
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

ESTIMATED WORLDWIDE MOS 256K DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
AMD	CMOS	256Kx1					0
AT&T Technologies	NMOS	256Kx1	5,000	5,000	5,000	5,000	20,000
Fujitsu	NMOS	256Kx1	20,000	28,000	10,000	15,000	73,000
	NMOS	64Kx1	100	500	1,000	2,000	3,600
	CMOS	256Kx1	25	100	250	500	875
	CMOS	64Kx4	25	50	150	300	525
Hitachi	NMOS	256Kx1	25,000	30,000	25,000	25,000	105,000
	CMOS	256Kx1	500	1,000	2,000	3,000	6,500
	NMOS	64Kx4	2,000	2,500	2,500	2,500	9,500
Inmos	CMOS	256Kx1	250	500	1,000	1,500	3,250
Intel	CMOS	256Kx1					0
	CMOS	64Kx4					0
Matsushita	NMOS	256Kx1	2,100	2,400	3,000	3,500	11,000
	NMOS	64Kx4					0
Micron Technology	NMOS	256Kx1	3,000	6,000	7,500	9,000	25,500
	NMOS	64Kx4	200	800	1,200	1,500	3,700
Mitsubishi	NMOS	256Kx1	17,000	12,500	28,500	21,000	79,000
	NMOS	64Kx4	5	50	100	200	350
Mostek	NMOS	32Kx8					0
	NMOS	256Kx1	50	200	500	1,000	1,750
Motorola	NMOS	256Kx1	0	100	700	1,300	2,100
	CMOS	256Kx1					0
National	NMOS	256Kx1					0
NEC	NMOS	256Kx1	24,490	28,840	26,720	28,000	108,050
	NMOS	64Kx4	400	560	7,310	5,000	13,270
	NMOS	32Kx8	600	750	750	1,000	3,100
Oki Electric	NMOS	256Kx1	3,000	4,000	5,000	6,000	18,000
	NMOS	64Kx4	5	100	300	600	1,000
Samsung	NMOS	256Kx1	500	2,000	5,000	5,000	12,500
Sharp	NMOS	256Kx1					0
	NMOS	64Kx4					0
Siemens	NMOS	256Kx1	200	500	800	1,500	3,000
Texas Instruments	NMOS	256Kx1	9,000	10,000	8,000	10,000	37,000
	NMOS	64Kx4	500	1,000	1,250	1,500	4,250
Toshiba	NMOS	256Kx1	11,000	14,000	18,500	22,000	65,500
	NMOS	64Kx4	1,000	1,600	1,900	2,300	6,800
Vitelic	CMOS	256Kx1	10	50	90	150	300
	CMOS	64Kx4	5	10	30	70	110
Total			125,950	153,110	164,050	175,420	618,530
Percent Change from Previous Quarter			49%	22%	7%	7%	
Cumulative Total			367,210	520,320	684,370	859,790	
Average Selling Price			$2.25	$2.30	$2.50	$2.20	$2.31
Revenue ($M)			283.4	352.2	410.1	385.9	1,431.6

	1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	14.1%	15.1%	14.8%	16.8%	15.3%
Japan	85.1	82.9	81.1	78.6	81.7
Europe	0.4	0.7	1.1	1.7	1.0
Asia Pacific	0.4	1.3	3.0	2.9	2.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

Table 6

ESTIMATED WORLDWIDE 1Mb DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
ATT Technolgoies	C	1Mbx1	S	S	S	1	1
Fujitsu	N	1Mbx1		S	0	0	0
Hitachi	C	1Mbx1	S	S	0	2	2
Micron	C	256Kx4					
Mitsubishi	N	1Mbx1				S	
	N	256Kx4				S	
NEC	N	1Mbx1		S	S	0	0
NMB	C	256Kx4					
Oki		1Mbx1					
Texas Instruments	C	1Mbx1				S	0
	C	256Kx4				S	0
Toshiba	C	1Mbx1		S	10	150	160
	N	1Mbx1	S	S	1	2	3
	C	256Kx4					
Vitelic	C	256Kx4				S	0
Total			0	0	11	155	166
Percent Change from Previous Quarter						1,309%	
Cumulative Total			0	0	11	166	
Average Selling Price			$150.00	$125.00	$110.00	$100.00	$100.66
Revenue ($M)			0.0	0.0	1.2	15.5	16.7

	1985 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	ERR	ERR	0.0	0.6%	0.6%
Japan	0.0%	0.0%	100.0%	99.4	99.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	ERR	ERR	100.0%	100.0%	100.0%

(Continued)

Table 6 (Continued)

ESTIMATED WORLDWIDE 1Mb DYNAMIC RAM SHIPMENTS
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
ATT Technolgoies	C	1Mbx1	10	50	150	300	510
Fujitsu	N	1Mbx1	10	20	50	100	180
Hitachi	C	1Mbx1	5	35	150	590	780
Micron	C	256Kx4	S	S	S	1	1
Mitsubishi	N	1Mbx1	5	50	100	450	605
	N	256Kx1	S	20	50	150	220
NEC	N	1Mbx1	0	0	S	5	5
NMB	C	256Kx4	S	S	5	20	25
Oki		1Mbx1		S	5	10	15
Texas Instruments	C	1Mbx1	2	S	5	10	17
	C	256Kx4	2	S	5	10	17
Toshiba	C	1Mbx1	200	400	700	1,700	3,000
	N	1Mbx1	5	10	15	25	55
	C	256Kx4	S	S	70	160	230
Vitelic	C	256Kx4	S	S	S	S	0
Total			239	585	1,305	3,531	5,660
Percent Change from Previous Quarter			54%	145%	123%	171%	
Cumulative Total			405	990	2,295	5,826	
Average Selling Price			$48.00	$20.00	$45.00	$25.00	$30.07
Revenue ($M)			11.5	11.7	58.7	88.3	170.2

	1986 1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Year
Market Share					
U.S.	5.9%	8.5%	12.3%	9.1%	9.6%
Japan	94.1	91.5	87.7	90.9	90.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
May 1987

DRAM Regional Consumption

DRAM CONSUMPTION OVERVIEW

The consumption of dynamic RAMs (DRAMs) on a regional basis has become more complicated. The pricing discrepancies among regions, the U.S.-Japan semiconductor trade arrangement, and availability concerns have caused semiconductor users to shop for DRAMs on a worldwide basis. DRAM purchasing locations no longer coincide with DRAM manufacturing locations. In 1985, purchasing organizations of major semiconductor companies were formed in Southeast Asia to take advantage of the low cost of components, especially memories, there.

Eventually, even manufacturing locations and operations have begun to move to the Pacific Rim, not only from the United States but from Japan as well. U.S. manufacturers are moving to realize lower labor and material costs required to compete with foreign goods. Japanese manufacturers are moving because of the highly appreciated yen. All of these factors cause dislocations in the normal purchasing and consumption patterns of dynamic RAMs.

HIGHLIGHTS

Dataquest divides the worldwide DRAM market into four regions:

- North America
- Japan
- Europe
- ROW (rest of world)

The Asia/Pacific region accounts for most of ROW.

This section presents a regional analysis of DRAM consumption, broken down by major densities, as shown in Table 1.

A region's consumption is defined as the product shipped into it directly from the factory. The true world, however, is much more complex. Many large DRAM users do not necessarily purchase where they manufacture. A company can conceivably be purchasing in Hong Kong, receiving shipment in Hong Kong, and eventually sending DRAMs to the United States for assembly. The gray market, a strong factor in 1986, purchased and received DRAMs in Japan or Southeast Asia and eventually resold these in the United States.

DRAM Regional Consumption

Table 1

1986 DYNAMIC RAM REGIONAL CONSUMPTION

Region	Density	Millions of Units	Millions of Dollars
North America	64K	166.6	$183.3
	256K	225.9	598.7
	1Mb	1.5	59.4
	Others	12.2	45.3
	Total	406.2	$886.7
Japan	64K	85.0	$ 82.4
	256K	247.2	509.3
	1Mb	3.9	106.3
	Others	7.7	11.5
	Total	343.8	$709.5
Europe	64K	61.7	$ 61.7
	256K	100.8	226.8
	1Mb	0.3	9.4
	Others	6.1	9.2
	Total	168.9	$307.1
Rest of World	64K	91.6	$ 87.0
	256K	44.6	93.6
	1Mb	0	0
	Others	4.6	13.8
	Total	140.8	$194.4

Source: Dataquest
June 1987

DRAM Regional Consumption

A major highlight of 1986 was that more DRAM units were shipped initially into the Japanese market than into the U.S. market, which was an evident break from history. Dataquest believes that a significant percentage of these units eventually found their way into the United States through gray-market channels.

Other highlights of this regional analysis include the following:

- As shown in Figure 1, the United States remains the largest DRAM market, accounting for approximately 42 percent of worldwide consumption, followed by Japan with approximately 34 percent. The United States still dominates the computer industry, which is by far the largest end-use market for DRAMs.

- The Asia/Pacific region, the dominant component of ROW, has grown dramatically to 8 percent of worldwide DRAM consumption. Several factors have led to this improvement:

    - DRAM consumption has increased most notably in South Korea, Taiwan, and Hong Kong, where IBM PC clones are being heavily manufactured. Successful brands, such as Leading Edge, have significantly grown in shipments.

    - The 64K DRAMs, though less visible elsewhere, are very much in demand here for talking teddy bears and other consumer applications.

    - The most significant factor causing the increase is the continuing migration of production and purchasing activities of U.S. system manufacturers to the region. The low labor costs and, more importantly, the lower component costs of the Asia/Pacific Rim are attracting more U.S. companies plagued by low-cost foreign competition.

- The Japanese market has the greatest momentum to convert to higher densities, as shown in Figure 2. Only about 12 percent of Japanese consumption is in 64K DRAMs, with most applications having moved to the 256K density. The Japanese market has also shown an early use of the 1Mb DRAM, consuming 70 percent of worldwide production. Much of this is attributable to Japanese leadership in DRAM technology and the captive markets of leading Japanese DRAM producers.

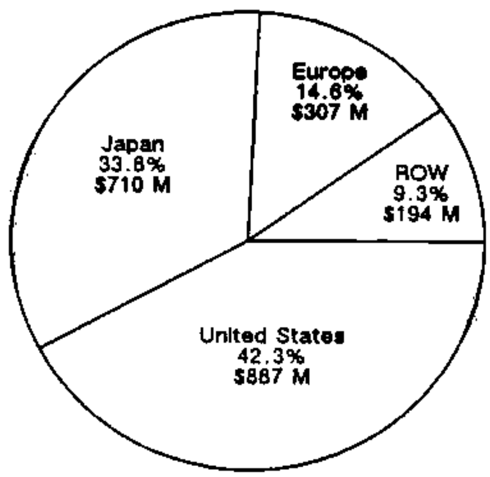
- In the other extreme, ROW is slow to convert. ROW producers tend to wait for lower prices before converting to the next density. That trend is slowly changing as more U.S. and Japanese producers bring more of their manufacturing to the Asia/Pacific area.

DRAM Regional Consumption

- Figure 3 shows the breakdown of densities by region in actual dollars. The U.S. market, in consumption dollars, far exceeds those of the other regions. It is the largest market in all but the 1Mb density, consuming 42 percent of 256K worldwide production and 44 percent of the 64K. Figure 4 shows how each major DRAM density is consumed on a regional basis.

Figure 1

**1986 REGIONAL CONSUMPTION
DYNAMIC RAMs**



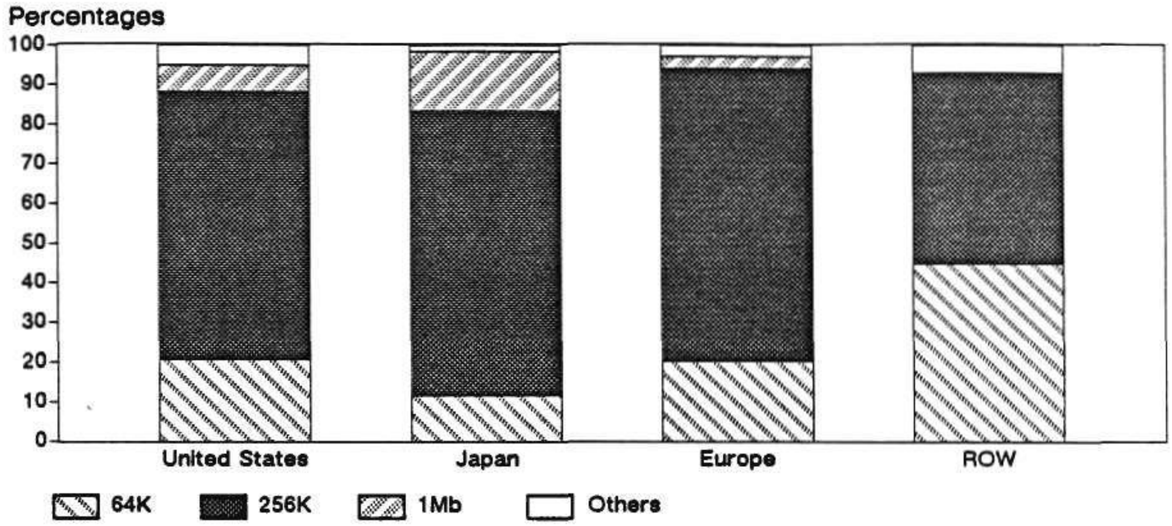
Total = $2.1 Billion

Source: Dataquest
June 1987

DRAM Regional Consumption

Figure 2

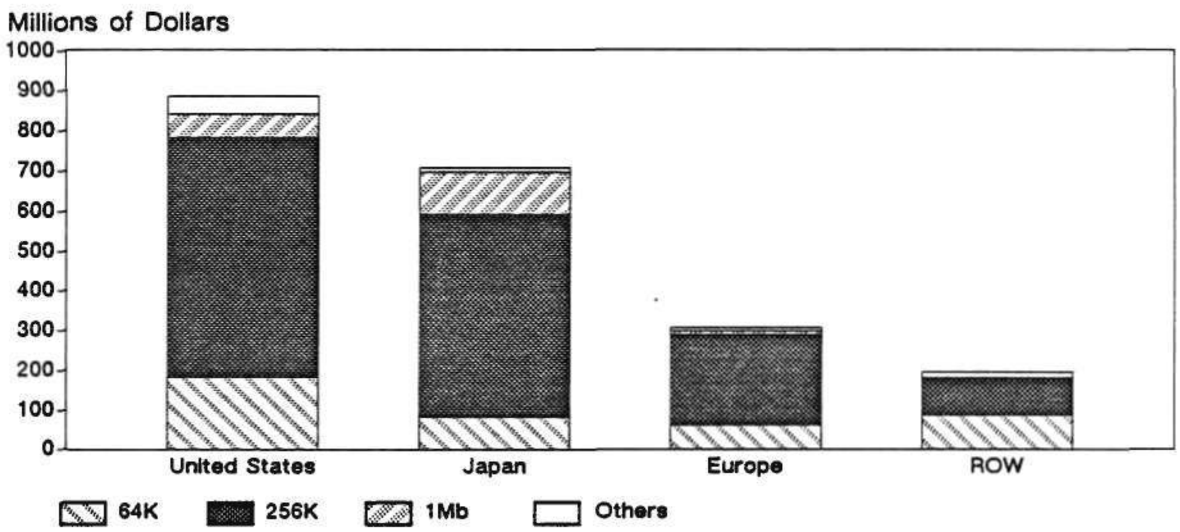
1986 REGIONAL CONSUMPTION BY PRODUCT



Source: Dataquest
June 1987

Figure 3

1986 DRAM MARKET BY REGION

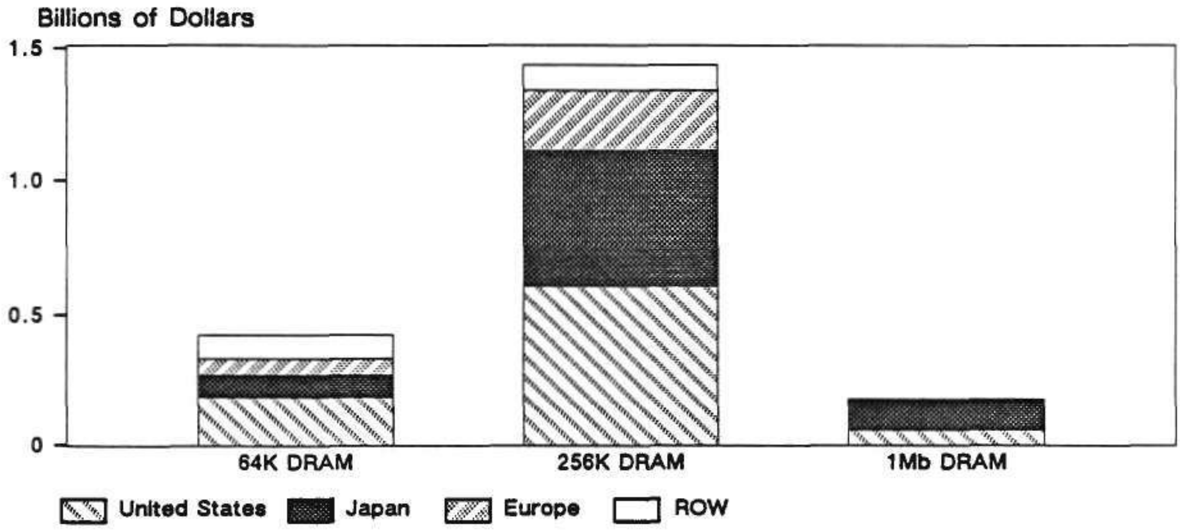


Source: Dataquest
June 1987

DRAM Regional Consumption

Figure 4

1986 PRODUCT CONSUMPTION BY REGION



Source: Dataquest
June 1987

DATAQUEST ANALYSIS

The United States is still the most attractive DRAM market, although the dominant DRAM producers are based in Japan. The United States has a balanced distribution of densities equivalent to their product lives and consumes most of worldwide production in each but the 1Mb density. Eventually, it will also be the largest market for 1Mb DRAMs. Dataquest believes that the success of the dominant Japanese producers depends on their access to--and competitiveness in--the U.S. market. Japanese manufacturers realize this and have agreed to terms and conditions of trade pacts brought forth by the U.S. government.

The Asia/Pacific region is a very attractive market that U.S. firms should not overlook. The Japanese currently have been the most aggressive in penetrating this market. Nevertheless, this region has strong potential for further growth not only because of further migration of U.S. manufacturing but because of its increasing domestic consumption.

DRAM--Data

MOS DYNAMIC RAMs—DATA

This section presents historical unit shipments of the more significant densities of dynamic RAMs (DRAMs) from 1974 to 1987. The 1987 estimated shipments are for the 64K to 1Mb densities. Included in the tables are estimated worldwide billing prices for each density and market share data (in units) for U.S.-based, Japan-based, Europe-based, and Asia-Pacific-based companies. The 1987 data are subject to review at a later date due to the qualifications discussed below. The tables are as follows:

- Table 1—4K DRAM (1974–1985)
- Table 2—16K 3ps DRAM (1976–1985)
- Table 3—16K 5V DRAM (1979–1985)
- Table 4—64K DRAM (1978–1987)
- Table 5—256K DRAM (1982–1987)
- Table 6—1Mb DRAM (1985–1987)

DEFINITIONS

Prices

Average selling price is the Dataquest estimate of the average worldwide billing price for that quarter. It incorporates prices for all package types and access times for both commercial and military markets.

Unit Shipments

Shipment data are factory revenue shipments as published in earlier sections, with occasional revisions based on the availability of more recent information. The unit shipments in the fourth quarter of 1986 are forecast numbers.

Quarterly Revenue

Revenue is calculated as total units shipped in the quarter multiplied by the average billing price of that quarter.

Table 1

Estimated Worldwide MOS 4K Dynamic RAM Shipments (Thousands of Units)

Company	1974 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
AMI					
Fairchild					
Fujitsu					
Hitachi					
Intel	40	100	150	220	510
Intersil					
Mostek			5	20	25
Motorola					
National					
NEC					
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	5	10	20	50	80
Total	40	110	175	290	615
Percentage Change from Previous Quarter	175%	59%	66%		
Cumulative Total	40	150	325	615	
Average Selling Price	$40.00	$25.00	$15.00	$12.00	$17.00
Revenue ($M)	1.6	2.8	2.6	3.5	10.5

	1974 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1975 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD				5	5
AMI			15	30	45
Fairchild		15	40	100	155
Fujitsu					
Hitachi					
Intel	260	425	675	1,050	2,410
Intersil			20	45	65
Mostek	35	95	210	390	730
Motorola		5	25	145	175
National		10	35	110	155
NEC	10	25	65	120	220
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	75	175	340	740	1,330
Total	380	750	1,425	2,735	5,290
Percentage Change from Previous Quarter	31%	97%	90%	92%	
Cumulative Total	995	1,745	3,170	5,905	
Average Selling Price	$10.00	$7.50	$6.00	$5.50	$6.24
Revenue ($M)	3.8	5.6	8.6	15.0	33.0

	1975 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	97.4%	96.7%	95.4%	95.6%	95.8%
Japan	2.6	3.3	4.6	4.4	4.2
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1976 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	23	105	165	175	468
AMI	0	0	0	0	0
Fairchild	290	430	435	330	1,485
Fujitsu	95	155	205	260	715
Hitachi			S	S	S
Intel	900	1,325	1,500	1,500	5,225
Intersil	42	85	190	195	512
Mostek	600	1,400	1,600	1,425	5,025
Motorola	190	180	360	475	1,205
National	300	480	560	775	2,115
NEC	575	790	1,100	1,275	3,740
SGS-Ates					
Signetics	S	35	65	120	220
STC (ITT)				S	S
Texas Instruments	1,400	1,800	2,000	2,100	7,300
Total	4,415	6,785	8,180	8,630	28,010
Percentage Change from Previous Quarter	61%	54%	21%	6%	
Cumulative Total	4,415	11,200	19,380	28,010	
Average Selling Price	$5.00	$4.50	$4.25	$4.00	$4.35
Revenue ($M)	22.1	30.5	34.8	34.5	121.9

	1976 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	84.8%	86.1%	84.0%	82.2%	84.1%
Japan	15.2	13.9	16.0	17.8	15.9
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1977 1st Qtr.	1977 2nd Qtr.	1977 3rd Qtr.	1977 4th Qtr.	1977 Year
AMD	290	450	600	1,000	2,340
AMI	0	0	0	0	0
Fairchild	380	450	550	700	2,080
Fujitsu	550	750	800	800	2,900
Hitachi	50	100	300	460	910
Intel	2,000	2,300	3,000	3,100	10,400
Intersil	240	220	220	220	900
Mostek	2,150	2,600	3,300	3,750	11,800
Motorola	540	700	750	750	2,740
National	825	925	925	1,000	3,675
NEC	1,400	1,500	1,600	1,600	6,100
SGS-Ates				S	S
Signetics	180	210	230	250	870
STC (ITT)	20	50	80	150	300
Texas Instruments	2,300	3,000	3,200	3,900	12,400
Total	10,925	13,255	15,555	17,680	57,415
Percentage Change from Previous Quarter	27%	21%	17%	14%	
Cumulative Total	38,935	52,190	67,745	85,425	
Average Selling Price	$3.50	$3.00	$2.50	$2.00	$2.65
Revenue ($M)	38.2	39.8	38.9	35.4	152.3

	1977 1st Qtr.	1977 2nd Qtr.	1977 3rd Qtr.	1977 4th Qtr.	1977 Year
Market Share					
U.S.	81.7%	82.3%	82.6%	83.8%	82.7%
Japan	18.3	17.7	17.4	16.2	17.3
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

	1978				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,100	1,500	1,800	2,200	6,600
AMI	0	0	0	0	0
Fairchild	500	400	200	100	1,200
Fujitsu	600	600	400	300	1,900
Hitachi	330	500	500	450	1,780
Intel	3,000	3,000	2,700	2,300	11,000
Intersil	150	100	100	100	450
Mostek	4,000	4,000	4,800	4,200	17,000
Motorola	1,000	1,300	1,500	1,900	5,700
National	1,200	1,200	1,500	1,700	5,600
NEC	1,600	1,600	1,600	1,350	6,150
SGS-Ates	60	75	100	125	360
Signetics	250	300	300	300	1,150
STC (ITT)	200	300	300	800	1,600
Texas Instruments	4,200	4,700	4,000	3,800	16,700
Total	18,190	19,575	19,800	19,625	77,190
Percentage Change from Previous Quarter	3%	8%	1%	(1%)	
Cumulative Total	103,615	123,190	142,990	162,615	
Average Selling Price	$2.00	$1.90	$1.80	$1.60	$1.82
Revenue ($M)	36.4	37.2	35.6	31.4	140.6

	1978				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	85.8%	85.8%	86.9%	88.7%	86.8%
Japan	13.9	13.8	12.6	10.7	12.7
Europe	0.3	0.4	0.5	0.6	0.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1979 1st Qtr.	1979 2nd Qtr.	1979 3rd Qtr.	1979 4th Qtr.	1979 Year
AMD	2,600	3,000	3,000	1,600	10,200
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	200	200	200	150	750
Hitachi	350	200	200	100	850
Intel	1,700	1,700	1,500	1,200	6,100
Intersil	100	100	300	500	1,000
Mostek	3,800	3,300	3,400	3,600	14,100
Motorola	1,500	1,150	1,800	2,000	6,450
National	2,000	2,400	2,000	1,500	7,900
NEC	1,350	1,900	1,300	1,000	5,550
SGS-Ates	150	175	200	225	750
Signetics	300	100	50	10	460
STC (ITT)	1,100	1,300	1,300	1,500	5,200
Texas Instruments	3,600	3,200	2,700	1,200	10,700
Total	18,750	18,725	17,950	14,585	70,010
Percentage Change from Previous Quarter	(4%)	0%	(4%)	(19%)	
Cumulative Total	181,365	200,090	218,040	232,625	
Average Selling Price	$1.50	$2.00	$2.00	$2.25	$1.92
Revenue ($M)	28.1	37.5	35.9	32.8	134.3

	1979 1st Qtr.	1979 2nd Qtr.	1979 3rd Qtr.	1979 4th Qtr.	1979 Year
Market Share					
U.S.	89.1%	86.8%	89.4%	89.9%	88.7%
Japan	10.1	12.3	9.5	8.6	10.2
Europe	0.8	0.9	1.1	1.5	1.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1980 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,300	750	450	435	2,935
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	200	200	150	650
Hitachi	100	100	0	0	200
Intel	900	100	0	0	1,000
Intersil	600	300	225	100	1,225
Mostek	2,500	2,000	1,400	1,200	7,100
Motorola	1,700	1,000	850	1,500	5,050
National	1,500	1,300	1,000	750	4,550
NEC	400	275	360	420	1,455
SGS-Ates	300	350	300	250	1,200
Signetics	0	0	0	0	0
STC (ITT)	1,400	600	1,500	1,500	5,000
Texas Instruments	700	100	0	0	800
Total	11,500	7,075	6,285	6,305	31,165
Percentage Change from Previous Quarter	(21%)	(38%)	(11%)	0%	
Cumulative Total	244,125	251,200	257,485	263,790	
Average Selling Price	$2.00	$1.90	$1.90	$1.90	$1.94
Revenue ($M)	23.0	13.4	11.9	12.0	60.4

	1980 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	92.2%	86.9%	86.3%	87.0%	88.8%
Japan	5.2	8.1	8.9	9.0	7.4
Europe	2.6	4.9	4.8	4.0	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	550	450	350	300	1,650
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	50	25	20	195
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	35	50	30	30	145
Mostek	800	650	500	300	2,250
Motorola	900	1,000	800	550	3,250
National	600	600	500	400	2,100
NEC	150	100	50	20	320
SGS-Ates	220	200	150	90	660
Signetics	0	0	0	0	0
STC (ITT)	1,100	570	450	350	2,470
Texas Instruments	0	0	0	0	0
Total	4,455	3,670	2,855	2,060	13,040
Percentage Change from Previous Quarter	(29%)	(18%)	(22%)	(28%)	
Cumulative Total	268,245	271,915	274,770	276,830	
Average Selling Price	$2.00	$1.75	$1.60	$1.50	$1.76
Revenue ($M)	8.9	6.4	4.6	3.1	23.0

	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	89.5%	90.5%	92.1%	93.7%	91.0%
Japan	5.6	4.1	2.6	1.9	3.9
Europe	4.9	5.4	5.3	4.4	5.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	200	40	15	0	255
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	10	5	0	0	15
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	250	250	200	200	900
Motorola	475	475	250	270	1,470
National	250	180	180	100	710
NEC	0	0	0	0	0
SGS-Ates	60	70	60	75	265
Signetics	0	0	0	0	0
STC (ITT)	400	200	200	220	1,020
Texas Instruments	0	0	0	0	0
Total	1,645	1,220	905	865	4,635
Percentage Change from Previous Quarter	(20%)	(26%)	(26%)	(4%)	
Cumulative Total	278,475	279,695	280,600	281,465	
Average Selling Price	$1.35	$1.60	$1.75	$2.00	$1.62
Revenue ($M)	2.2	2.0	1.6	1.7	7.5

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	95.7%	93.9%	93.4%	91.3%	94.0%
Japan	0.6	0.4	0.0	0.0	0.3
Europe	3.6	5.7	6.6	8.7	5.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	200	200	200	225	825
Motorola	175	50	50	25	300
National	100	100	50	0	250
NEC	0	0	0	0	0
SGS-Ates	75	100	200	50	425
Signetics	0	0	0	0	0
STC (ITT)	200	200	150	50	600
Texas Instruments	0	0	0	0	0
Total	750	650	650	350	2,400
Percentage Change from Previous Quarter	(13%)	(13%)	0%	(46%)	
Cumulative Total	282,215	282,865	283,515	283,865	
Average Selling Price	$2.75	$2.50	$2.75	$3.00	$2.72
Revenue ($M)	2.1	1.6	1.8	1.1	6.5

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	90.0%	84.6%	69.2%	85.7%	82.3%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	10.0	15.4	30.8	14.3	17.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1984 1st Qtr.	1984 2nd Qtr.	1984 3rd Qtr.	1984 4th Qtr.	Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	300	350	350	500	1,500
Motorola	25	25	25	25	100
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	100	50	50	50	250
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	525	525	525	675	2,250
Percentage Change from Previous Quarter	(78%)	0%	0%	29%	
Cumulative Total	284,390	284,915	285,440	286,115	
Average Selling Price	$3.00	$3.00	$3.00	$3.00	$3.00
Revenue ($M)	1.6	1.6	1.6	2.0	6.8

	1984 1st Qtr.	1984 2nd Qtr.	1984 3rd Qtr.	1984 4th Qtr.	Year
Market Share					
U.S.	81.0%	90.5%	90.5%	92.6%	88.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	19.0	9.5	9.5	7.4	11.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	500	400	500	500	1,900
Motorola	0	0	0	0	0
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	50	0	0	0	50
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	650	500	600	600	2,350
Percentage Change from Previous Quarter	(4%)	(23%)	20%	0%	
Cumulative Total	286,765	287,265	287,865	288,465	
Average Selling Price	$3.00	$3.50	$4.00	$4.50	$3.74
Revenue ($M)	2.0	1.8	2.4	2.7	8.8

	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
Market Share					
U.S.	92.3%	100.0%	100.0%	100.0%	97.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	7.7	0.0	0.0	0.0	2.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

Table 2

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1976				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
Eurotechnique					
Fairchild					
Fujitsu					
Hitachi					
Intel			0	20	20
Intersil					
Matsushita					
Mitsubishi					
Mostek			5	25	30
Motorola					
National					
NEC					
SGS-Ates					
Siemens					
Signetics					
STC (ITT)					
Texas Instruments				4	4
Toshiba					
Zilog					
Total	0	0	5	49	59

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Percent Change from Previous Quarter				880%	
Cumulative Total	0	0	5	54	
Average Selling Price			$60.00	$45.00	$46.39
Revenue ($M)	0.0	0.0	0.3	2.2	2.5

	1976				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.			100.0%	100.0%	100.0%
Japan			0.0	0.0	0.0
Europe			0.0	0.0	0.0
Total			100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1977				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
Eurotechnique					
Fairchild				25	25
Fujitsu		15	70	175	260
Hitachi				S	S
Intel	55	120	160	225	560
Intersil					
Matsushita					
Mitsubishi				S	S
Mostek	80	160	170	350	760
Motorola			S	50	50
National				S	S
NEC		15	70	225	310
SGS-Ates					
Siemens					
Signetics				S	S
STC (ITT)				S	S
Texas Instruments	3	0	0	40	43
Toshiba					
Zilog				S	S
Total	138	310	470	1,090	2,008
Percent Change from Previous Quarter	182%	125%	52%	132%	
Cumulative Total	192	502	972	2,062	
Average Selling Price	$35.00	$22.00	$20.00	$15.00	$18.63
Revenue ($M)	4.8	6.8	9.4	16.4	37.4

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1977				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	100.0%	90.3%	70.2%	63.3%	71.6%
Japan	0.0	9.7	29.8	36.7	28.4
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1978				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD				S	S
Eurotechnique					
Fairchild	25	40	200	200	465
Fujitsu	250	350	500	900	2,000
Hitachi	120	240	350	500	1,210
Intel	400	500	600	900	2,400
Intersil				S	S
Matsushita	0	0	0	0	0
Mitsubishi					
Mostek	700	1,000	1,400	1,800	4,900
Motorola	200	500	550	500	1,750
National	12	50	75	150	287
NEC	650	800	1,100	1,300	3,850
SGS-Ates					
Siemens	5	15	25	40	85
Signetics	S	30	30	80	140
STC (ITT)	3	25	75	100	203
Texas Instruments	300	500	950	1,400	3,150
Toshiba	20	35	80	150	285
Zilog	10	15	15	20	60
Total	2,695	4,100	5,950	8,040	20,785
Percent Change from Previous Quarter	147%	52%	45%	35%	
Cumulative Total	4,757	8,857	14,807	22,847	
Average Selling Price	$12.00	$10.00	$8.00	$7.00	$8.53
Revenue ($M)	32.3	41.0	47.6	56.3	177.2

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1978				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	61.2%	64.9%	65.5%	64.1%	64.3%
Japan	38.6	34.8	34.1	35.4	35.3
Europe	0.2	0.4	0.4	0.5	0.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1979				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	5	5	10	50	65
Eurotechnique					
Fairchild	300	400	500	700	1,900
Fujitsu	1,100	1,300	1,600	2,500	6,500
Hitachi	800	1,400	2,200	2,700	7,100
Intel	600	700	900	900	3,100
Intersil	5	5	5	0	10
Matsushita	0	0	0	0	0
Mitsubishi	100	200	400	550	1,250
Mostek	2,400	3,600	4,800	6,000	16,800
Motorola	700	1,200	1,000	1,800	4,700
National	250	450	1,000	1,500	3,200
NEC	1,700	2,200	3,200	4,200	11,300
SGS-Ates				3	3
Siemens	100	150	250	375	875
Signetics	75	40	50	10	175
STC (ITT)	200	300	600	600	1,700
Texas Instruments	1,800	2,200	1,800	3,200	9,000
Toshiba	150	350	450	1,050	2,000
Zilog	20	50	50	70	190
Total	10,295	14,550	18,815	26,208	69,868
Percent Change from Previous Quarter	28%	41%	29%	39%	
Cumulative Total	33,142	47,692	66,507	92,715	
Average Selling Price	$6.50	$6.25	$6.00	$5.75	$6.03
Revenue ($M)	66.9	90.9	112.9	150.7	421.4

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1979				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	61.6%	61.5%	56.9%	56.6%	58.5%
Japan	37.4	37.5	41.7	42.0	40.3
Europe	1.0	1.0	1.3	1.4	1.3
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	300	700	700	1,600	3,300
Eurotechnique					
Fairchild	800	1,000	1,000	800	3,600
Fujitsu	4,500	6,000	5,800	6,200	22,500
Hitachi	3,200	3,700	3,700	3,700	14,300
Intel	1,000	1,000	700	1,100	3,800
Intersil	0	0	0	0	0
Matsushita	5	100	100	100	305
Mitsubishi	700	1,100	1,100	1,100	4,000
Mostek	7,400	10,500	9,500	8,500	35,900
Motorola	3,000	3,000	2,500	2,500	11,000
National	3,500	4,800	5,800	6,000	20,100
NEC	6,100	7,500	6,700	5,900	26,200
SGS-Ates	10	30	50	60	150
Siemens	600	750	800	800	2,950
Signetics	0	0	0	0	0
STC (ITT)	750	1,050	1,200	1,500	4,500
Texas Instruments	4,200	5,200	5,700	6,600	21,700
Toshiba	1,700	2,000	2,300	2,600	8,600
Zilog	0	0	0	50	50
Total	37,765	48,430	47,650	49,110	182,955
Percent Change from Previous Quarter	44%	28%	(2%)	3%	
Cumulative Total	130,480	178,910	226,560	275,670	
Average Selling Price	$5.50	$5.25	$4.50	$4.00	$4.77
Revenue ($M)	207.7	254.3	214.4	196.4	872.8

(Continued)

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Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	55.5%	56.3%	56.9%	58.3%	56.8%
Japan	42.9	42.1	41.3	39.9	41.5
Europe	1.6	1.6	1.8	1.8	1.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,900	2,200	3,000	4,800	11,900
Eurotechnique		S	100	600	700
Fairchild	800	800	800	900	3,300
Fujitsu	6,800	7,300	7,600	7,400	29,100
Hitachi	3,600	3,750	3,600	1,900	12,850
Intel	900	1,400	1,400	1,500	5,200
Intersil	0	0	0	0	0
Matsushita	120	100	250	250	720
Mitsubishi	500	900	1,250	1,250	3,900
Mostek	8,900	11,100	9,990	9,000	38,990
Motorola	1,970	2,160	2,350	2,650	9,130
National	5,500	5,990	6,400	7,000	24,890
NEC	6,300	7,100	7,900	9,000	30,300
SGS-Ates	20	20	15	25	80
Siemens	800	850	900	1,500	4,050
Signetics	0	0	0	0	0
STC (ITT)	1,600	1,800	2,000	3,000	8,400
Texas Instruments	6,300	6,600	6,800	6,000	25,700
Toshiba	1,750	1,650	1,550	1,600	6,550
Zilog	0	0	0	0	0
Total	47,760	53,720	55,905	58,375	215,760
Percent Change from Previous Quarter	(3%)	12%	4%	4%	
Cumulative Total	323,430	377,150	433,055	491,430	
Average Selling Price	$3.15	$2.25	$1.65	$1.40	$2.06
Revenue ($M)	150.4	120.9	92.2	81.7	445.3

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1981				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	58.4%	59.7%	58.6%	59.7%	59.1%
Japan	39.9	38.7	39.6	36.7	38.7
Europe	1.7	1.6	1.8	3.6	2.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	4,400	4,700	4,700	5,000	18,800
Eurotechnique	900	1,200	1,300	1,400	4,800
Fairchild	900	900	750	700	3,250
Fujitsu	6,800	6,250	5,400	4,800	23,250
Hitachi	4,000	4,000	4,000	3,500	15,500
Intel	1,500	1,500	1,500	1,500	6,000
Intersil	0	0	0	0	0
Matsushita	250	250	100	100	700
Mitsubishi	500	450	800	500	2,250
Mostek	9,000	9,000	9,400	8,900	36,300
Motorola	3,015	3,190	4,550	3,600	14,355
National	8,995	9,500	9,500	8,300	36,295
NEC	10,000	10,000	10,000	10,000	40,000
SGS-Ates	50	50	35	15	150
Siemens	1,700	2,200	2,800	2,800	9,500
Signetics	0	0	0	0	0
STC (ITT)	2,800	3,200	5,100	6,300	17,400
Texas Instruments	6,500	7,000	7,000	7,000	27,500
Toshiba	1,500	1,700	1,800	2,000	7,000
Zilog	0	0	0	0	0
Total	62,810	65,090	68,735	66,415	263,050
Percent Change from Previous Quarter	8%	4%	6%	(3%)	
Cumulative Total	554,240	619,330	688,065	754,480	
Average Selling Price	$1.35	$1.30	$1.20	$1.10	$1.24
Revenue ($M)	84.8	84.6	82.5	73.1	324.9

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1982				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	59.1%	59.9%	61.8%	62.2%	60.8%
Japan	36.7	34.8	32.2	31.5	33.7
Europe	4.2	5.3	6.0	6.3	5.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	5,100	5,800	5,200	4,000	20,100
Eurotechnique	1,800	2,000	2,500	2,500	8,800
Fairchild	600	400	300	300	1,600
Fujitsu	4,000	3,500	2,500	2,500	12,500
Hitachi	3,000	3,000	3,500	3,500	13,000
Intel	1,500	1,000	1,000	1,000	4,500
Intersil	0	0	0	0	0
Matsushita	100	50	50	0	200
Mitsubishi	400	240	200	150	990
Mostek	4,300	5,500	4,500	3,500	17,800
Motorola	3,800	3,600	4,100	3,500	15,000
National	4,500	6,000	5,000	4,500	20,000
NEC	9,800	9,500	11,000	10,000	40,300
SGS-Ates	20	100	150	50	320
Siemens	3,000	3,000	3,000	3,000	12,000
Signetics	0	0	0	0	0
STC (ITT)	5,600	6,200	6,200	5,500	23,500
Texas Instruments	7,000	12,000	10,000	9,500	38,500
Toshiba	2,400	3,000	2,500	2,200	10,100
Zilog	0	0	0	0	0
Total	56,920	64,890	61,700	55,700	239,210
Percent Change from Previous Quarter	(14%)	14%	(5%)	(10%)	
Cumulative Total	811,400	876,290	937,990	993,690	
Average Selling Price	$1.15	$1.10	$1.00	$0.95	$1.05
Revenue ($M)	65.5	71.4	61.7	52.9	251.5

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1983				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	56.9%	62.4%	58.8%	57.1%	58.9%
Japan	34.6	29.7	32.0	32.9	32.2
Europe	8.5	7.9	9.2	10.0	8.8
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1984				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	2,500	2,500	2,000	1,500	8,500
Eurotechnique	2,000	2,000	1,200	1,000	6,200
Fairchild	200	100	0	0	300
Fujitsu	2,000	1,800	1,000	800	5,600
Hitachi	3,000	3,000	1,200	800	8,000
Intel	800	500	350	0	1,650
Intersil	0	0	0	0	0
Matsushita	0	0	0	0	0
Mitsubishi	170	170	0	0	340
Mostek	2,500	1,500	1,000	1,000	6,000
Motorola	3,000	2,500	1,600	1,200	8,300
National	3,500	2,500	1,200	1,200	8,400
NEC	8,000	6,000	4,200	2,500	20,700
SGS-Ates	0	0	0	0	0
Siemens	3,000	3,000	1,500	1,200	8,700
Signetics	0	0	0	0	0
STC (ITT)	4,000	3,500	2,200	1,500	11,200
Texas Instruments	8,000	6,500	4,000	2,500	21,000
Toshiba	1,800	1,600	1,200	1,200	5,800
Zilog	0	0	0	0	0
Total	44,470	37,170	22,650	16,400	120,690
Percent Change from Previous Quarter	(81%)	(16%)	(39%)	(28%)	
Cumulative Total	1,038,160	1,075,330	1,097,980	1,114,380	
Average Selling Price	$1.00	$1.10	$1.15	$1.20	$1.09
Revenue ($M)	44.5	40.9	26.0	19.7	131.1

(Continued)

Table 2 (Continued)

Estimated Worldwide 3–Power–Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1984				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	46.1%	43.3%	44.8%	45.1%	44.9%
Japan	33.7	33.8	33.6	32.3	33.5
Europe	20.2	22.9	21.6	22.6	21.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,250	1,100	1,100	1,100	4,550
Eurotechnique	1,200	1,200	1,200	1,200	4,800
Fairchild					
Fujitsu	500	250	300	300	1,350
Hitachi	500	200	400	400	1,500
Intel					
Intersil					
Matsushita					
Mitsubishi					
Mostek	800	700	600	400	2,500
Motorola	1,000	800	600	400	2,800
National	1,200	1,200	1,500	1,200	5,100
NEC	2,100	1,800	1,500	620	6,020
SGS-Ates					
Siemens	2,500	2,000	2,000	1,500	8,000
Signetics					
STC (ITT)	1,800	2,000	1,500	1,200	6,500
Texas Instruments	2,200	2,000	0	0	4,200
Toshiba	1,000	800	600	250	2,650
Zilog					
Total	16,050	14,050	11,300	8,570	49,970
Percent Change from Previous Quarter	(2%)	(12%)	(20%)	(24%)	
Cumulative Total	1,130,430	1,144,480	1,155,780	1,164,350	
Average Selling Price	$1.25	$1.30	$1.35	$1.45	$1.32
Revenue ($M)	20.1	18.3	15.3	12.4	66.0

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	40.2%	41.3%	33.6%	36.2%	38.3%
Japan	25.5	21.7	24.8	18.3	23.1
Europe	34.3	37.0	41.6	45.5	38.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

Table 3

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments (Thousands of Units)

	1979				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu					
Hitachi					
Intel	S	10	50	90	150
Mostek					
Motorola					
National					
Texas Instruments					
Total	0	10	50	90	150
Percentage Change from Previous Quarter			400%	80%	
Cumulative Total	0	10	60	150	
Average Selling Price	$40.00	$30.00	$20.00	$15.00	$17.67
Revenue ($M)	0.0	0.3	1.0	1.4	2.7

	1979				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu				S	S
Hitachi			15	30	45
Intel	150	200	300	400	1,050
Mostek				S	S
Motorola			5	15	20
National				S	S
Texas Instruments				S	S
Total	150	200	320	445	1,115
Percentage Change from Previous Quarter	67%	33%	60%	39%	
Cumulative Total	300	500	820	1,265	
Average Selling Price	$10.00	$8.00	$7.00	$6.50	$7.38
Revenue ($M)	1.5	1.6	2.2	2.9	8.2

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	100.0%	100.0%	95.3%	93.3%	96.0%
Japan	0.0	0.0	4.7	6.7	4.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1981				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	S	10	80	150	240
Hitachi	100	250	400	600	1,350
Intel	600	800	1,100	1,300	3,800
Mostek	0	S	10	100	110
Motorola	30	40	50	60	180
National	S	10	5	5	20
Texas Instruments	0	S	3	10	13
Total	730	1,110	1,648	2,225	5,713
Percentage Change from Previous Quarter	64%	52%	48%	35%	
Cumulative Total	1,995	3,105	4,753	6,978	
Average Selling Price	$5.00	$4.50	$4.00	$3.00	$3.84
Revenue ($M)	3.7	5.0	6.6	6.7	21.9

	1981				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	86.3%	76.6%	70.9%	66.3%	72.2%
Japan	13.7	23.4	29.1	33.7	27.8
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	200	250	600	1,200	2,250
Hitachi	1,000	1,500	2,400	2,400	7,300
Intel	1,500	2,000	2,200	2,000	7,700
Mostek	500	1,200	1,200	1,700	4,600
Motorola	85	110	150	800	1,145
National	5	0	0	0	5
Texas Instruments	20	20	50	150	240
Total	3,310	5,080	6,600	8,250	23,240
Precentage Change from Previous Quarter	49%	53%	30%	25%	
Cumulative Total	10,288	15,368	21,968	30,218	
Average Selling Price	$2.70	$2.50	$2.25	$1.85	$2.23
Revenue ($M)	8.9	12.7	14.9	15.3	51.7

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	63.7%	65.6%	54.5%	56.4%	58.9%
Japan	36.3	34.4	45.5	43.6	41.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1983				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	1,500	2,000	3,000	3,000	9,500
Hitachi	3,000	3,500	3,500	3,500	13,500
Intel	2,000	1,700	1,500	1,500	6,700
Mostek	3,000	2,800	3,500	4,500	13,800
Motorola	2,200	3,300	4,000	3,000	12,500
National	0	0	0	0	0
Texas Instruments	250	350	400	400	1,400
Total	11,950	13,650	15,900	15,900	57,400
Percentage Change from Previous Quarter	45%	14%	16%	0%	
Cumulative Total	42,168	55,818	71,718	87,618	
Average Selling Price	$1.75	$1.85	$2.00	$2.25	$1.98
Revenue ($M)	20.9	25.3	31.8	35.8	113.7

	1983				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	62.3%	59.7%	59.1%	59.1%	59.9%
Japan	37.7	40.3	40.9	40.9	40.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitu	3,000	2,500	2,000	1,500	9,000
Hitachi	3,000	2,000	2,000	1,500	8,500
Intel	1,500	1,500	1,200	800	5,000
Mostek	2,000	1,500	1,700	900	6,100
Motorola	1,600	2,500	3,200	3,500	10,800
National	0	0	0	0	0
Texas Instruments	500	500	200	0	1,200
Total	11,600	10,500	10,300	8,200	40,600
Percentage Change from Previous Quarter	(27%)	(9%)	(2%)	(20%)	
Cumulative Total	99,218	109,718	120,018	128,218	
Average Selling Price	$2.10	$2.10	$2.10	$1.95	$2.07
Revenue ($M)	24.4	22.1	21.6	16.0	84.0

	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	48.3%	57.1%	61.2%	63.4%	56.9%
Japan	51.7	42.9	38.8	36.6	43.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitu	800	500	500	400	2,200
Hitachi	1,500	1,200	1,000	800	4,500
Intel	600	500	250	100	1,450
Mostek	600	500	500	500	2,100
Motorola	3,200	3,000	2,500	2,000	10,700
National	0	0	0	0	0
Texas Instruments	0	0	0	0	0
Total	6,700	5,700	4,750	3,800	20,950
Percentage Change from Previous Quarter	(18%)	(15%)	(17%)	(20%)	
Cumulative Total	134,918	140,618	145,368	149,168	
Average Selling Price	$1.65	$1.55	$1.60	$1.70	$1.62
Revenue ($M)	11.1	8.8	7.6	6.5	34.0

	1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	65.7%	70.2%	68.4%	68.4%	68.0%
Japan	34.3	29.8	31.6	31.6	32.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

Table 4

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1978 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD						
Fairchild						
Fujitsu	64Kx1		S	S	S	S
	16Kx4					
	CMOS 8Kx8					
Hitachi	64Kx1					
	16Kx4					
Inmos	64Kx1					
	16Kx4					
	8Kx8					
Intel	64Kx1					
	CMOS 64Kx1					
Matsushita	64Kx1					
	16Kx4					
	8Kx8					
Micron Technology						
Mitsubishi	64Kx1					
	16Kx4					
Mostek						
Motorola						
National						
NEC	64Kx1					
	CMOS 64Kx1					
	16Kx4					
Oki Electric						
Samsung						
Sharp						
Siemens						
STC (ITT)						
Texas Instruments	64Kx1				S	S
	16Kx4					
Toshiba						
Vitelic	CMOS 64Kx1					
Total		0	0	0	0	0

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1978 1st Qtr.	1978 2nd Qtr.	1978 3rd Qtr.	1978 4th Qtr.	1978 Year
Percent Change from Previous Quarter					
Cumulative Total	0	0	0	0	
Average Selling Price		$200.00	$175.00	$150.00	$150.00
Revenue ($M)	0.0	0.0	0.0	0.0	0.0

	1978 1st Qtr.	1978 2nd Qtr.	1978 3rd Qtr.	1978 4th Qtr.	1978 Year
Market Share					
U.S.		0.0	0.0	0.0	0.0
Japan		100.0%	100.0%	100.0%	100.0%
Europe		0.0	0.0	0.0	0.0
Asia Pacific		0.0	0.0	0.0	0.0
Total		100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD							
Fairchild							
Fujitsu		64Kx1	3	5	7	9	24
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1				S	S
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1					
	CMOS	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1				S	S
		16Kx4					
Mostek							
Motorola			S	1	3	6	10
National							
NEC		64Kx1					
	CMOS	64Kx1					
		16Kx4					
Oki Electric							
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1	S	S	1	1	2
		16Kx4					
Toshiba							
Vitelic	X	64Kx1					
Total			3	6	11	16	36

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter		100%	83%	45%	
Cumulative Total	3	9	20	36	
Average Selling Price	$135.00	$125.00	$110.00	$100.00	$110.14
Revenue ($M)	0.4	0.8	1.2	1.6	4.0

	1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	0.0	16.7%	36.4%	43.8%	33.3%
Japan	100.0%	83.3	63.6	56.3	66.7
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.1%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1980 1st Qtr.	1980 2nd Qtr.	1980 3rd Qtr.	1980 4th Qtr.	1980 Year
AMD							
Fairchild							
Fujitsu		64Kx1	10	25	30	65	130
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	S	10	35	60	105
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1		S	S	3	3
	CMOS	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1	S	S	2	15	17
		16Kx4					
Mostek							
Motorola			10	30	40	70	150
National						S	S
NEC		64Kx1			S	5	5
	CMOS	64Kx1					
		16Kx4					
Oki Electric						S	S
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1	1	3	5	15	24
		16Kx4					
Toshiba			S	S	2	5	7
Vitelic	CMOS	64Kx1					
Total			21	68	114	238	441

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	31%	224%	68%	109%	
Cumulative Total	57	125	239	477	
Average Selling Price	$90.00	$75.00	$55.00	$30.00	$46.26
Revenue ($M)	1.9	5.1	6.3	7.1	20.4

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	52.4%	48.5%	39.5%	37.0%	40.1%
Japan	47.6	51.5	60.5	63.0	59.9
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD							
Fairchild						S	S
Fujitsu		64Kx1	110	360	550	900	1,920
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	200	700	1,100	1,900	3,900
		16Kx4					
Inmos		64Kx1				S	S
		16Kx4					
		8Kx8					
Intel		64Kx1	5	10	10	5	30
	CMOS	64Kx1					
Matsushita		64Kx1				S	S
		16Kx4					
		8Kx8					
Micron Technology						S	S
Mitsubishi		64Kx1	36	70	320	640	1,066
		16Kx4					
Mostek			S	10	30	100	140
Motorola			125	350	700	800	1,975
National			S	S	S	S	S
NEC		64Kx1	50	100	300	1,000	1,450
	CMOS	64Kx1					
		16Kx4					
Oki Electric			5	30	100	600	735
Samsung							
Sharp							
Siemens						S	S
STC (ITT)							
Texas Instruments		64Kx1	35	130	370	800	1,335
		16Kx4					
Toshiba			10	20	20	30	80
Vitelic	CMOS	64Kx1					
Total			576	1,780	3,500	6,775	12,631

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	142%	209%	97%	94%	
Cumulative Total	1,053	2,833	6,333	13,108	
Average Selling Price	$22.00	$15.00	$12.00	$8.50	$11.00
Revenue ($M)	12.7	26.7	42.0	57.6	139.0

	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	28.6%	28.1%	31.7%	25.2%	27.6%
Japan	71.4	71.9	68.3	74.8	72.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD						S	S
Fairchild			S	S	10	5	15
Fujitsu		64Kx1	2,000	3,500	4,700	6,300	16,500
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	2,500	3,600	5,400	6,800	18,300
		16Kx4					
Inmos		64Kx1	5	10	20	75	110
		16Kx4					
		8Kx8					
Intel		64Kx1	5	100	350	1,100	1,555
	CMOS	64Kx1					
Matsushita		64Kx1	S	S	10	20	30
		16Kx4					
		8Kx8					
Micron Technology			20	150	450	600	1,200
Mitsubishi		64Kx1	1,300	1,800	3,200	5,500	11,800
		16Kx4					
Mostek			450	650	1,700	3,200	6,000
Motorola			1,100	2,300	3,100	4,600	11,100
National			S	S	0	0	S
NEC		64Kx1	2,200	2,700	4,500	5,500	14,900
	CMOS	64Kx1					
		16Kx4					
Oki Electric			1,150	1,770	2,500	1,200	6,620
Samsung							
Sharp							
Siemens			5	25	75	200	305
STC (ITT)						S	S
Texas Instruments		64Kx1	1,700	3,400	4,000	4,800	13,900
		16Kx4		S	200	500	700
Toshiba			30	80	200	600	910
Vitelic	CMOS	64Kx1					
Total			12,465	20,085	30,415	41,000	103,965

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	84%	61%	51%	35%	
Cumulative Total	25,573	45,658	76,073	117,073	
Average Selling Price	$6.50	$6.00	$5.50	$4.75	$5.42
Revenue ($M)	81.0	120.5	167.3	194.8	563.6

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	26.3%	32.9%	32.3%	36.1%	33.2%
Japan	73.6	67.0	67.4	63.2	66.4
Europe	0.1	0.2	0.3	0.7	0.4
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.1%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			S	10	100	250	360
Fairchild			0	0	0	S	S
Fujitsu		64Kx1	7,500	9,200	11,200	11,500	39,400
		16Kx4	S	100	300	1,000	1,400
	CMOS	8Kx8				S	S
Hitachi		64Kx1	11,000	14,500	16,500	18,500	60,500
		16Kx4			S	S	S
Inmos		64Kx1	150	350	625	1,400	2,525
		16Kx4	S	50	250	600	900
		8Kx8		S	25	100	125
Intel		64Kx1	1,800	2,600	3,500	5,000	12,900
	CMOS	64Kx1			S	S	S
Matsushita		64Kx1	80	400	1,800	3,000	5,280
		16Kx4					
		8Kx8					
Micron Technology			950	1,500	2,500	4,000	8,950
Mitsubishi		64Kx1	6,800	7,000	8,900	10,800	33,500
		16Kx4					
Mostek			4,000	8,500	12,300	16,200	41,000
Motorola			4,000	6,300	8,900	12,000	31,200
National			0	S	10	150	160
NEC		64Kx1	8,500	12,000	15,000	18,000	53,500
	CMOS	64Kx1				S	S
		16Kx4					
Oki Electric			2,200	4,000	6,500	8,000	20,700
Samsung							
Sharp						S	S
Siemens			350	500	1,000	2,000	3,850
STC (ITT)			15	75	100	100	290
Texas Instruments		64Kx1	7,400	8,500	9,000	13,700	38,600
		16Kx4	600	1,500	3,000	3,000	8,100
Toshiba			1,000	1,500	2,600	3,000	8,100
Vitelic	CMOS	64Kx1					
Total			56,345	78,585	104,110	132,300	371,340

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	37%	39%	32%	27%	
Cumulative Total	173,418	252,003	356,113	488,413	
Average Selling Price	$4.00	$3.75	$3.80	$3.90	$3.86
Revenue ($M)	225.4	294.7	395.6	516.0	1,431.7

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	33.3%	36.9%	37.9%	41.1%	38.1%
Japan	65.8	62.0	60.3	55.8	59.9
Europe	0.9	1.1	1.8	3.1	2.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			500	1,000	1,500	3,000	6,000
Fairchild			10	25	0	0	35
Fujitsu		64Kx1	14,500	18,000	25,000	28,500	86,000
		16Kx4	1,500	2,000	2,500	3,000	9,000
	CMOS	8Kx8	S	10	10	25	45
Hitachi		64Kx1	22,300	25,500	27,500	28,000	103,300
		16Kx4	10	25	150	300	485
Inmos		64Kx1	2,000	2,200	2,500	2,500	9,200
		16Kx4	800	1,200	1,800	1,500	5,300
		8Kx8	250	350	400	250	1,250
Intel		64Kx1	5,000	4,000	3,000	1,600	13,600
	CMOS	64Kx1	50	150	200	200	600
Matsushita		64Kx1	4,200	6,000	8,000	7,000	25,200
		16Kx4	S	10	100	350	460
		8Kx8		S	5	20	25
Micron Technology			6,200	9,300	14,000	19,200	48,700
Mitsubishi		64Kx1	13,500	18,400	24,000	26,000	81,900
		16Kx4	S	100	1,000	1,500	2,600
Mostek			15,000	17,000	20,000	21,500	73,500
Motorola			11,000	13,100	18,000	18,700	60,800
National			500	1,200	2,500	3,500	7,700
NEC		64Kx1	21,100	23,600	27,000	30,000	101,700
	CMOS	64Kx1	50	150	850	1,250	2,300
		16Kx4				S	S
Oki Electric			11,000	13,500	16,000	18,500	59,000
Samsung				S	S	1,500	1,500
Sharp			50	150	500	1,000	1,700
Siemens			3,000	4,000	4,000	4,500	15,500
STC (ITT)			200	400	600	1,000	2,200
Texas Instruments		64Kx1	17,000	22,000	25,500	24,000	88,500
		16Kx4	3,500	4,000	5,600	7,000	20,100
Toshiba			4,500	4,700	5,200	9,000	23,400
Vitelic	CMOS	64Kx1				S	S
Total			157,720	192,070	237,415	264,395	851,600

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1984				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	19%	22%	24%	11%	
Cumulative Total	646,133	838,203	1,075,618	1,340,013	
Average Selling Price	$3.50	$3.40	$3.15	$2.80	$3.16
Revenue ($M)	552.0	653.0	747.9	740.3	2,693.2

	1984				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	37.3%	37.4%	38.0%	37.3%	37.5%
Japan	58.8	58.4	58.0	58.4	58.4
Europe	4.0	4.2	3.9	3.7	3.9
Asia Pacific	0.0	0.0	0.0	0.6	0.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1	2,000	1,000	1,000	1,000	5,000
Fairchild			0	0	0	0	0
Fujitsu	NMOS	64Kx1	19,000	18,000	10,000	8,500	55,500
	NMOS	16Kx4	2,200	1,500	1,200	1,000	5,900
	CMOS	8Kx8	25	25	10	0	60
Hitachi	NMOS	64Kx1	20,000	17,500	14,000	13,500	65,000
	NMOS	16Kx4	500	700	1,000	1,250	3,450
Inmos	NMOS	64Kx1	2,500	2,200	2,000	2,100	8,800
	NMOS	16Kx4	800	500	400	500	2,200
	NMOS	8Kx8	50	40	20	0	110
Intel	NMOS	64Kx1	500	0	0	0	500
	CMOS	64Kx1	250	250	200	100	800
Matsushita	NMOS	64Kx1	3,000	2,000	1,500	1,200	7,700
	NMOS	16Kx4	400	300	200	150	1,050
	NMOS	8Kx8	100	150	100	80	430
Micron Technology	NMOS		12,500	12,000	6,000	2,800	33,300
Mitsubishi	NMOS	64Kx1	15,000	15,000	12,500	13,500	56,000
	NMOS	16Kx4	1,000	800	650	850	3,300
Mostek	NMOS		8,000	10,000	7,500	5,000	30,500
Motorola	NMOS		10,000	12,000	5,000	3,500	30,500
National	NMOS		2,500	1,500	1,200	500	5,700
NEC	NMOS	64Kx1	22,500	18,000	14,400	7,520	62,420
	CMOS	64Kx1	800	350	40	0	1,190
	NMOS	16Kx4	150	500	1,630	1,820	4,100
Oki Electric	NMOS		7,500	8,000	5,500	5,000	26,000
Samsung	NMOS		3,000	6,000	5,500	5,500	20,000
Sharp	NMOS		500	500	250	0	1,250
Siemens	NMOS		3,500	2,500	2,000	2,000	10,000
STC (ITT)	NMOS		500	400	400	400	1,700
Texas Instruments	NMOS	64Kx1	13,000	10,000	7,000	6,000	36,000
	NMOS	16Kx4	3,500	4,000	3,200	2,500	13,200
Toshiba	NMOS		6,000	4,000	4,000	4,000	18,000
Vitelic	CMOS	64Kx1	S	S	S	10	10
Total			161,275	149,715	108,400	90,280	509,670

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1985				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	(39%)	(7%)	(28%)	(17%)	
Cumulative Total	1,501,288	1,651,003	1,759,403	1,849,683	
Average Selling Price	$1.65	$1.10	$0.75	$0.85	$1.16
Revenue ($M)	266.1	164.7	81.3	76.7	588.8

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	32.4%	33.9%	28.7%	23.7%	30.5%
Japan	61.2	58.3	61.8	64.7	61.1
Europe	4.6	3.8	4.4	5.5	4.5
Asia Pacific	1.9	4.0	5.1	6.1	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1	700	500	500	500	2,200
Fairchild							0
Fujitsu	NMOS	64Kx1	8,000	7,000	6,000	5,000	26,000
	NMOS	16Kx4	1,000	1,000	1,000	1,000	4,000
	CMOS	8Kx8	0	0	0	0	0
Hitachi	NMOS	64Kx1	14,000	10,000	8,000	5,000	37,000
	NMOS	16Kx4	1,250	1,000	1,000	500	3,750
Inmos	NMOS	64Kx1	1,800	1,700	1,500	1,200	6,200
	NMOS	16Kx4	500	500	500	500	2,000
	NMOS	8Kx8	0	0	0	0	0
Intel	NMOS	64Kx1	0	0	0	0	0
	CMOS	64Kx1	200	200	100	100	600
Matsushita	NMOS	64Kx1	2,000	2,500	2,500	2,500	9,500
	NMOS	16Kx4	700	1,000	1,300	1,500	4,500
	NMOS	8Kx8	500	1,000	1,500	2,500	5,500
Micron Technology	NMOS	64Kx1	4,000	4,500	5,000	4,500	18,000
Mitsubishi	NMOS	64Kx1	20,000	18,000	12,000	4,500	54,500
	NMOS	16Kx4	3,300	1,600	4,000	2,300	11,200
Mostek	NMOS	64Kx1	3,000	2,000	1,000	1,000	7,000
Motorola	NMOS	64Kx1	1,362	1,141	1,718	1,055	5,276
National	NMOS	64Kx1	500	500	500	500	2,000
NEC	NMOS	64Kx1	14,930	15,560	6,290	5,800	42,580
	CMOS	64Kx1	0	0	0	0	0
	NMOS	16Kx4	1,880	2,690	4,080	5,200	13,850
Oki Electric	NMOS	64Kx1	5,000	5,000	5,000	4,000	19,000
Samsung	NMOS	64Kx1	8,000	10,000	10,000	10,000	38,000
Sharp	NMOS	64Kx1	700	500	500	500	2,200
Siemens	NMOS	64Kx1	2,500	2,500	2,500	2,500	10,000
STC (ITT)	NMOS	64Kx1	500	400	400	400	1,700
Texas	NMOS	64Kx1	6,000	6,000	6,000	5,000	23,000
Instruments	NMOS	16Kx4	3,000	3,000	2,500	2,500	11,000
Toshiba	NMOS	64Kx1	8,000	6,000	4,000	3,000	21,000
Vitelic	CMOS	64Kx1	50	100	150	200	500
Total			113,372	105,891	89,538	73,255	382,056

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1986				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	26%	(7%)	(15%)	(18%)	
Cumulative Total	1,963,055	2,068,946	2,158,484	2,231,739	
Average Selling Price	$1.10	$1.05	$1.05	$0.90	$1.04
Revenue ($M)	124.7	111.2	94.0	65.9	395.8

	1986				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	16.6%	16.9%	19.5%	21.0%	18.2%
Japan	71.7	68.8	63.8	59.1	66.6
Europe	4.7	4.8	5.5	6.3	5.2
Asia Pacific	7.1	9.4	11.2	13.7	9.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1					
Fairchild							
Fujitsu	NMOS	64Kx1	2,000	2,000	2,000	2,000	8,000
	NMOS	16Kx4	700	500	500	500	2,200
	CMOS	8Kx8	0				0
Hitachi	NMOS	64Kx1	2,000	1,000	1,000	1,000	5,000
	NMOS	16Kx4	500	500	500	500	2,000
Inmos	NMOS	64Kx1	600	300	100	100	1,100
	NMOS	16Kx4	200	100	50	50	400
	NMOS	8Kx8					0
Intel	NMOS	64Kx1					0
	CMOS	64Kx1					0
Matsushita	NMOS	64Kx1	1,500	850	500	200	3,050
	NMOS	16Kx4	500	403	300	100	1,303
	NMOS	8Kx8	500	447	350	130	1,427
Micron Technology	NMOS	64Kx1	2,500	2,000	1,800	1,500	7,800
Mitsubishi	NMOS	64Kx1	4,900	4,500	4,000	3,500	16,900
	NMOS	16Kx4	1,600	1,500	1,200	1,000	5,300
Mostek	NMOS	64Kx1	500	500	500	500	2,000
Motorola	NMOS	64Kx1	663	1,046	990	372	3,071
National	NMOS	64Kx1					
NEC	NMOS	64Kx1	8,020	4,350	4,650	2,850	19,870
	CMOS	64Kx1	0	100	30	0	130
	NMOS	16Kx4	1,510	0	1,150	70	2,730
Oki Electric	NMOS	64Kx1	4,000	3,000	3,000	2,000	12,000
Samsung	NMOS	64Kx1	8,000	7,000	6,000	5,000	26,000
Sharp	NMOS	64Kx1	500	500	500	500	2,000
Siemens	NMOS	64Kx1	2,000	2,000	1,500	1,500	7,000
STC (ITT)	NMOS	64Kx1	300	300	100	100	800
Texas Instruments	NMOS	64Kx1	3,000	3,000	2,800	2,800	11,600
	NMOS	16Kx4	1,500	1,500	1,200	1,200	5,400
Toshiba	NMOS	64Kx1	2,000	1,500	1,000	1,000	5,500
Vitelic	CMOS	64Kx1					
Total			49,493	38,896	35,720	28,472	152,581

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	(32%)	(21%)	(8%)	(20%)	
Cumulative Total	2,281,232	2,320,128	2,355,848	2,384,320	
Average Selling Price	$0.99	$1.05	$1.15	$1.20	$1.08
Revenue ($M)	49.0	40.8	41.1	34.2	165.0

	1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	16.5%	20.7%	20.4%	22.4%	19.6%
Japan	61.1	54.4	57.9	53.9	57.3
Europe	6.3	6.9	4.9	6.1	6.1
Asia Pacific	16.2	18.0	16.8	17.6	17.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

Table 5

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

	MOS Process/		1982				
Company	Organization		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1				S	S
Fujitsu	NMOS	256Kx1				S	S
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1			S	10	10
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron	NMOS	256Kx1					
Technology	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1					
	NMOS	64Kx4					
Mostek	NMOS	32Kx8					
	NMOS	256Kx1					
Motorola	NMOS	256Kx1					
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1					
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1				S	S
	NMOS	64Kx4					
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1					
Instruments	NMOS	64Kx4					
Toshiba	NMOS	256Kx1				S	S
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4	-	-	-	—	—
Total			0	0	0	10	10
Percent Change from Previous Quarter							
Cumulative Total			0	0	0	10	
Average Selling Price				$200.00	$150.00	$150.00	
Revenue ($M)			0.0	0.0	0.0	1.5	1.5

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.				0.0	0.0
Japan				100.0%	100.0%
Europe				0.0	0.0
Asia Pacific				0.0	0.0
Total				100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1	S	S	20	100	120
Fujitsu	NMOS	256Kx1	S	30	150	300	480
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1	25	50	175	400	650
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron	NMOS	256Kx1					
Technology	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1		S	10	50	60
	NMOS	64Kx4					
Mostek	NMOS	32Kx8			S	5	5
	NMOS	256Kx1					
Motorola	NMOS	256Kx1		S	S	0	S
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1	S	S	100	200	300
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1	S	S	5	10	15
	NMOS	64Kx4					
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1			S	S	S
Instruments	NMOS	64Kx4					
Toshiba	NMOS	256Kx1	S	S	20	50	70
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			25	80	480	1,115	1,700
Percent Change from Previous Quarter				220%	500%	132%	
Cumulative Total			25	105	585	1,700	
Average Selling Price			$100.00	$80.00	$55.00	$41.00	$47.66
Revenue ($M)			2.5	6.4	26.4	45.7	81.0

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	0.0	0.0	4.2%	9.4%	7.4%
Japan	100.0%	100.0%	95.8	90.6	92.6
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS 256Kx1					
AT&T Technologies	NMOS 256Kx1	200	500	800	1,500	3,000
Fujitsu	NMOS 256Kx1	600	1,500	2,500	3,300	7,900
	NMOS 64Kx1					
	CMOS 256Kx1					
	CMOS 64Kx4					
Hitachi	NMOS 256Kx1	700	2,200	3,000	4,800	10,700
	CMOS 256Kx1					
	NMOS 64Kx4			S	5	5
Inmos	CMOS 256Kx1					
Intel	CMOS 256Kx1		S	S	20	20
	CMOS 64Kx4				S	S
Matsushita	NMOS 256Kx1					
	NMOS 64Kx4					
Micron Technology	NMOS 256Kx1			S	20	20
	NMOS 64Kx4					
Mitsubishi	NMOS 256Kx1	50	50	300	750	1,150
	NMOS 64Kx4					
Mostek	NMOS 32Kx8	15	35	40	60	150
	NMOS 256Kx1				S	S
Motorola	NMOS 256Kx1				S	S
	CMOS 256Kx1					
National	NMOS 256Kx1		S	S	10	10
NEC	NMOS 256Kx1	800	1,500	3,500	4,100	9,900
	NMOS 64Kx4	S	150	90	120	360
	NMOS 32Kx8			S	5	5
Oki Electric	NMOS 256Kx1	50	100	350	500	1,000
	NMOS 64Kx4					
Samsung	NMOS 256Kx1					
Sharp	NMOS 256Kx1					
	NMOS 64Kx4					
Siemens	NMOS 256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas Instruments	NMOS	256Kx1	10	25	50	75	160
	NMOS	64Kx4	S	S	S	S	S
Toshiba	NMOS	256Kx1	200	500	1,100	1,800	3,600
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			2,625	6,560	11,730	17,065	37,980
Percent Change from Previous Quarter			135%	150%	79%	45%	
Cumulative Total			4,325	10,885	22,615	39,680	
Average Selling Price			$31.00	$23.50	$17.50	$14.00	$17.90
Revenue ($M)			81.4	154.2	205.3	238.9	679.7

	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	8.6%	8.5%	7.6%	9.9%	8.8%
Japan	91.4	91.5	92.4	90.1	91.2
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1			S	S	S
AT&T Technologies	NMOS	256Kx1	1,600	2,200	3,500	5,000	12,300
Fujitsu	NMOS	256Kx1	3,700	5,600	8,500	13,000	30,800
	NMOS	64Kx1			S	25	25
	CMOS	256Kx1				S	S
	CMOS	64Kx4				S	S
Hitachi	NMOS	256Kx1	6,000	8,500	14,500	20,000	49,000
	CMOS	256Kx1	S	5	50	250	305
	NMOS	64Kx4	25	100	400	1,000	1,525
Inmos	CMOS	256Kx1	S	S	S	5	5
Intel	CMOS	256Kx1	200	400	600	750	1,950
	CMOS	64Kx4	10	100	600	1,100	1,810
Matsushita	NMOS	256Kx1	S	50	250	1,500	1,800
	NMOS	64Kx4					0
Micron	NMOS	256Kx1	20	10	400	1,500	1,930
Technology	NMOS	64Kx4		S	S	25	25
Mitsubishi	NMOS	256Kx1	900	1,800	3,200	5,500	11,400
	NMOS	64Kx4				S	S
Mostek	NMOS	32Kx8	50	50	50	25	175
	NMOS	256Kx1	S	25	25	25	75
Motorola	NMOS	256Kx1	S	5	0	0	5
	CMOS	256Kx1			S	S	S
National	NMOS	256Kx1	25	50	0	0	75
NEC	NMOS	256Kx1	4,650	6,500	13,750	16,780	41,680
	NMOS	64Kx4	420	600	260	80	1,360
	NMOS	32Kx8	10	150	250	450	860
Oki Electric	NMOS	256Kx1	600	800	1,200	2,000	4,600
	NMOS	64Kx4					
Samsung	NMOS	256Kx1	S	S	5	10	15
Sharp	NMOS	256Kx1			S	S	0
	NMOS	64Kx4			S	S	0
Siemens	NMOS	256Kx1			S	150	150

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	500	1,200	4,000	6,000	11,700
Instruments	NMOS	64Kx4	10	15	150	300	510
Toshiba	NMOS	256Kx1	4,000	6,000	7,000	8,000	25,000
	NMOS	64Kx4	S	500	1,000	1,000	2,500
Vitelic	CMOS	256Kx1			S	S	S
	CMOS	64Kx4					S
Total			22,720	34,695	59,690	84,475	201,580
Percent Change from Previous Quarter			33%	53%	72%	42%	
Cumulative Total			62,400	97,095	156,785	241,260	
Average Selling Price			$9.50	$5.15	$3.00	$2.25	$3.79
Revenue ($M)			215.8	178.7	179.1	190.1	763.7

	1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	10.6%	11.8%	15.6%	17.4%	15.2%
Japan	89.4	88.2	84.4	82.4	84.8
Europe	0.0	0.0	0.0	0.2	0.1
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					0
AT&T Technologies	NMOS	256Kx1	5,000	5,000	5,000	5,000	20,000
Fujitsu	NMOS	256Kx1	20,000	20,500	20,000	15,000	75,500
	NMOS	64Kx4	100	500	1,000	1,500	3,100
	CMOS	256Kx1		500	1,000	3,000	4,500
	CMOS	64Kx4		50	100	200	350
Hitachi	NMOS	256Kx1	25,000	30,000	22,000	23,500	100,500
	CMOS	256Kx1	500	1,000	1,500	2,000	5,000
	NMOS	64Kx4	2,000	2,500	2,500	2,500	9,500
Inmos	CMOS	256Kx1	250	500	800	1,200	2,750
Intel	CMOS	256Kx1					0
	CMOS	64Kx4					0
Matsushita	NMOS	256Kx1	1,700	1,900	2,100	2,200	7,900
	NMOS	64Kx4					0
Micron Technology	NMOS	256Kx1	3,000	6,000	6,000	6,000	21,000
	NMOS	64Kx4	200	800	1,200	1,500	3,700
Mitsubishi	NMOS	256Kx1	19,000	13,200	23,400	24,200	79,800
	NMOS	64Kx4	510	800	1,600	2,300	5,210
Mostek	NMOS	32Kx8					0
	NMOS	256Kx1					0
Motorola	NMOS	256Kx1	12	0	812	1,297	2,121
	CMOS	256Kx1					0
National	NMOS	256Kx1					0
NEC	NMOS	256Kx1	24,490	28,840	26,720	28,000	108,050
	NMOS	64Kx4	400	560	7,310	10,000	18,270
	NMOS	32Kx8	600	750	750	1,000	3,100
NMB	CMOS	256Kx1	300	600	1,200	2,400	4,500
Oki Electric	NMOS	256Kx1	3,000	4,000	5,000	7,000	19,000
	NMOS	64Kx4	S	100	300	1,000	1,400
Samsung	NMOS	256Kx1	500	2,000	5,000	5,000	14,000
Sharp	NMOS	256Kx1					0
	NMOS	64Kx4					0
Siemens	NMOS	256Kx1	200	500	800	1,500	3,000

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	9,000	10,000	10,000	12,000	41,000
Instruments	NMOS	64Kx4	500	1,000	1,250	1,500	4,250
Toshiba	NMOS	256Kx1	11,000	12,000	15,000	18,000	56,000
	NMOS	64Kx4	1,000	1,600	1,500	1,500	5,600
Vitelic	CMOS	256Kx1	10	50	90	150	300
	CMOS	64Kx4		10	30	70	110
Total			128,272	145,260	163,962	182,517	620,011
Percent Change from Previous Quarter			52%	13%	13%	11%	
Cumulative Total			369,682	514,942	678,904	861,421	
Average Selling Price			$2.25	$2.30	$2.50	$2.20	$2.31
Revenue ($M)			288.6	334.1	409.9	401.5	1,434.2

	1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	14.1%	15.1%	14.8%	16.8%	15.3%
Japan	85.1	82.9	81.1	78.6	81.7
Europe	0.4	0.7	1.1	1.7	1.0
Asia Pacific	0.4	1.3	3.0	2.9	2.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

			1987				
Company	MOS Process/ Organization		1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1					
Fujitsu	NMOS	256Kx1	16,500	15,000	15,300	15,300	62,100
	NMOS	64Kx4	1,000	1,000	1,500	2,000	5,500
	CMOS	256Kx1	3,500	3,500	4,000	4,700	15,700
	CMOS	64Kx4	500	500	700	1,000	2,700
Hitachi	NMOS	256Kx1	16,800	14,000	13,700	13,400	57,900
	CMOS	256Kx1	2,200	2,500	3,000	3,500	11,200
	NMOS	64Kx4	2,000	2,000	2,000	2,000	8,000
Inmos	CMOS	256Kx1	1,500	1,500	1,500	1,500	6,000
Intel	CMOS	256Kx1				2,000	2,000
	CMOS	64Kx4					0
Matsushita	NMOS	256Kx1	1,600	2,100	4,000	5,500	13,200
	NMOS	64Kx4					0
Micron	NMOS	256Kx1	6,000	7,000	8,000	9,000	30,000
Technology	NMOS	64Kx4	2,000	2,800	3,600	4,500	12,900
Mitsubishi	NMOS	256Kx1	17,100	16,800	18,000	20,900	72,800
	NMOS	64Kx4	2,900	3,000	3,500	4,000	13,400
Mostek	NMOS	32Kx8					0
	NMOS	256Kx1					0
Motorola	NMOS	256Kx1	5,398	6,075	5,624	7,347	24,444
	CMOS	256Kx1					0
National	NMOS	256Kx1					0
NEC	NMOS	256Kx1	20,190	15,530	20,780	6,900	63,400
	NMOS	64Kx4	13,250	13,500	12,820	14,600	54,170
	NMOS	32Kx8	1,000	1,500	2,000	2,000	6,500
NMB	CMOS	256Kx1	2,800	3,500	4,500	5,200	16,000
Oki Electric	NMOS	256Kx1	6,000	5,400	7,200	8,500	27,100
	NMOS	64Kx4	900	810	1,500	2,000	5,210
Samsung	NMOS	256Kx1	12,000	16,000	19,000	20,000	67,000
Sharp	NMOS	256Kx1	1,005	4,419	5,857	7,800	19,081
	NMOS	64Kx4					0
Siemens	NMOS	256Kx1	2,000	2,500	3,000	3,500	11,000

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	19,000	23,500	27,000	30,400	99,900
Instruments	NMOS	64Kx4	2,000	2,500	3,500	4,500	12,500
Toshiba	NMOS	256Kx1	8,700	7,700	7,000	6,800	30,200
	NMOS	64Kx4	2,000	3,000	4,000	5,700	14,700
Vitelic	CMOS	256Kx1	250	275	300	350	1,175
	CMOS	64Kx4	100	120	150	180	550
Total			170,193	178,029	203,031	215,077	766,330
Percent Change from Previous Quarter			(7%)	5%	14%	6%	
Cumulative Total			1,031,614	1,209,643	1,412,674	1,627,751	
Average Selling Price			$2.25	$2.30	$2.40	$2.45	$2.36
Revenue ($M)			382.9	409.5	487.3	526.9	1,807.0

	1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	20.4%	23.7%	23.7%	27.1%	23.9%
Japan	70.5	65.0	64.7	61.3	65.1
Europe	2.1	2.2	2.2	2.3	2.2
Asia Pacific	7.1	9.0	9.4	9.3	8.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

Table 6

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS	1Mbx1	S	S	S	1	1
Fujitsu	NMOS	1Mbx1		S	0	0	0
Hitachi	CMOS	1Mbx1	S	S	0	2	2
	CMOS	256Kx4					
Matsushita	NMOS	1Mbx1					
	NMOS	256Kx4					
Micron Technology	CMOS	256Kx4					
Mitsubishi	NMOS	1Mbx1				S	
	NMOS	256Kx4				S	
NEC	NMOS	1Mbx1		S	S	0	0
NMB	CMOS	256Kx4					
Oki Electric	CMOS	1Mbx1					
Samsung	CMOS	1Mbx1					
Sharp	CMOS	1Mbx1					
Siemens	CMOS	1Mbx1					
Texas Instruments	CMOS	1Mbx1				S	0
	CMOS	256Kx4				S	0
Toshiba	CMOS	1Mbx1		S	10	150	160
	NMOS	1Mbx1	S	S	1	2	3
	CMOS	256Kx4					
Vitelic	CMOS	256Kx4	-	-	-	S	0
Total			0	0	11	155	166
Percent Change from Previous Quarter						1,309%	
Cumulative Total			0	0	11	166	
Average Selling Price			$150.00	$125.00	$110.00	$100.00	$100.66
Revenue ($M)			0.0	0.0	1.2	15.5	16.7

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	0.0	0.0	0.0	0.6%	0.6%
Japan	0.0	0.0	100.0%	99.4	99.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	100.0%	100.0%	100.0%

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS	1Mbx1	10	50	150	300	510
Fujitsu	NMOS	1Mbx1	10	20	50	100	180
Hitachi	CMOS	1Mbx1	5	35	150	400	590
	CMOS	256Kx4					
Matsushita	NMOS	1Mbx1					
	NMOS	256Kx4					
Micron Technology	CMOS	256Kx4					
Mitsubishi	NMOS	1Mbx1			20	130	150
	NMOS	256Kx1			10	60	70
NEC	NMOS	1Mbx1			S	100	100
	CMOS	1Mbx1				200	200
	CMOS	256Kx4					
NMB	CMOS	256Kx4					
Oki Electric	CMOS	1Mbx1		S	5	10	15
Samsung	CMOS	1Mbx1					
Sharp	CMOS	1Mbx1					
Siemens	CMOS	1Mbx1					
Texas Instruments	CMOS	1Mbx1	2	S	5	10	17
	CMOS	256Kx4	2	S	5	10	17
Toshiba	CMOS	1Mbx1	150	250	500	1,350	2,250
	NMOS	1Mbx1					
	CMOS	256Kx4	S	20	50	150	220
Vitelic	CMOS	256Kx4					
Total			179	375	945	2,820	4,319
Percent Change from Previous Quarter			15%	109%	152%	198%	
Cumulative Total			345	720	1,665	4,485	
Average Selling Price			$48.00	$34.00	$45.00	$25.00	$31.11
Revenue ($M)			8.6	12.8	42.5	70.5	134.4

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1986				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	7.8%	13.3%	16.9%	11.3%	12.6%
Japan	92.2	86.7	83.1	88.7	87.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/	Organization	1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS	1Mbx1					
Fujitsu	NMOS	1Mbx1	100	200	400	900	1,600
Hitachi	CMOS	1Mbx1	800	1,200	1,625	2,200	5,825
	CMOS	256Kx4		5	25	100	130
Matsushita	NMOS	1Mbx1					
	NMOS	256Kx4	S	30	90	290	410
Micron	CMOS	256Kx4				5	5
Mitsubishi	CMOS	1Mbx1	503	525	728	1,275	3,030
	CMOS	256Kx1	377	859	698	806	2,739
NEC	NMOS	1Mbx1	150	140	200	30	520
	CMOS	1Mbx1	50	260	740	1,800	2,850
	CMOS	256Kx4					
NMB	CMOS	256Kx4					0
Oki	CMOS	1Mbx1	100	300	350	1,250	2,000
Samsung	CMOS	1Mbx1			S	5	5
Sharp	CMOS	1Mbx1				S	0
Siemens	CMOS	1Mbx1			S	5	5
Texas Instruments	CMOS	1Mbx1	20	50	100	200	370
	CMOS	256Kx4	10	30	50	100	190
Toshiba	CMOS	1Mbx1	2,800	3,300	5,000	7,700	18,800
	NMOS	1Mbx1					
	CMOS	256Kx4	300	500	1,300	2,000	4,100
Vitelic	CMOS	256Kx4					
Total			5,209	7,399	11,306	18,666	42,580
Percent Change from Previous Quarter			83%	42%	53%	65%	
Cumulative Total			9,719	17,118	28,424	47,090	
Average Selling Price			$17.00	$15.00	$13.50	$15.00	$14.95
Revenue ($M)			93.1	111.0	152.6	280.0	637.0

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1987				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
U.S.	0.6%	1.1%	1.3%	1.6%	1.3%
Japan	99.4	98.9	98.7	98.3	98.6
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
May 1988

DRAM—Data Update

MOS DYNAMIC RAMs—DATA

This section presents unit shipments of the more significant densities of dynamic RAMs (DRAMs) for 1988. The 1988 estimated shipments are for the 64K to 4Mb densities. Included in the tables are estimated worldwide billing prices for each density and market share data (in units) for North America-based, Japan-based, Europe-based, and Asia/Pacific-based companies. The tables are as follows:

- Table 1—64K DRAM (1978-1988)
- Table 2—256K DRAM (1982-1988)
- Table 3—1Mb DRAM (1985-1988)
- Table 4—4Mb DRAM (1988)

DEFINITIONS

Prices

Average selling price (ASP) is the Dataquest estimate of the average worldwide billing price for that quarter. It incorporates prices for all package types and access times for both commercial and military markets.

Unit Shipments

Shipment data are factory revenue shipments as published in earlier sections, with occasional revisions based on the availability of more recent information.

Quarterly Revenue

Revenue is calculated as total units shipped in the quarter multiplied by the average billing price of that quarter.

Table 1

Estimated Worldwide MOS 64K DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization		1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			0	0	0	0	0
Fujitsu.	NMOS	64Kx1	900	800	700	600	3,000
	NMOS	16Kx4	250	250	200	200	900
Hitachi	NMOS	64Kx1	120	40	20	0	180
	NMOS	16Kx4	30	10	0		40
Inmos	NMOS	64Kx1	371	201	543	423	1,538
Intel	NMOS	64Kx1	1,050	1,300	1,300	1,050	4,700
Matsushita	NMOS	64Kx1	1,400	1,500	1,500	1,500	5,900
	NMOS	16Kx4	700	700	700	700	2,800
	NMOS	8Kx8	700	700	700	700	2,800
Micron	NMOS	64Kx1	2,000	2,500	2,500	2,500	9,500
Mitsubishi	NMOS	64Kx1	1,030	800	600	600	3,030
	NMOS	16Kx4	1,100	1,000	1,200	1,200	4,500
Mostek			0	0	0	0	0
Motorola	NMOS	64Kx1	509	340	0	0	849
National			0	0	0	0	0
NEC	NMOS	16Kx4	500	350	155	100	1,105
	NMOS	8Kx8	1,650	1,700	1,481	956	5,787
	NMOS	64Kx1	1,500	1,200	1,464	944	5,108
Oki Electric	NMOS	64Kx1	2,000	2,000	2,000	2,000	8,000
Samsung	NMOS	64Kx1	7,500	7,500	7,000	7,000	29,000
SGS-Thomson	NMOS	64Kx1	600	550	500	450	2,100
Sharp	NMOS	64Kx1	1,950	2,400	2,400	2,500	9,250
Siemens			0	0	0	0	0
Texas Instruments	NMOS	64Kx1	2,091	2,091	1,742	1,742	7,667
	NMOS	64Kx1	909	909	758	758	3,333
Toshiba	NMOS	64Kx1	500	100	0	0	600
Vitelic			0	0	0	0	0
	Total		29,360	28,941	27,463	25,923	111,687

(Continued)

DRAM—Data Update

Table 1 (Continued)

Estimated Worldwide MOS 64K DRAM Shipments
(Thousands of Units)

	1988				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	3%	(1%)	(5%)	(6%)	
Cumulative Total (Thousands of Units)	181,941	210,882	238,345	264,268	
Average Selling Price	$1.38	$1.44	$1.57	$1.65	$1.50
Revenue ($M)	40.5	41.7	43.1	42.8	168.1

	1988				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	22.3%	24.7%	22.9%	23.3%	23.3%
Japan	48.8	46.8	47.8	46.3	47.5
Europe	3.3	2.6	3.8	3.4	3.3
Asia/Pacific	25.5	25.9	25.5	27.0	26.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

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

Source: Dataquest
August 1989

Table 2

Estimated Worldwide MOS 256K DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			0	0	0	0	0
AT&T Micro-electronics			0	0	0	0	0
Fujitsu	NMOS	256Kx1	14,500	15,000	14,250	12,825	56,575
	CMOS	256Kx1	4,500	5,000	4,750	4,275	18,525
	NMOS	64Kx4	2,000	2,500	2,375	2,138	9,013
	CMOS	64Kx4	1,300	1,300	1,235	1,112	4,947
Goldstar			0	0	100	800	900
Hitachi	NMOS	256Kx1	13,000	12,000	12,000	11,000	48,000
	CMOS	256Kx1	4,000	3,600	3,400	3,000	14,000
	NMOS	64Kx4	4,000	3,600	3,600	3,600	14,800
Hyundai			1,000	2,000	3,500	4,500	11,000
Inmos			0	0	0	0	0
Intel	CMOS	256Kx1	2,100	2,200	1,900	2,100	8,300
Matsushita	NMOS	256Kx1	4,200	5,400	5,600	5,500	20,700
Micron Technology	NMOS	256Kx1	15,000	16,500	14,000	15,000	60,500
	NMOS	64Kx4	2,500	2,500	3,000	3,000	11,000
Mitsubishi	NMOS	256Kx1	14,000	14,000	10,000	9,000	47,000
	NMOS	64Kx4	3,300	3,800	2,800	3,300	13,200
Motorola	NMOS	256Kx1	7,600	6,200	6,177	4,905	24,882
	NMOS	64Kx4	100	109	434	461	1,104
National			0	0	0	0	0
NEC	NMOS	256Kx1	17,600	18,450	17,425	17,425	70,900
	NMOS	64Kx4	13,650	14,400	15,675	15,675	59,400
NMB	CMOS	256Kx1	8,500	9,600	10,500	11,500	40,100
Oki Electric	NMOS	256Kx1	12,500	13,500	14,000	13,000	53,000
	NMOS	64Kx4	3,000	3,500	3,000	3,000	12,500
Samsung	NMOS	256Kx1	21,500	21,000	20,000	19,000	81,500
Sharp	NMOS	256Kx1	9,500	10,000	10,500	10,500	40,500
Siemens	NMOS	256Kx1	4,000	4,500	5,000	5,000	18,500
Texas Instruments	NMOS	256Kx1	33,511	33,511	32,533	31,111	130,667
	NMOS	64Kx4	4,189	4,189	4,067	3,889	16,333
Toshiba	NMOS	256Kx1	14,000	10,000	9,000	9,000	42,000
	NMOS	64Kx4	3,000	2,700	2,400	2,000	10,100
Vitelic	CMOS	256Kx1	618	1,350	1,760	2,100	5,828
	CMOS	64Kx4	32	150	440	900	1,522
Total			238,700	242,559	235,421	230,616	947,296

Table 2 (Contiued)

Estimated Worldwide MOS 256K DRAM Shipments
(Thousands of Units)

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	1988 Year
Percent Change from Previous Quarter	11%	2%	(3%)	(2%)	
Cumulative Total (Thousands of Units)	1,866,451	2,109,010	2,344,431	2,575,047	
Average Selling Price	$2.79	$2.97	$3.19	$3.30	$3.06
Revenue ($M)	666.0	720.4	751.0	761.0	2,898.4

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	1988 Year
Market Share					
North America	27.5%	27.5%	27.3%	27.5%	27.5%
Japan	61.4	61.2	60.5	59.8	60.7
Europe	1.7	1.9	2.1	2.2	2.0
Asia/Pacific	9.4	9.5	10.0	10.5	9.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

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

Source: Dataquest
August 1989

Table 3

Estimated Worldwide MOS 1Mb DRAM Shipments
(Thousands of Units)

			1988				
Company	MOS Process/	Organization	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AT&T Micro-electronics			0	0	0	0	0
Fujitsu	NMOS	1Mx1	2,500	3,500	5,000	7,000	18,000
Goldstar			0	0	0	0	0
Hitachi	CMOS	1Mx1	2,500	3,100	4,500	6,400	16,500
	CMOS	256Kx4	500	1,000	1,600	2,400	5,500
Hyundai			0	0	0	0	0
Intel	CMOS	1Mx1	0	S	150	150	300
Matsushita	NMOS	256Kx4	500	1,000	2,000	2,000	5,500
Micron	CMOS	256Kx4	20	100	300	500	920
Mitsubishi	CMOS	1Mx1	1,900	3,000	4,000	5,000	13,900
	CMOS	256Kx4	1,300	2,000	3,500	4,500	11,300
Motorola	CMOS	1Mx1	600	878	930	1,576	3,984
	CMOS	256Kx4	0	33	303	438	774
NEC	NMOS	1Mx1	180	0	0	0	180
	CMOS	1Mx1	3,000	4,000	5,333	6,733	19,067
	CMOS	256Kx4	1,820	2,000	2,667	3,367	9,853
NMB	CMOS	1Mx1	5	10	500	540	1,055
Oki	NMOS	1Mx1	1,500	2,000	3,500	5,000	12,000
Samsung	CMOS	1Mx1	200	500	2,600	4,500	7,800
Sanyo			0	0	0	S	0
Sharp	NMOS	1Mx1.	650	800	800	1,500	3,750
Siemens	CMOS	1Mx1	160	600	1,320	2,100	4,180
	CMOS	256Kx4	40	400	880	1,400	2,720
Texas Instruments	CMOS	1Mx1	367	1,000	2,000	4,000	7,367
	CMOS	256Kx4	183	500	1,000	2,000	3,683
Toshiba	CMOS	1Mx1	8,500	11,000	13,000	15,000	47,500
	CMOS	256Kx4	2,500	3,300	4,000	6,000	15,800
Vitelic	CMOS		0	0	0	0	0
Total			28,925	40,721	59,883	82,104	211,633

(Continued)

Table 3 (Continued)

Estimated Worldwide MOS 1Mb DRAM Shipments
(Thousands of Units)

	1988				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total
Percent Change from Previous Quarter	55%	41%	47%	37%	
Cumulative Total (Thousands of Units)	76,015	116,736	176,619	258,723	
Average Selling Price	$15.20	$16.51	$17.48	$17.28	$16.90
Revenue ($M)	439.7	672.3	1,046.8	1,418.8	3,577.5

	1988				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	4.0%	6.2%	7.8%	10.6%	8.0%
Japan	94.6	90.2	84.2	79.7	85.0
Europe	0.7	2.5	3.7	4.3	3.3
Asia/Pacific	0.7	1.2	4.3	5.5	3.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

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

Source: Dataquest
August 1989

Table 4

Estimated Worldwide MOS 4Mb DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Year
Fujitsu	CMOS	4Mx1	0	0	0	1	1
Hitachi	CMOS	4Mx1	0	0	1	3	4
Mitsubishi	CMOS	4Mx1	0	0	0	1	1
NEC	CMOS	4Mx1	0	0	1	2	3
Oki	CMOS	4Mx1	0	0	0	1	1
Seimens	CMOS	4Mx1	0	0	0	1	1
Texas Instruments	CMOS	4Mx1	0	0	0	1	1
Toshiba	CMOS	4Mx1	0	0	2	5	7
Total			N/A	N/A	4	15	19

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Total
Percent Change from Previous Quarter				263%	
Cumulative Total (Thousands of Units)			4	19	
Average Selling Price			$540.00	$428.21	$452.38
Revenue ($M)	0	0	2.2	6.2	8.4

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Year
Market Share					
North America	N/A	N/A	0	6.9%	5.4%
Japan	N/A	N/A	100.0%	89.7	91.9
Europe	N/A	N/A	0	3.4	2.7
Asia/Pacific	N/A	N/A	0	0	0
Total	N/A	N/A	100.0%	100.0%	100.0%

N/A = Not Available

Source: Dataquest
August 1989

DRAM--Data

MOS DYNAMIC RAMs—DATA

This section presents historical unit shipments of the more significant densities of dynamic RAMs (DRAMs) from 1974 to 1987. The 1987 estimated shipments are for the 64K to 1Mb densities. Included in the tables are estimated worldwide billing prices for each density and market share data (in units) for North America-based, Japan-based, Europe-based, and Asia-Pacific-based companies. The 1987 data are subject to review at a later date due to the qualifications discussed below. The tables are as follows:

- Table 1—4K DRAM (1974-1985)
- Table 2—16K 3ps DRAM (1976-1985)
- Table 3—16K 5V DRAM (1979-1985)
- Table 4—64K DRAM (1978-1987)
- Table 5—256K DRAM (1982-1987)
- Table 6—1Mb DRAM (1985-1987)

DEFINITIONS

Prices

Average selling price is the Dataquest estimate of the average worldwide billing price for that quarter. It incorporates prices for all package types and access times for both commercial and military markets.

Unit Shipments

Shipment data are factory revenue shipments as published in earlier sections, with occasional revisions based on the availability of more recent information. The unit shipments in the fourth quarter of 1986 are forecast numbers.

Quarterly Revenue

Revenue is calculated as total units shipped in the quarter multiplied by the average billing price of that quarter.

Table 1

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1974 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
AMI					
Fairchild					
Fujitsu					
Hitachi					
Intel	40	100	150	220	510
Intersil					
Mostek			5	20	25
Motorola					
National					
NEC					
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	5	10	20	50	80
Total	40	110	175	290	615
Percentage Change from Previous Quarter	175%	59%	66%		
Cumulative Total	40	150	325	615	
Average Selling Price	$40.00	$25.00	$15.00	$12.00	$17.00
Revenue ($M)	1.6	2.8	2.6	3.5	10.5

	1974 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1975 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD				5	5
AMI			15	30	45
Fairchild		15	40	100	155
Fujitsu					
Hitachi					
Intel	260	425	675	1,050	2,410
Intersil			20	45	65
Mostek	35	95	210	390	730
Motorola		5	25	145	175
National		10	35	110	155
NEC	10	25	65	120	220
SGS-Ates					
Signetics					
STC (ITT)					
Texas Instruments	75	175	340	740	1,330
Total	380	750	1,425	2,735	5,290
Percentage Change from Previous Quarter	31%	97%	90%	92%	
Cumulative Total	995	1,745	3,170	5,905	
Average Selling Price	$10.00	$7.50	$6.00	$5.50	$6.24
Revenue ($M)	3.8	5.6	8.6	15.0	33.0

	1975 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	97.4%	96.7%	95.4%	95.6%	95.8%
Japan	2.6	3.3	4.6	4.4	4.2
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1976 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	23	105	165	175	468
AMI	0	0	0	0	0
Fairchild	290	430	435	330	1,485
Fujitsu	95	155	205	260	715
Hitachi			S	S	S
Intel	900	1,325	1,500	1,500	5,225
Intersil	42	85	190	195	512
Mostek	600	1,400	1,600	1,425	5,025
Motorola	190	180	360	475	1,205
National	300	480	560	775	2,115
NEC	575	790	1,100	1,275	3,740
SGS-Ates					
Signetics	S	35	65	120	220
STC (ITT)				S	S
Texas Instruments	1,400	1,800	2,000	2,100	7,300
Total	4,415	6,785	8,180	8,630	28,010
Percentage Change from Previous Quarter	61%	54%	21%	6%	
Cumulative Total	4,415	11,200	19,380	28,010	
Average Selling Price	$5.00	$4.50	$4.25	$4.00	$4.35
Revenue ($M)	22.1	30.5	34.8	34.5	121.9

	1976 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	84.8%	86.1%	84.0%	82.2%	84.1%
Japan	15.2	13.9	16.0	17.8	15.9
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1977 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	290	450	600	1,000	2,340
AMI	0	0	0	0	0
Fairchild	380	450	550	700	2,080
Fujitsu	550	750	800	800	2,900
Hitachi	50	100	300	460	910
Intel	2,000	2,300	3,000	3,100	10,400
Intersil	240	220	220	220	900
Mostek	2,150	2,600	3,300	3,750	11,800
Motorola	540	700	750	750	2,740
National	825	925	925	1,000	3,675
NEC	1,400	1,500	1,600	1,600	6,100
SGS-Ates				S	S
Signetics	180	210	230	250	870
STC (ITT)	20	50	80	150	300
Texas Instruments	2,300	3,000	3,200	3,900	12,400
Total	10,925	13,255	15,555	17,680	57,415
Percentage Change from Previous Quarter	27%	21%	17%	14%	
Cumulative Total	38,935	52,190	67,745	85,425	
Average Selling Price	$3.50	$3.00	$2.50	$2.00	$2.65
Revenue ($M)	38.2	39.8	38.9	35.4	152.3

	1977 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	81.7%	82.3%	82.6%	83.8%	82.7%
Japan	18.3	17.7	17.4	16.2	17.3
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

	1978				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,100	1,500	1,800	2,200	6,600
AMI	0	0	0	0	0
Fairchild	500	400	200	100	1,200
Fujitsu	600	600	400	300	1,900
Hitachi	330	500	500	450	1,780
Intel	3,000	3,000	2,700	2,300	11,000
Intersil	150	100	100	100	450
Mostek	4,000	4,000	4,800	4,200	17,000
Motorola	1,000	1,300	1,500	1,900	5,700
National	1,200	1,200	1,500	1,700	5,600
NEC	1,600	1,600	1,600	1,350	6,150
SGS-Ates	60	75	100	125	360
Signetics	250	300	300	300	1,150
STC (ITT)	200	300	300	800	1,600
Texas Instruments	4,200	4,700	4,000	3,800	16,700
Total	18,190	19,575	19,800	19,625	77,190
Percentage Change from Previous Quarter	3%	8%	1%	(1%)	
Cumulative Total	103,615	123,190	142,990	162,615	
Average Selling Price	$2.00	$1.90	$1.80	$1.60	$1.82
Revenue ($M)	36.4	37.2	35.6	31.4	140.6

	1978				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	85.8%	85.8%	86.9%	88.7%	86.8%
Japan	13.9	13.8	12.6	10.7	12.7
Europe	0.3	0.4	0.5	0.6	0.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1979 1st Qtr.	1979 2nd Qtr.	1979 3rd Qtr.	1979 4th Qtr.	1979 Year
AMD	2,600	3,000	3,000	1,600	10,200
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	200	200	200	150	750
Hitachi	350	200	200	100	850
Intel	1,700	1,700	1,500	1,200	6,100
Intersil	100	100	300	500	1,000
Mostek	3,800	3,300	3,400	3,600	14,100
Motorola	1,500	1,150	1,800	2,000	6,450
National	2,000	2,400	2,000	1,500	7,900
NEC	1,350	1,900	1,300	1,000	5,550
SGS-Ates	150	175	200	225	750
Signetics	300	100	50	10	460
STC (ITT)	1,100	1,300	1,300	1,500	5,200
Texas Instruments	3,600	3,200	2,700	1,200	10,700
Total	18,750	18,725	17,950	14,585	70,010
Percentage Change from Previous Quarter	(4%)	0%	(4%)	(19%)	
Cumulative Total	181,365	200,090	218,040	232,625	
Average Selling Price	$1.50	$2.00	$2.00	$2.25	$1.92
Revenue ($M)	28.1	37.5	35.9	32.8	134.3

	1979 1st Qtr.	1979 2nd Qtr.	1979 3rd Qtr.	1979 4th Qtr.	1979 Year
Market Share					
North America	89.1%	86.8%	89.4%	89.9%	88.7%
Japan	10.1	12.3	9.5	8.6	10.2
Europe	0.8	0.9	1.1	1.5	1.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,300	750	450	435	2,935
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	200	200	150	650
Hitachi	100	100	0	0	200
Intel	900	100	0	0	1,000
Intersil	600	300	225	100	1,225
Mostek	2,500	2,000	1,400	1,200	7,100
Motorola	1,700	1,000	850	1,500	5,050
National	1,500	1,300	1,000	750	4,550
NEC	400	275	360	420	1,455
SGS-Ates	300	350	300	250	1,200
Signetics	0	0	0	0	0
STC (ITT)	1,400	600	1,500	1,500	5,000
Texas Instruments	700	100	0	0	800
Total	11,500	7,075	6,285	6,305	31,165
Percentage Change from Previous Quarter	(21%)	(38%)	(11%)	0%	
Cumulative Total	244,125	251,200	257,485	263,790	
Average Selling Price	$2.00	$1.90	$1.90	$1.90	$1.94
Revenue ($M)	23.0	13.4	11.9	12.0	60.4

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	92.2%	86.9%	86.3%	87.0%	88.8%
Japan	5.2	8.1	8.9	9.0	7.4
Europe	2.6	4.9	4.8	4.0	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	550	450	350	300	1,650
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	100	50	25	20	195
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	35	50	30	30	145
Mostek	800	650	500	300	2,250
Motorola	900	1,000	800	550	3,250
National	600	600	500	400	2,100
NEC	150	100	50	20	320
SGS-Ates	220	200	150	90	660
Signetics	0	0	0	0	0
STC (ITT)	1,100	570	450	350	2,470
Texas Instruments	0	0	0	0	0
Total	4,455	3,670	2,855	2,060	13,040
Percentage Change from Previous Quarter	(29%)	(18%)	(22%)	(28%)	
Cumulative Total	268,245	271,915	274,770	276,830	
Average Selling Price	$2.00	$1.75	$1.60	$1.50	$1.76
Revenue ($M)	8.9	6.4	4.6	3.1	23.0

	1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	89.5%	90.5%	92.1%	93.7%	91.0%
Japan	5.6	4.1	2.6	1.9	3.9
Europe	4.9	5.4	5.3	4.4	5.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	200	40	15	0	255
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	10	5	0	0	15
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	250	250	200	200	900
Motorola	475	475	250	270	1,470
National	250	180	180	100	710
NEC	0	0	0	0	0
SGS-Ates	60	70	60	75	265
Signetics	0	0	0	0	0
STC (ITT)	400	200	200	220	1,020
Texas Instruments	0	0	0	0	0
Total	1,645	1,220	905	865	4,635
Percentage Change from Previous Quarter	(20%)	(26%)	(26%)	(4%)	
Cumulative Total	278,475	279,695	280,600	281,465	
Average Selling Price	$1.35	$1.60	$1.75	$2.00	$1.62
Revenue ($M)	2.2	2.0	1.6	1.7	7.5

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	95.7%	93.9%	93.4%	91.3%	94.0%
Japan	0.6	0.4	0.0	0.0	0.3
Europe	3.6	5.7	6.6	8.7	5.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	200	200	200	225	825
Motorola	175	50	50	25	300
National	100	100	50	0	250
NEC	0	0	0	0	0
SGS-Ates	75	100	200	50	425
Signetics	0	0	0	0	0
STC (ITT)	200	200	150	50	600
Texas Instruments	0	0	0	0	0
Total	750	650	650	350	2,400
Percentage Change from Previous Quarter	(13%)	(13%)	0%	(46%)	
Cumulative Total	282,215	282,865	283,515	283,865	
Average Selling Price	$2.75	$2.50	$2.75	$3.00	$2.72
Revenue ($M)	2.1	1.6	1.8	1.1	6.5

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	90.0%	84.6%	69.2%	85.7%	82.3%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	10.0	15.4	30.8	14.3	17.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1984 1st Qtr.	1984 2nd Qtr.	1984 3rd Qtr.	1984 4th Qtr.	1984 Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	300	350	350	500	1,500
Motorola	25	25	25	25	100
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	100	50	50	50	250
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	525	525	525	675	2,250
Percentage Change from Previous Quarter	(78%)	0%	0%	29%	
Cumulative Total	284,390	284,915	285,440	286,115	
Average Selling Price	$3.00	$3.00	$3.00	$3.00	$3.00
Revenue ($M)	1.6	1.6	1.6	2.0	6.8

	1984 1st Qtr.	1984 2nd Qtr.	1984 3rd Qtr.	1984 4th Qtr.	1984 Year
Market Share					
North America	81.0%	90.5%	90.5%	92.6%	88.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	19.0	9.5	9.5	7.4	11.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 4K Dynamic RAM Shipments
(Thousands of Units)

Company	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
AMD	0	0	0	0	0
AMI	0	0	0	0	0
Fairchild	0	0	0	0	0
Fujitsu	0	0	0	0	0
Hitachi	0	0	0	0	0
Intel	0	0	0	0	0
Intersil	0	0	0	0	0
Mostek	500	400	500	500	1,900
Motorola	0	0	0	0	0
National	0	0	0	0	0
NEC	0	0	0	0	0
SGS-Ates	50	0	0	0	50
Signetics	0	0	0	0	0
STC (ITT)	100	100	100	100	400
Texas Instruments	0	0	0	0	0
Total	650	500	600	600	2,350
Percentage Change from Previous Quarter	(4%)	(23%)	20%	0%	
Cumulative Total	286,765	287,265	287,865	288,465	
Average Selling Price	$3.00	$3.50	$4.00	$4.50	$3.74
Revenue ($M)	2.0	1.8	2.4	2.7	8.8

	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
Market Share					
North America	92.3%	100.0%	100.0%	100.0%	97.9%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	7.7	0.0	0.0	0.0	2.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

Table 2

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1976				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
Eurotechnique					
Fairchild					
Fujitsu					
Hitachi					
Intel			0	20	20
Intersil					
Matsushita					
Mitsubishi					
Mostek			5	25	30
Motorola					
National					
NEC					
SGS-Ates					
Siemens					
Signetics					
STC (ITT)					
Texas Instruments				4	4
Toshiba					
Zilog	—	—	—	—	—
Total	0	0	5	49	59

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Percent Change from Previous Quarter				880%	
Cumulative Total	0	0	5	54	
Average Selling Price			$60.00	$45.00	$46.39
Revenue ($M)	0.0	0.0	0.3	2.2	2.5

	1976				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America			100.0%	100.0%	100.0%
Japan			0.0	0.0	0.0
Europe			0.0	0.0	0.0
Total			100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3–Power–Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1977 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD					
Eurotechnique					
Fairchild				25	25
Fujitsu		15	70	175	260
Hitachi				S	S
Intel	55	120	160	225	560
Intersil					
Matsushita					
Mitsubishi				S	S
Mostek	80	160	170	350	760
Motorola			S	50	50
National				S	S
NEC		15	70	225	310
SGS-Ates					
Siemens					
Signetics				S	S
STC (ITT)				S	S
Texas Instruments	3	0	0	40	43
Toshiba					
Zilog				S	S
Total	138	310	470	1,090	2,008
Percent Change from Previous Quarter	182%	125%	52%	132%	
Cumulative Total	192	502	972	2,062	
Average Selling Price	$35.00	$22.00	$20.00	$15.00	$18.63
Revenue ($M)	4.8	6.8	9.4	16.4	37.4

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1977				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	100.0%	90.3%	70.2%	63.3%	71.6%
Japan	0.0	9.7	29.8	36.7	28.4
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1978				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD				S	S
Eurotechnique					
Fairchild	25	40	200	200	465
Fujitsu	250	350	500	900	2,000
Hitachi	120	240	350	500	1,210
Intel	400	500	600	900	2,400
Intersil				S	S
Matsushita	0	0	0	0	0
Mitsubishi					
Mostek	700	1,000	1,400	1,800	4,900
Motorola	200	500	550	500	1,750
National	12	50	75	150	287
NEC	650	800	1,100	1,300	3,850
SGS-Ates					
Siemens	5	15	25	40	85
Signetics	S	30	30	80	140
STC (ITT)	3	25	75	100	203
Texas Instruments	300	500	950	1,400	3,150
Toshiba	20	35	80	150	285
Zilog	10	15	15	20	60
Total	2,695	4,100	5,950	8,040	20,785
Percent Change from Previous Quarter	147%	52%	45%	35%	
Cumulative Total	4,757	8,857	14,807	22,847	
Average Selling Price	$12.00	$10.00	$8.00	$7.00	$8.53
Revenue ($M)	32.3	41.0	47.6	56.3	177.2

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1978				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	61.2%	64.9%	65.5%	64.1%	64.3%
Japan	38.6	34.8	34.1	35.4	35.3
Europe	0.2	0.4	0.4	0.5	0.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1979				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	5	5	10	50	65
Eurotechnique					
Fairchild	300	400	500	700	1,900
Fujitsu	1,100	1,300	1,600	2,500	6,500
Hitachi	800	1,400	2,200	2,700	7,100
Intel	600	700	900	900	3,100
Intersil	5	5	5	0	10
Matsushita	0	0	0	0	0
Mitsubishi	100	200	400	550	1,250
Mostek	2,400	3,600	4,800	6,000	16,800
Motorola	700	1,200	1,000	1,800	4,700
National	250	450	1,000	1,500	3,200
NEC	1,700	2,200	3,200	4,200	11,300
SGS-Ates				3	3
Siemens	100	150	250	375	875
Signetics	75	40	50	10	175
STC (ITT)	200	300	600	600	1,700
Texas Instruments	1,800	2,200	1,800	3,200	9,000
Toshiba	150	350	450	1,050	2,000
Zilog	20	50	50	70	190
Total	10,295	14,550	18,815	26,208	69,868
Percent Change from Previous Quarter	28%	41%	29%	39%	
Cumulative Total	33,142	47,692	66,507	92,715	
Average Selling Price	$6.50	$6.25	$6.00	$5.75	$6.03
Revenue ($M)	66.9	90.9	112.9	150.7	421.4

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1979				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	61.6%	61.5%	56.9%	56.6%	58.5%
Japan	37.4	37.5	41.7	42.0	40.3
Europe	1.0	1.0	1.3	1.4	1.3
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	300	700	700	1,600	3,300
Eurotechnique					
Fairchild	800	1,000	1,000	800	3,600
Fujitsu	4,500	6,000	5,800	6,200	22,500
Hitachi	3,200	3,700	3,700	3,700	14,300
Intel	1,000	1,000	700	1,100	3,800
Intersil	0	0	0	0	0
Matsushita	5	100	100	100	305
Mitsubishi	700	1,100	1,100	1,100	4,000
Mostek	7,400	10,500	9,500	8,500	35,900
Motorola	3,000	3,000	2,500	2,500	11,000
National	3,500	4,800	5,800	6,000	20,100
NEC	6,100	7,500	6,700	5,900	26,200
SGS-Ates	10	30	50	60	150
Siemens	600	750	800	800	2,950
Signetics	0	0	0	0	0
STC (ITT)	750	1,050	1,200	1,500	4,500
Texas Instruments	4,200	5,200	5,700	6,600	21,700
Toshiba	1,700	2,000	2,300	2,600	8,600
Zilog	0	0	0	50	50
Total	37,765	48,430	47,650	49,110	182,955
Percent Change from Previous Quarter	44%	28%	(2%)	3%	
Cumulative Total	130,480	178,910	226,560	275,670	
Average Selling Price	$5.50	$5.25	$4.50	$4.00	$4.77
Revenue ($M)	207.7	254.3	214.4	196.4	872.8

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	55.5%	56.3%	56.9%	58.3%	56.8%
Japan	42.9	42.1	41.3	39.9	41.5
Europe	1.6	1.6	1.8	1.8	1.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1981				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,900	2,200	3,000	4,800	11,900
Eurotechnique		S	100	600	700
Fairchild	800	800	800	900	3,300
Fujitsu	6,800	7,300	7,600	7,400	29,100
Hitachi	3,600	3,750	3,600	1,900	12,850
Intel	900	1,400	1,400	1,500	5,200
Intersil	0	0	0	0	0
Matsushita	120	100	250	250	720
Mitsubishi	500	900	1,250	1,250	3,900
Mostek	8,900	11,100	9,990	9,000	38,990
Motorola	1,970	2,160	2,350	2,650	9,130
National	5,500	5,990	6,400	7,000	24,890
NEC	6,300	7,100	7,900	9,000	30,300
SGS-Ates	20	20	15	25	80
Siemens	800	850	900	1,500	4,050
Signetics	0	0	0	0	0
STC (ITT)	1,600	1,800	2,000	3,000	8,400
Texas Instruments	6,300	6,600	6,800	6,000	25,700
Toshiba	1,750	1,650	1,550	1,600	6,550
Zilog	0	0	0	0	0
Total	47,760	53,720	55,905	58,375	215,760
Percent Change from Previous Quarter	(3%)	12%	4%	4%	
Cumulative Total	323,430	377,150	433,055	491,430	
Average Selling Price	$3.15	$2.25	$1.65	$1.40	$2.06
Revenue ($M)	150.4	120.9	92.2	81.7	445.3

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1981 1st Qtr.	1981 2nd Qtr.	1981 3rd Qtr.	1981 4th Qtr.	1981 Year
Market Share					
North America	58.4%	59.7%	58.6%	59.7%	59.1%
Japan	39.9	38.7	39.6	36.7	38.7
Europe	1.7	1.6	1.8	3.6	2.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1982				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	4,400	4,700	4,700	5,000	18,800
Eurotechnique	900	1,200	1,300	1,400	4,800
Fairchild	900	900	750	700	3,250
Fujitsu	6,800	6,250	5,400	4,800	23,250
Hitachi	4,000	4,000	4,000	3,500	15,500
Intel	1,500	1,500	1,500	1,500	6,000
Intersil	0	0	0	0	0
Matsushita	250	250	100	100	700
Mitsubishi	500	450	800	500	2,250
Mostek	9,000	9,000	9,400	8,900	36,300
Motorola	3,015	3,190	4,550	3,600	14,355
National	8,995	9,500	9,500	8,300	36,295
NEC	10,000	10,000	10,000	10,000	40,000
SGS-Ates	50	50	35	15	150
Siemens	1,700	2,200	2,800	2,800	9,500
Signetics	0	0	0	0	0
STC (ITT)	2,800	3,200	5,100	6,300	17,400
Texas Instruments	6,500	7,000	7,000	7,000	27,500
Toshiba	1,500	1,700	1,800	2,000	7,000
Zilog	0	0	0	0	0
Total	62,810	65,090	68,735	66,415	263,050
Percent Change from Previous Quarter	8%	4%	6%	(3%)	
Cumulative Total	554,240	619,330	688,065	754,480	
Average Selling Price	$1.35	$1.30	$1.20	$1.10	$1.24
Revenue ($M)	84.8	84.6	82.5	73.1	324.9

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1982				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	59.1%	59.9%	61.8%	62.2%	60.8%
Japan	36.7	34.8	32.2	31.5	33.7
Europe	4.2	5.3	6.0	6.3	5.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments (Thousands of Units)

	1983				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	5,100	5,800	5,200	4,000	20,100
Eurotechnique	1,800	2,000	2,500	2,500	8,800
Fairchild	600	400	300	300	1,600
Fujitsu	4,000	3,500	2,500	2,500	12,500
Hitachi	3,000	3,000	3,500	3,500	13,000
Intel	1,500	1,000	1,000	1,000	4,500
Intersil	0	0	0	0	0
Matsushita	100	50	50	0	200
Mitsubishi	400	240	200	150	990
Mostek	4,300	5,500	4,500	3,500	17,800
Motorola	3,800	3,600	4,100	3,500	15,000
National	4,500	6,000	5,000	4,500	20,000
NEC	9,800	9,500	11,000	10,000	40,300
SGS-Ates	20	100	150	50	320
Siemens	3,000	3,000	3,000	3,000	12,000
Signetics	0	0	0	0	0
STC (ITT)	5,600	6,200	6,200	5,500	23,500
Texas Instruments	7,000	12,000	10,000	9,500	38,500
Toshiba	2,400	3,000	2,500	2,200	10,100
Zilog	0	0	0	0	0
Total	56,920	64,890	61,700	55,700	239,210
Percent Change from Previous Quarter	(14%)	14%	(5%)	(10%)	
Cumulative Total	811,400	876,290	937,990	993,690	
Average Selling Price	$1.15	$1.10	$1.00	$0.95	$1.05
Revenue ($M)	65.5	71.4	61.7	52.9	251.5

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1983				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	56.9%	62.4%	58.8%	57.1%	58.9%
Japan	34.6	29.7	32.0	32.9	32.2
Europe	8.5	7.9	9.2	10.0	8.8
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1984				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	2,500	2,500	2,000	1,500	8,500
Eurotechnique	2,000	2,000	1,200	1,000	6,200
Fairchild	200	100	0	0	300
Fujitsu	2,000	1,800	1,000	800	5,600
Hitachi	3,000	3,000	1,200	800	8,000
Intel	800	500	350	0	1,650
Intersil	0	0	0	0	0
Matsushita	0	0	0	0	0
Mitsubishi	170	170	0	0	340
Mostek	2,500	1,500	1,000	1,000	6,000
Motorola	3,000	2,500	1,600	1,200	8,300
National	3,500	2,500	1,200	1,200	8,400
NEC	8,000	6,000	4,200	2,500	20,700
SGS-Ates	0	0	0	0	0
Siemens	3,000	3,000	1,500	1,200	8,700
Signetics	0	0	0	0	0
STC (ITT)	4,000	3,500	2,200	1,500	11,200
Texas Instruments	8,000	6,500	4,000	2,500	21,000
Toshiba	1,800	1,600	1,200	1,200	5,800
Zilog	0	0	0	0	0
Total	44,470	37,170	22,650	16,400	120,690
Percent Change from Previous Quarter	(81%)	(16%)	(39%)	(28%)	
Cumulative Total	1,038,160	1,075,330	1,097,980	1,114,380	
Average Selling Price	$1.00	$1.10	$1.15	$1.20	$1.09
Revenue ($M)	44.5	40.9	26.0	19.7	131.1

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1984				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	46.1%	43.3%	44.8%	45.1%	44.9%
Japan	33.7	33.8	33.6	32.3	33.5
Europe	20.2	22.9	21.6	22.6	21.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1985				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	1,250	1,100	1,100	1,100	4,550
Eurotechnique	1,200	1,200	1,200	1,200	4,800
Fairchild					
Fujitsu	500	250	300	300	1,350
Hitachi	500	200	400	400	1,500
Intel					
Intersil					
Matsushita					
Mitsubishi					
Mostek	800	700	600	400	2,500
Motorola	1,000	800	600	400	2,800
National	1,200	1,200	1,500	1,200	5,100
NEC	2,100	1,800	1,500	620	6,020
SGS-Ates					
Siemens	2,500	2,000	2,000	1,500	8,000
Signetics					
STC (ITT)	1,800	2,000	1,500	1,200	6,500
Texas Instruments	2,200	2,000	0	0	4,200
Toshiba	1,000	800	600	250	2,650
Zilog					
Total	16,050	14,050	11,300	8,570	49,970
Percent Change from Previous Quarter	(2%)	(12%)	(20%)	(24%)	
Cumulative Total	1,130,430	1,144,480	1,155,780	1,164,350	
Average Selling Price	$1.25	$1.30	$1.35	$1.45	$1.32
Revenue ($M)	20.1	18.3	15.3	12.4	66.0

(Continued)

Table 2 (Continued)

Estimated Worldwide 3-Power-Supply MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	40.2%	41.3%	33.6%	36.2%	38.3%
Japan	25.5	21.7	24.8	18.3	23.1
Europe	34.3	37.0	41.6	45.5	38.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

Table 3

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments (Thousands of Units)

	1979				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu					
Hitachi					
Intel	S	10	50	90	150
Mostek					
Motorola					
National					
Texas Instruments	—	—	—	—	—
Total	0	10	50	90	150
Percentage Change from Previous Quarter			400%	80%	
Cumulative Total	0	10	60	150	
Average Selling Price	$40.00	$30.00	$20.00	$15.00	$17.67
Revenue ($M)	0.0	0.3	1.0	1.4	2.7

	1979				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	100.0%	100.0%	100.0%	100.0%	100.0%
Japan	0.0	0.0	0.0	0.0	0.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1980 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu				S	S
Hitachi			15	30	45
Intel	150	200	300	400	1,050
Mostek				S	S
Motorola			5	15	20
National				S	S
Texas Instruments				S	S
Total	150	200	320	445	1,115
Percentage Change from Previous Quarter	67%	33%	60%	39%	
Cumulative Total	300	500	820	1,265	
Average Selling Price	$10.00	$8.00	$7.00	$6.50	$7.38
Revenue ($M)	1.5	1.6	2.2	2.9	8.2

	1980 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	100.0%	100.0%	95.3%	93.3%	96.0%
Japan	0.0	0.0	4.7	6.7	4.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1981				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	S	10	80	150	240
Hitachi	100	250	400	600	1,350
Intel	600	800	1,100	1,300	3,800
Mostek	0	S	10	100	110
Motorola	30	40	50	60	180
National	S	10	5	5	20
Texas Instruments	0	S	3	10	13
Total	730	1,110	1,648	2,225	5,713
Percentage Change from Previous Quarter	64%	52%	48%	35%	
Cumulative Total	1,995	3,105	4,753	6,978	
Average Selling Price	$5.00	$4.50	$4.00	$3.00	$3.84
Revenue ($M)	3.7	5.0	6.6	6.7	21.9

	1981				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	86.3%	76.6%	70.9%	66.3%	72.2%
Japan	13.7	23.4	29.1	33.7	27.8
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	200	250	600	1,200	2,250
Hitachi	1,000	1,500	2,400	2,400	7,300
Intel	1,500	2,000	2,200	2,000	7,700
Mostek	500	1,200	1,200	1,700	4,600
Motorola	85	110	150	800	1,145
National	5	0	0	0	5
Texas Instruments	20	20	50	150	240
Total	3,310	5,080	6,600	8,250	23,240
Precentage Change from Previous Quarter	49%	53%	30%	25%	
Cumulative Total	10,288	15,368	21,968	30,218	
Average Selling Price	$2.70	$2.50	$2.25	$1.85	$2.23
Revenue ($M)	8.9	12.7	14.9	15.3	51.7

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	63.7%	65.6%	54.5%	56.4%	58.9%
Japan	36.3	34.4	45.5	43.6	41.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	1,500	2,000	3,000	3,000	9,500
Hitachi	3,000	3,500	3,500	3,500	13,500
Intel	2,000	1,700	1,500	1,500	6,700
Mostek	3,000	2,800	3,500	4,500	13,800
Motorola	2,200	3,300	4,000	3,000	12,500
National	0	0	0	0	0
Texas Instruments	250	350	400	400	1,400
Total	11,950	13,650	15,900	15,900	57,400
Percentage Change from Previous Quarter	45%	14%	16%	0%	
Cumulative Total	42,168	55,818	71,718	87,618	
Average Selling Price	$1.75	$1.85	$2.00	$2.25	$1.98
Revenue ($M)	20.9	25.3	31.8	35.8	113.7

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	62.3%	59.7%	59.1%	59.1%	59.9%
Japan	37.7	40.3	40.9	40.9	40.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

Company	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitu	3,000	2,500	2,000	1,500	9,000
Hitachi	3,000	2,000	2,000	1,500	8,500
Intel	1,500	1,500	1,200	800	5,000
Mostek	2,000	1,500	1,700	900	6,100
Motorola	1,600	2,500	3,200	3,500	10,800
National	0	0	0	0	0
Texas Instruments	500	500	200	0	1,200
Total	11,600	10,500	10,300	8,200	40,600
Percentage Change from Previous Quarter	(27%)	(9%)	(2%)	(20%)	
Cumulative Total	99,218	109,718	120,018	128,218	
Average Selling Price	$2.10	$2.10	$2.10	$1.95	$2.07
Revenue ($M)	24.4	22.1	21.6	16.0	84.0

	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	48.3%	57.1%	61.2%	63.4%	56.9%
Japan	51.7	42.9	38.8	36.6	43.1
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide 5-Volt MOS 16K Dynamic RAM Shipments
(Thousands of Units)

	1985				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitu	800	500	500	400	2,200
Hitachi	1,500	1,200	1,000	800	4,500
Intel	600	500	250	100	1,450
Mostek	600	500	500	500	2,100
Motorola	3,200	3,000	2,500	2,000	10,700
National	0	0	0	0	0
Texas Instruments	0	0	0	0	0
Total	6,700	5,700	4,750	3,800	20,950
Percentage Change from Previous Quarter	(18%)	(15%)	(17%)	(20%)	
Cumulative Total	134,918	140,618	145,368	149,168	
Average Selling Price	$1.65	$1.55	$1.60	$1.70	$1.62
Revenue ($M)	11.1	8.8	7.6	6.5	34.0

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	65.7%	70.2%	68.4%	68.4%	68.0%
Japan	34.3	29.8	31.6	31.6	32.0
Europe	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

Table 4

Estimated Worldwide MOS 64K Dynamic RAM Shipments (Thousands of Units)

		1978				
Company	MOS Process/ Organization	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD						
Fairchild						
Fujitsu	64Kx1		S	S	S	S
	16Kx4					
	CMOS 8Kx8					
Hitachi	64Kx1					
	16Kx4					
Inmos	64Kx1					
	16Kx4					
	8Kx8					
Intel	64Kx1					
	CMOS 64Kx1					
Matsushita	64Kx1					
	16Kx4					
	8Kx8					
Micron Technology						
Mitsubishi	64Kx1					
	16Kx4					
Mostek						
Motorola						
National						
NEC	64Kx1					
	CMOS 64Kx1					
	16Kx4					
Oki Electric						
Samsung						
Sharp						
Siemens						
STC (ITT)						
Texas Instruments	64Kx1				S	S
	16Kx4					
Toshiba						
Vitelic	CMOS 64Kx1	—	—	—	—	—
Total		0	0	0	0	0

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1978 1st Qtr.	1978 2nd Qtr.	1978 3rd Qtr.	1978 4th Qtr.	1978 Year
Percent Change from Previous Quarter					
Cumulative Total	0	0	0	0	
Average Selling Price		$200.00	$175.00	$150.00	$150.00
Revenue ($M)	0.0	0.0	0.0	0.0	0.0

	1978 1st Qtr.	1978 2nd Qtr.	1978 3rd Qtr.	1978 4th Qtr.	1978 Year
Market Share					
North America		0.0	0.0	0.0	0.0
Japan		100.0%	100.0%	100.0%	100.0%
Europe		0.0	0.0	0.0	0.0
Asia Pacific		0.0	0.0	0.0	0.0
Total		100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/	Organization	1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD							
Fairchild							
Fujitsu		64Kx1	3	5	7	9	24
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1				S	S
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1					
	CMOS	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1				S	S
		16Kx4					
Mostek							
Motorola			S	1	3	6	10
National							
NEC		64Kx1					
	CMOS	64Kx1					
		16Kx4					
Oki Electric							
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1	S	S	1	1	2
		16Kx4					
Toshiba							
Vitelic	X	64Kx1	_	_	_	_	_
Total			3	6	11	16	36

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter		100%	83%	45%	
Cumulative Total	3	9	20	36	
Average Selling Price	$135.00	$125.00	$110.00	$100.00	$110.14
Revenue ($M)	0.4	0.8	1.2	1.6	4.0

	1979 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	0.0	16.7%	36.4%	43.8%	33.3%
Japan	100.0%	83.3	63.6	56.3	66.7
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.1%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1980 1st Qtr.	1980 2nd Qtr.	1980 3rd Qtr.	1980 4th Qtr.	1980 Year
AMD							
Fairchild							
Fujitsu		64Kx1	10	25	30	65	130
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	S	10	35	60	105
		16Kx4					
Inmos		64Kx1					
		16Kx4					
		8Kx8					
Intel		64Kx1		S	S	3	3
	CMOS	64Kx1					
Matsushita		64Kx1					
		16Kx4					
		8Kx8					
Micron Technology							
Mitsubishi		64Kx1	S	S	2	15	17
		16Kx4					
Mostek							
Motorola			10	30	40	70	150
National		-				S	S
NEC		64Kx1			S	5	5
	CMOS	64Kx1					
		16Kx4					
Oki Electric						S	S
Samsung							
Sharp							
Siemens							
STC (ITT)							
Texas Instruments		64Kx1	1	3	5	15	24
		16Kx4					
Toshiba			S	S	2	5	7
Vitelic	CMOS	64Kx1					
Total			21	68	114	238	441

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1980				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	31%	224%	68%	109%	
Cumulative Total	57	125	239	477	
Average Selling Price	$90.00	$75.00	$55.00	$30.00	$46.26
Revenue ($M)	1.9	5.1	6.3	7.1	20.4

	1980				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	52.4%	48.5%	39.5%	37.0%	40.1%
Japan	47.6	51.5	60.5	63.0	59.9
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1981 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD							
Fairchild						S	S
Fujitsu		64Kx1	110	360	550	900	1,920
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	200	700	1,100	1,900	3,900
		16Kx4					
Inmos		64Kx1				S	S
		16Kx4					
		8Kx8					
Intel		64Kx1	5	10	10	5	30
	CMOS	64Kx1					
Matsushita		64Kx1				S	S
		16Kx4					
		8Kx8					
Micron Technology						S	S
Mitsubishi		64Kx1	36	70	320	640	1,066
		16Kx4					
Mostek			S	10	30	100	140
Motorola			125	350	700	800	1,975
National			S	S	S	S	S
NEC		64Kx1	50	100	300	1,000	1,450
	CMOS	64Kx1					
		16Kx4					
Oki Electric			5	30	100	600	735
Samsung							
Sharp							
Siemens						S	S
STC (ITT)							
Texas Instruments		64Kx1	35	130	370	800	1,335
		16Kx4					
Toshiba			10	20	20	30	80
Vitelic	CMOS	64Kx1					
Total			576	1,780	3,500	6,775	12,631

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1981 1st Qtr.	1981 2nd Qtr.	1981 3rd Qtr.	1981 4th Qtr.	1981 Year
Percent Change from Previous Quarter	142%	209%	97%	94%	
Cumulative Total	1,053	2,833	6,333	13,108	
Average Selling Price	$22.00	$15.00	$12.00	$8.50	$11.00
Revenue ($M)	12.7	26.7	42.0	57.6	139.0

	1981 1st Qtr.	1981 2nd Qtr.	1981 3rd Qtr.	1981 4th Qtr.	1981 Year
Market Share					
North America	28.6%	28.1%	31.7%	25.2%	27.6%
Japan	71.4	71.9	68.3	74.8	72.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD						S	S
Fairchild			S	S	10	5	15
Fujitsu		64Kx1	2,000	3,500	4,700	6,300	16,500
		16Kx4					
	CMOS	8Kx8					
Hitachi		64Kx1	2,500	3,600	5,400	6,800	18,300
		16Kx4					
Inmos		64Kx1	5	10	20	75	110
		16Kx4					
		8Kx8					
Intel		64Kx1	5	100	350	1,100	1,555
	CMOS	64Kx1					
Matsushita		64Kx1	S	S	10	20	30
		16Kx4					
		8Kx8					
Micron Technology			20	150	450	600	1,200
Mitsubishi		64Kx1	1,300	1,800	3,200	5,500	11,800
		16Kx4					
Mostek			450	650	1,700	3,200	6,000
Motorola			1,100	2,300	3,100	4,600	11,100
National			S	S	0	0	S
NEC		64Kx1	2,200	2,700	4,500	5,500	14,900
	CMOS	64Kx1					
		16Kx4					
Oki Electric			1,150	1,770	2,500	1,200	6,620
Samsung							
Sharp							
Siemens			5	25	75	200	305
STC (ITT)						S	S
Texas Instruments		64Kx1	1,700	3,400	4,000	4,800	13,900
		16Kx4		S	200	500	700
Toshiba			30	80	200	600	910
Vitelic	CMOS	64Kx1					
Total			12,465	20,085	30,415	41,000	103,965

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	84%	61%	51%	35%	
Cumulative Total	25,573	45,658	76,073	117,073	
Average Selling Price	$6.50	$6.00	$5.50	$4.75	$5.42
Revenue ($M)	81.0	120.5	167.3	194.8	563.6

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	26.3%	32.9%	32.3%	36.1%	33.2%
Japan	73.6	67.0	67.4	63.2	66.4
Europe	0.1	0.2	0.3	0.7	0.4
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.1%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			S	10	100	250	360
Fairchild			0	0	0	S	S
Fujitsu		64Kx1	7,500	9,200	11,200	11,500	39,400
		16Kx4	S	100	300	1,000	1,400
	CMOS	8Kx8				S	S
Hitachi		64Kx1	11,000	14,500	16,500	18,500	60,500
		16Kx4			S	S	S
Inmos		64Kx1	150	350	625	1,400	2,525
		16Kx4	S	50	250	600	900
		8Kx8		S	25	100	125
Intel		64Kx1	1,800	2,600	3,500	5,000	12,900
	CMOS	64Kx1			S	S	S
Matsushita		64Kx1	80	400	1,800	3,000	5,280
		16Kx4					
		8Kx8					
Micron Technology			950	1,500	2,500	4,000	8,950
Mitsubishi		64Kx1	6,800	7,000	8,900	10,800	33,500
		16Kx4					
Mostek			4,000	8,500	12,300	16,200	41,000
Motorola			4,000	6,300	8,900	12,000	31,200
National			0	S	10	150	160
NEC		64Kx1	8,500	12,000	15,000	18,000	53,500
	CMOS	64Kx1				S	S
		16Kx4					
Oki Electric			2,200	4,000	6,500	8,000	20,700
Samsung							
Sharp						S	S
Siemens			350	500	1,000	2,000	3,850
STC (ITT)			15	75	100	100	290
Texas Instruments		64Kx1	7,400	8,500	9,000	13,700	38,600
		16Kx4	600	1,500	3,000	3,000	8,100
Toshiba			1,000	1,500	2,600	3,000	8,100
Vitelic	CMOS	64Kx1					
Total			56,345	78,585	104,110	132,300	371,340

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	37%	39%	32%	27%	
Cumulative Total	173,418	252,003	356,113	488,413	
Average Selling Price	$4.00	$3.75	$3.80	$3.90	$3.86
Revenue ($M)	225.4	294.7	395.6	516.0	1,431.7

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	33.3%	36.9%	37.9%	41.1%	38.1%
Japan	65.8	62.0	60.3	55.8	59.9
Europe	0.9	1.1	1.8	3.1	2.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD			500	1,000	1,500	3,000	6,000
Fairchild			10	25	0	0	35
Fujitsu		64Kx1	14,500	18,000	25,000	28,500	86,000
		16Kx4	1,500	2,000	2,500	3,000	9,000
	CMOS	8Kx8	S	10	10	25	45
Hitachi		64Kx1	22,300	25,500	27,500	28,000	103,300
		16Kx4	10	25	150	300	485
Inmos		64Kx1	2,000	2,200	2,500	2,500	9,200
		16Kx4	800	1,200	1,800	1,500	5,300
		8Kx8	250	350	400	250	1,250
Intel		64Kx1	5,000	4,000	3,000	1,600	13,600
	CMOS	64Kx1	50	150	200	200	600
Matsushita		64Kx1	4,200	6,000	8,000	7,000	25,200
		16Kx4	S	10	100	350	460
		8Kx8		S	5	20	25
Micron Technology			6,200	9,300	14,000	19,200	48,700
Mitsubishi		64Kx1	13,500	18,400	24,000	26,000	81,900
		16Kx4	S	100	1,000	1,500	2,600
Mostek			15,000	17,000	20,000	21,500	73,500
Motorola			11,000	13,100	18,000	18,700	60,800
National			500	1,200	2,500	3,500	7,700
NEC		64Kx1	21,100	23,600	27,000	30,000	101,700
	CMOS	64Kx1	50	150	850	1,250	2,300
		16Kx4				S	S
Oki Electric			11,000	13,500	16,000	18,500	59,000
Samsung				S	S	1,500	1,500
Sharp			50	150	500	1,000	1,700
Siemens			3,000	4,000	4,000	4,500	15,500
STC (ITT)			200	400	600	1,000	2,200
Texas Instruments		64Kx1	17,000	22,000	25,500	24,000	88,500
		16Kx4	3,500	4,000	5,600	7,000	20,100
Toshiba			4,500	4,700	5,200	9,000	23,400
Vitelic	CMOS	64Kx1				S	S
Total			157,720	192,070	237,415	264,395	851,600

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	19%	22%	24%	11%	-
Cumulative Total	646,133	838,203	1,075,618	1,340,013	
Average Selling Price	$3.50	$3.40	$3.15	$2.80	$3.16
Revenue ($M)	552.0	653.0	747.9	740.3	2,693.2

	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	37.3%	37.4%	38.0%	37.3%	37.5%
Japan	58.8	58.4	58.0	58.4	58.4
Europe	4.0	4.2	3.9	3.7	3.9
Asia Pacific	0.0	0.0	0.0	0.6	0.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1	2,000	1,000	1,000	1,000	5,000
Fairchild			0	0	0	0	0
Fujitsu	NMOS	64Kx1	19,000	18,000	10,000	8,500	55,500
	NMOS	16Kx4	2,200	1,500	1,200	1,000	5,900
	CMOS	8Kx8	25	25	10	0	60
Hitachi	NMOS	64Kx1	20,000	17,500	14,000	13,500	65,000
	NMOS	16Kx4	500	700	1,000	1,250	3,450
Inmos	NMOS	64Kx1	2,500	2,200	2,000	2,100	8,800
	NMOS	16Kx4	800	500	400	500	2,200
	NMOS	8Kx8	50	40	20	0	110
Intel	NMOS	64Kx1	500	0	0	0	500
	CMOS	64Kx1	250	250	200	100	800
Matsushita	NMOS	64Kx1	3,000	2,000	1,500	1,200	7,700
	NMOS	16Kx4	400	300	200	150	1,050
	NMOS	8Kx8	100	150	100	80	430
Micron Technology	NMOS		12,500	12,000	6,000	2,800	33,300
Mitsubishi	NMOS	64Kx1	15,000	15,000	12,500	13,500	56,000
	NMOS	16Kx4	1,000	800	650	850	3,300
Mostek	NMOS		8,000	10,000	7,500	5,000	30,500
Motorola	NMOS		10,000	12,000	5,000	3,500	30,500
National	NMOS		2,500	1,500	1,200	500	5,700
NEC	NMOS	64Kx1	22,500	18,000	14,400	7,520	62,420
	CMOS	64Kx1	800	350	40	0	1,190
	NMOS	16Kx4	150	500	1,630	1,820	4,100
Oki Electric	NMOS		7,500	8,000	5,500	5,000	26,000
Samsung	NMOS		3,000	6,000	5,500	5,500	20,000
Sharp	NMOS		500	500	250	0	1,250
Siemens	NMOS		3,500	2,500	2,000	2,000	10,000
STC (ITT)	NMOS		500	400	400	400	1,700
Texas Instruments	NMOS	64Kx1	13,000	10,000	7,000	6,000	36,000
	NMOS	16Kx4	3,500	4,000	3,200	2,500	13,200
Toshiba	NMOS		6,000	4,000	4,000	4,000	18,000
Vitelic	CMOS	64Kx1	S	S	S	10	10
Total			161,275	149,715	108,400	90,280	509,670

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
Percent Change from Previous Quarter	(39%)	(7%)	(28%)	(17%)	
Cumulative Total	1,501,288	1,651,003	1,759,403	1,849,683	
Average Selling Price	$1.65	$1.10	$0.75	$0.85	$1.16
Revenue ($M)	266.1	164.7	81.3	76.7	588.8

	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
Market Share					
North America	32.4%	33.9%	28.7%	23.7%	30.5%
Japan	61.2	58.3	61.8	64.7	61.1
Europe	4.6	3.8	4.4	5.5	4.5
Asia Pacific	1.9	4.0	5.1	6.1	3.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1	700	500	500	500	2,200
Fairchild							0
Fujitsu	NMOS	64Kx1	8,000	7,000	6,000	5,000	26,000
	NMOS	16Kx4	1,000	1,000	1,000	1,000	4,000
	CMOS	8Kx8	0	0	0	0	0
Hitachi	NMOS	64Kx1	14,000	10,000	8,000	5,000	37,000
	NMOS	16Kx4	1,250	1,000	1,000	500	3,750
Inmos	NMOS	64Kx1	1,800	1,700	1,500	1,200	6,200
	NMOS	16Kx4	500	500	500	500	2,000
	NMOS	8Kx8	0	0	0	0	0
Intel	NMOS	64Kx1	0	0	0	0	0
	CMOS	64Kx1	200	200	100	100	600
Matsushita	NMOS	64Kx1	2,000	2,500	2,500	2,500	9,500
	NMOS	16Kx4	700	1,000	1,300	1,500	4,500
	NMOS	8Kx8	500	1,000	1,500	2,500	5,500
Micron Technology	NMOS	64Kx1	4,000	4,500	5,000	4,500	18,000
Mitsubishi	NMOS	64Kx1	20,000	18,000	12,000	4,500	54,500
	NMOS	16Kx4	3,300	1,600	4,000	2,300	11,200
Mostek	NMOS	64Kx1	3,000	2,000	1,000	1,000	7,000
Motorola	NMOS	64Kx1	1,362	1,141	1,718	1,055	5,276
National	NMOS	64Kx1	500	500	500	500	2,000
NEC	NMOS	64Kx1	14,930	15,560	6,290	5,800	42,580
	CMOS	64Kx1	0	0	0	0	0
	NMOS	16Kx4	1,880	2,690	4,080	5,200	13,850
Oki Electric	NMOS	64Kx1	5,000	5,000	5,000	4,000	19,000
Samsung	NMOS	64Kx1	8,000	10,000	10,000	10,000	38,000
Sharp	NMOS	64Kx1	700	500	500	500	2,200
Siemens	NMOS	64Kx1	2,500	2,500	2,500	2,500	10,000
STC (ITT)	NMOS	64Kx1	500	400	400	400	1,700
Texas	NMOS	64Kx1	6,000	6,000	6,000	5,000	23,000
Instruments	NMOS	16Kx4	3,000	3,000	2,500	2,500	11,000
Toshiba	NMOS	64Kx1	8,000	6,000	4,000	3,000	21,000
Vitelic	CMOS	64Kx1	50	100	150	200	500
Total			113,372	105,891	89,538	73,255	382,056

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	1986 1st Qtr.	1986 2nd Qtr.	1986 3rd Qtr.	1986 4th Qtr.	Year
Percent Change from Previous Quarter	26%	(7%)	(15%)	(18%)	
Cumulative Total	1,963,055	2,068,946	2,158,484	2,231,739	
Average Selling Price	$1.10	$1.05	$1.05	$0.90	$1.04
Revenue ($M)	124.7	111.2	94.0	65.9	395.8

	1986 1st Qtr.	1986 2nd Qtr.	1986 3rd Qtr.	1986 4th Qtr.	Year
Market Share					
North America	16.6%	16.9%	19.5%	21.0%	18.2%
Japan	71.7	68.8	63.8	59.1	66.6
Europe	4.7	4.8	5.5	6.3	5.2
Asia Pacific	7.1	9.4	11.2	13.7	9.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	NMOS	64Kx1					
Fairchild							
Fujitsu	NMOS	64Kx1	2,000	2,000	2,000	2,000	8,000
	NMOS	16Kx4	700	500	500	500	2,200
	CMOS	8Kx8	0				0
Hitachi	NMOS	64Kx1	2,000	1,000	1,000	1,000	5,000
	NMOS	16Kx4	500	500	500	500	2,000
Inmos	NMOS	64Kx1	600	300	100	100	1,100
	NMOS	16Kx4	200	100	50	50	400
	NMOS	8Kx8					0
Intel	NMOS	64Kx1					0
	CMOS	64Kx1					0
Matsushita	NMOS	64Kx1	1,500	850	500	200	3,050
	NMOS	16Kx4	500	403	300	100	1,303
	NMOS	8Kx8	500	447	350	130	1,427
Micron Technology	NMOS	64Kx1	2,500	2,000	1,800	1,500	7,800
Mitsubishi	NMOS	64Kx1	4,900	4,500	4,000	3,500	16,900
	NMOS	16Kx4	1,600	1,500	1,200	1,000	5,300
Mostek	NMOS	64Kx1	500	500	500	500	2,000
Motorola	NMOS	64Kx1	663	1,046	990	372	3,071
National	NMOS	64Kx1					
NEC	NMOS	64Kx1	8,020	4,350	4,650	2,850	19,870
	CMOS	64Kx1	0	100	30	0	130
	NMOS	16Kx4	1,510	0	1,150	70	2,730
Oki Electric	NMOS	64Kx1	4,000	3,000	3,000	2,000	12,000
Samsung	NMOS	64Kx1	8,000	7,000	6,000	5,000	26,000
Sharp	NMOS	64Kx1	500	500	500	500	2,000
Siemens	NMOS	64Kx1	2,000	2,000	1,500	1,500	7,000
STC (ITT)	NMOS	64Kx1	300	300	100	100	800
Texas Instruments	NMOS	64Kx1	3,000	3,000	2,800	2,800	11,600
	NMOS	16Kx4	1,500	1,500	1,200	1,200	5,400
Toshiba	NMOS	64Kx1	2,000	1,500	1,000	1,000	5,500
Vitelic	CMOS	64Kx1					
Total			49,493	38,896	35,720	28,472	152,581

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 64K Dynamic RAM Shipments
(Thousands of Units)

	1987				
Company	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	(32%)	(21%)	(8%)	(20%)	
Cumulative Total	2,281,232	2,320,128	2,355,848	2,384,320	
Average Selling Price	$0.99	$1.05	$1.15	$1.20	$1.08
Revenue ($M)	49.0	40.8	41.1	34.2	165.0

	1987				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	16.5%	20.7%	20.4%	22.4%	19.6%
Japan	61.1	54.4	57.9	53.9	57.3
Europe	6.3	6.9	4.9	6.1	6.1
Asia Pacific	16.2	18.0	16.8	17.6	17.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

Table 5

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1				S	S
Fujitsu	NMOS	256Kx1				S	S
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1			S	10	10
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron	NMOS	256Kx1					
Technology	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1					
	NMOS	64Kx4					
Mostek	NMOS	32Kx8					
	NMOS	256Kx1					
Motorola	NMOS	256Kx1					
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1					
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1				S	S
	NMOS	64Kx4					
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1					
Instruments	NMOS	64Kx4					
Toshiba	NMOS	256Kx1				S	S
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4	-	-	-	—	—
Total			0	0	0	10	10
Percent Change from Previous Quarter							
Cumulative Total			0	0	0	10	
Average Selling Price				$200.00	$150.00	$150.00	
Revenue ($M)			0.0	0.0	0.0	1.5	1.5

	1982 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America				0.0	0.0
Japan				100.0%	100.0%
Europe				0.0	0.0
Asia Pacific				0.0	0.0
Total				100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1	S	S	20	100	120
Fujitsu	NMOS	256Kx1	S	30	150	300	480
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1	25	50	175	400	650
	CMOS	256Kx1					
	NMOS	64Kx4					
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1					
	CMOS	64Kx4					
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron	NMOS	256Kx1					
Technology	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1		S	10	50	60
	NMOS	64Kx4					
Mostek	NMOS	32Kx8			S	5	5
	NMOS	256Kx1					
Motorola	NMOS	256Kx1		S	S	0	S
	CMOS	256Kx1					
National	NMOS	256Kx1					
NEC	NMOS	256Kx1	S	S	100	200	300
	NMOS	64Kx4					
	NMOS	32Kx8					
Oki Electric	NMOS	256Kx1	S	S	5	10	15
	NMOS	64Kx4					
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments (Thousands of Units)

Company	MOS Process/ Organization		1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas Instruments	NMOS	256Kx1			S	S	S
	NMOS	64Kx4					
Toshiba	NMOS	256Kx1	S	S	20	50	70
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			25	80	480	1,115	1,700
Percent Change from Previous Quarter				220%	500%	132%	
Cumulative Total			25	105	585	1,700	
Average Selling Price			$100.00	$80.00	$55.00	$41.00	$47.66
Revenue ($M)			2.5	6.4	26.4	45.7	81.0

	1983 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	0.0	0.0	4.2%	9.4%	7.4%
Japan	100.0%	100.0%	95.8	90.6	92.6
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

			1984				
Company	MOS Process/	Organization	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1	200	500	800	1,500	3,000
Fujitsu	NMOS	256Kx1	600	1,500	2,500	3,300	7,900
	NMOS	64Kx1					
	CMOS	256Kx1					
	CMOS	64Kx4					
Hitachi	NMOS	256Kx1	700	2,200	3,000	4,800	10,700
	CMOS	256Kx1					
	NMOS	64Kx4			S	5	5
Inmos	CMOS	256Kx1					
Intel	CMOS	256Kx1		S	S	20	20
	CMOS	64Kx4				S	S
Matsushita	NMOS	256Kx1					
	NMOS	64Kx4					
Micron	NMOS	256Kx1			S	20	20
Technology	NMOS	64Kx4					
Mitsubishi	NMOS	256Kx1	50	50	300	750	1,150
	NMOS	64Kx4					
Mostek	NMOS	32Kx8	15	35	40	60	150
	NMOS	256Kx1				S	S
Motorola	NMOS	256Kx1				S	S
	CMOS	256Kx1					
National	NMOS	256Kx1		S	S	10	10
NEC	NMOS	256Kx1	800	1,500	3,500	4,100	9,900
	NMOS	64Kx4	S	150	90	120	360
	NMOS	32Kx8			S	5	5
Oki Electric	NMOS	256Kx1	50	100	350	500	1,000
	NMOS	64Kx4					
Samsung	NMOS	256Kx1					
Sharp	NMOS	256Kx1					
	NMOS	64Kx4					
Siemens	NMOS	256Kx1					

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas Instruments	NMOS	256Kx1	10	25	50	75	160
	NMOS	64Kx4	S	S	S	S	S
Toshiba	NMOS	256Kx1	200	500	1,100	1,800	3,600
	NMOS	64Kx4					
Vitelic	CMOS	256Kx1					
	CMOS	64Kx4					
Total			2,625	6,560	11,730	17,065	37,980
Percent Change from Previous Quarter			135%	150%	79%	45%	
Cumulative Total			4,325	10,885	22,615	39,680	
Average Selling Price			$31.00	$23.50	$17.50	$14.00	$17.90
Revenue ($M)			81.4	154.2	205.3	238.9	679.7

	1984 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	8.6%	8.5%	7.6%	9.9%	8.8%
Japan	91.4	91.5	92.4	90.1	91.2
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1			S	S	S
AT&T Technologies	NMOS	256Kx1	1,600	2,200	3,500	5,000	12,300
Fujitsu	NMOS	256Kx1	3,700	5,600	8,500	13,000	30,800
	NMOS	64Kx1			S	25	25
	CMOS	256Kx1				S	S
	CMOS	64Kx4				S	S
Hitachi	NMOS	256Kx1	6,000	8,500	14,500	20,000	49,000
	CMOS	256Kx1	S	5	50	250	305
	NMOS	64Kx4	25	100	400	1,000	1,525
Inmos	CMOS	256Kx1	S	S	S	5	5
Intel	CMOS	256Kx1	200	400	600	750	1,950
	CMOS	64Kx4	10	100	600	1,100	1,810
Matsushita	NMOS	256Kx1	S	50	250	1,500	1,800
	NMOS	64Kx4					0
Micron	NMOS	256Kx1	20	10	400	1,500	1,930
Technology	NMOS	64Kx4		S	S	25	25
Mitsubishi	NMOS	256Kx1	900	1,800	3,200	5,500	11,400
	NMOS	64Kx4				S	S
Mostek	NMOS	32Kx8	50	50	50	25	175
	NMOS	256Kx1	S	25	25	25	75
Motorola	NMOS	256Kx1	S	5	0	0	5
	CMOS	256Kx1			S	S	S
National	NMOS	256Kx1	25	50	0	0	75
NEC	NMOS	256Kx1	4,650	6,500	13,750	16,780	41,680
	NMOS	64Kx4	420	600	260	80	1,360
	NMOS	32Kx8	10	150	250	450	860
Oki Electric	NMOS	256Kx1	600	800	1,200	2,000	4,600
	NMOS	64Kx4					
Samsung	NMOS	256Kx1	S	S	5	10	15
Sharp	NMOS	256Kx1			S	S	0
	NMOS	64Kx4			S	S	0
Siemens	NMOS	256Kx1			S	150	150

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	500	1,200	4,000	6,000	11,700
Instruments	NMOS	64Kx4	10	15	150	300	510
Toshiba	NMOS	256Kx1	4,000	6,000	7,000	8,000	25,000
	NMOS	64Kx4	S	500	1,000	1,000	2,500
Vitelic	CMOS	256Kx1			S	S	S
	CMOS	64Kx4					S
Total			22,720	34,695	59,690	84,475	201,580
Percent Change from Previous Quarter			33%	53%	72%	42%	
Cumulative Total			62,400	97,095	156,785	241,260	
Average Selling Price			$9.50	$5.15	$3.00	$2.25	$3.79
Revenue ($M)			215.8	178.7	179.1	190.1	763.7

	1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	10.6%	11.8%	15.6%	17.4%	15.2%
Japan	89.4	88.2	84.4	82.4	84.8
Europe	0.0	0.0	0.0	0.2	0.1
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					0
AT&T Technologies	NMOS	256Kx1	5,000	5,000	5,000	5,000	20,000
Fujitsu	NMOS	256Kx1	20,000	20,500	20,000	15,000	75,500
	NMOS	64Kx4	100	500	1,000	1,500	3,100
	CMOS	256Kx1		500	1,000	3,000	4,500
	CMOS	64Kx4		50	100	200	350
Hitachi	NMOS	256Kx1	25,000	30,000	22,000	23,500	100,500
	CMOS	256Kx1	500	1,000	1,500	2,000	5,000
	NMOS	64Kx4	2,000	2,500	2,500	2,500	9,500
Inmos	CMOS	256Kx1	250	500	800	1,200	2,750
Intel	CMOS	256Kx1					0
	CMOS	64Kx4					0
Matsushita	NMOS	256Kx1	1,700	1,900	2,100	2,200	7,900
	NMOS	64Kx4					0
Micron Technology	NMOS	256Kx1	3,000	6,000	6,000	6,000	21,000
	NMOS	64Kx4	200	800	1,200	1,500	3,700
Mitsubishi	NMOS	256Kx1	19,000	13,200	23,400	24,200	79,800
	NMOS	64Kx4	510	800	1,600	2,300	5,210
Mostek	NMOS	32Kx8					0
	NMOS	256Kx1					0
Motorola	NMOS	256Kx1	12	0	812	1,297	2,121
	CMOS	256Kx1					0
National	NMOS	256Kx1					0
NEC	NMOS	256Kx1	24,490	28,840	26,720	28,000	108,050
	NMOS	64Kx4	400	560	7,310	10,000	18,270
	NMOS	32Kx8	600	750	750	1,000	3,100
NMB	CMOS	256Kx1	300	600	1,200	2,400	4,500
Oki Electric	NMOS	256Kx1	3,000	4,000	5,000	7,000	19,000
	NMOS	64Kx4	S	100	300	1,000	1,400
Samsung	NMOS	256Kx1	500	2,000	5,000	5,000	14,000
Sharp	NMOS	256Kx1					0
	NMOS	64Kx4					0
Siemens	NMOS	256Kx1	200	500	800	1,500	3,000

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	9,000	10,000	10,000	12,000	41,000
Instruments	NMOS	64Kx4	500	1,000	1,250	1,500	4,250
Toshiba	NMOS	256Kx1	11,000	12,000	15,000	18,000	56,000
	NMOS	64Kx4	1,000	1,600	1,500	1,500	5,600
Vitelic	CMOS	256Kx1	10	50	90	150	300
	CMOS	64Kx4		10	30	70	110
Total			128,272	145,260	163,962	182,517	620,011
Percent Change from Previous Quarter			52%	13%	13%	11%	
Cumulative Total			369,682	514,942	678,904	861,421	
Average Selling Price			$2.25	$2.30	$2.50	$2.20	$2.31
Revenue ($M)			288.6	334.1	409.9	401.5	1,434.2

	1986 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	14.1%	15.1%	14.8%	16.8%	15.3%
Japan	85.1	82.9	81.1	78.6	81.7
Europe	0.4	0.7	1.1	1.7	1.0
Asia Pacific	0.4	1.3	3.0	2.9	2.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
AMD	CMOS	256Kx1					
AT&T Technologies	NMOS	256Kx1					
Fujitsu	NMOS	256Kx1	16,500	15,000	15,300	15,300	62,100
	NMOS	64Kx4	1,000	1,000	1,500	2,000	5,500
	CMOS	256Kx1	3,500	3,500	4,000	4,700	15,700
	CMOS	64Kx4	500	500	700	1,000	2,700
Hitachi	NMOS	256Kx1	16,800	14,000	13,700	13,400	57,900
	CMOS	256Kx1	2,200	2,500	3,000	3,500	11,200
	NMOS	64Kx4	2,000	2,000	2,000	2,000	8,000
Inmos	CMOS	256Kx1	1,500	1,500	1,500	1,500	6,000
Intel	CMOS	256Kx1				2,000	2,000
	CMOS	64Kx4					0
Matsushita	NMOS	256Kx1	1,600	2,100	4,000	5,500	13,200
	NMOS	64Kx4					0
Micron	NMOS	256Kx1	6,000	7,000	8,000	9,000	30,000
Technology	NMOS	64Kx4	2,000	2,800	3,600	4,500	12,900
Mitsubishi	NMOS	256Kx1	17,100	16,800	18,000	20,900	72,800
	NMOS	64Kx4	2,900	3,000	3,500	4,000	13,400
Mostek	NMOS	32Kx8					0
	NMOS	256Kx1					0
Motorola	NMOS	256Kx1	5,398	6,075	5,624	7,347	24,444
	CMOS	256Kx1					0
National	NMOS	256Kx1					0
NEC	NMOS	256Kx1	20,190	15,530	20,780	6,900	63,400
	NMOS	64Kx4	13,250	13,500	12,820	14,600	54,170
	NMOS	32Kx8	1,000	1,500	2,000	2,000	6,500
NMB	CMOS	256Kx1	2,800	3,500	4,500	5,200	16,000
Oki Electric	NMOS	256Kx1	6,000	5,400	7,200	8,500	27,100
	NMOS	64Kx4	900	810	1,500	2,000	5,210
Samsung	NMOS	256Kx1	12,000	16,000	19,000	20,000	67,000
Sharp	NMOS	256Kx1	1,005	4,419	5,857	7,800	19,081
	NMOS	64Kx4					0
Siemens	NMOS	256Kx1	2,000	2,500	3,000	3,500	11,000

(Continued)

Table 5 (Continued)

Estimated Worldwide MOS 256K Dynamic RAM Shipments (Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas	NMOS	256Kx1	19,000	23,500	27,000	30,400	99,900
Instruments	NMOS	64Kx4	2,000	2,500	3,500	4,500	12,500
Toshiba	NMOS	256Kx1	8,700	7,700	7,000	6,800	30,200
	NMOS	64Kx4	2,000	3,000	4,000	5,700	14,700
Vitelic	CMOS	256Kx1	250	275	300	350	1,175
	CMOS	64Kx4	100	120	150	180	550
Total			170,193	178,029	203,031	215,077	766,330
Percent Change from Previous Quarter			(7%)	5%	14%	6%	
Cumulative Total			1,031,614	1,209,643	1,412,674	1,627,751	
Average Selling Price			$2.25	$2.30	$2.40	$2.45	$2.36
Revenue ($M)			382.9	409.5	487.3	526.9	1,807.0

	1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	20.4%	23.7%	23.7%	27.1%	23.9%
Japan	70.5	65.0	64.7	61.3	65.1
Europe	2.1	2.2	2.2	2.3	2.2
Asia Pacific	7.1	9.0	9.4	9.3	8.7
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

Table 6

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1985 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS	1Mbx1	S	S	S	1	1
Fujitsu	NMOS	1Mbx1		S	0	0	0
Hitachi	CMOS	1Mbx1	S	S	0	2	2
	CMOS	256Kx4					
Matsushita	NMOS	1Mbx1					
	NMOS	256Kx4					
Micron Technology	CMOS	256Kx4					
Mitsubishi	NMOS	1Mbx1				S	
	NMOS	256Kx4				S	
NEC	NMOS	1Mbx1		S	S	0	0
NMB	CMOS	256Kx4					
Oki Electric	CMOS	1Mbx1					
Samsung	CMOS	1Mbx1					
Sharp	CMOS	1Mbx1					
Siemens	CMOS	1Mbx1					
Texas Instruments	CMOS	1Mbx1				S	0
	CMOS	256Kx4				S	0
Toshiba	CMOS	1Mbx1		S	10	150	160
	NMOS	1Mbx1	S	S	1	2	3
	CMOS	256Kx4					
Vitelic	CMOS	256Kx4	_	_	__	S	0
Total			0	0	11	155	166
Percent Change from Previous Quarter						1,309%	
Cumulative Total			0	0	11	166	
Average Selling Price			$150.00	$125.00	$110.00	$100.00	$100.66
Revenue ($M)			0.0	0.0	1.2	15.5	16.7

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1985				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	0.0	0.0	0.0	0.6%	0.6%
Japan	0.0	0.0	100.0%	99.4	99.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	100.0%	100.0%	100.0%

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

		1986				
Company	MOS Process/ Organization	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS 1Mbx1	10	50	150	300	510
Fujitsu	NMOS 1Mbx1	10	20	50	100	180
Hitachi	CMOS 1Mbx1	5	35	150	400	590
	CMOS 256Kx4					
Matsushita	NMOS 1Mbx1					
	NMOS 256Kx4					
Micron Technology	CMOS 256Kx4					
Mitsubishi	NMOS 1Mbx1			20	130	150
	NMOS 256Kx1			10	60	70
NEC	NMOS 1Mbx1			S	100	100
	CMOS 1Mbx1				200	200
	CMOS 256Kx4					
NMB	CMOS 256Kx4					
Oki Electric	CMOS 1Mbx1		S	5	10	15
Samsung	CMOS 1Mbx1					
Sharp	CMOS 1Mbx1					
Siemens	CMOS 1Mbx1					
Texas Instruments	CMOS 1Mbx1	2	S	5	10	17
	CMOS 256Kx4	2	S	5	10	17
Toshiba	CMOS 1Mbx1	150	250	500	1,350	2,250
	NMOS 1Mbx1					
	CMOS 256Kx4	S	20	50	150	220
Vitelic	CMOS 256Kx4					
Total		179	375	945	2,820	4,319
Percent Change from Previous Quarter		15%	109%	152%	198%	
Cumulative Total		345	720	1,665	4,485	
Average Selling Price		$48.00	$34.00	$45.00	$25.00	$31.11
Revenue ($M)		8.6	12.8	42.5	70.5	134.4

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1986 1st Qtr.	1986 2nd Qtr.	1986 3rd Qtr.	1986 4th Qtr.	1986 Year
Market Share					
North America	7.8%	13.3%	16.9%	11.3%	12.6%
Japan	92.2	86.7	83.1	88.7	87.4
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization		1987 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
ATT Technologies	CMOS	1Mbx1					
Fujitsu	NMOS	1Mbx1	100	200	400	900	1,600
Hitachi	CMOS	1Mbx1	800	1,200	1,625	2,200	5,825
	CMOS	256Kx4		5	25	100	130
Matsushita	NMOS	1Mbx1					
	NMOS	256Kx4	S	30	90	290	410
Micron	CMOS	256Kx4				5	5
Mitsubishi	CMOS	1Mbx1	503	525	728	1,275	3,030
	CMOS	256Kx1	377	859	698	806	2,739
NEC	NMOS	1Mbx1	150	140	200	30	520
	CMOS	1Mbx1	50	260	740	1,800	2,850
	CMOS	256Kx4					
NMB	CMOS	256Kx4					0
Oki	CMOS	1Mbx1	100	300	350	1,250	2,000
Samsung	CMOS	1Mbx1			S	5	5
Sharp	CMOS	1Mbx1				S	0
Siemens	CMOS	1Mbx1			S	5	5
Texas Instruments	CMOS	1Mbx1	20	50	100	200	370
	CMOS	256Kx4	10	30	50	100	190
Toshiba	CMOS	1Mbx1	2,800	3,300	5,000	7,700	18,800
	NMOS	1Mbx1					
	CMOS	256Kx4	300	500	1,300	2,000	4,100
Vitelic	CMOS	256Kx4					
Total			5,209	7,399	11,306	18,666	42,580
Percent Change from Previous Quarter			83%	42%	53%	65%	
Cumulative Total			9,719	17,118	28,424	47,090	
Average Selling Price			$17.00	$15.00	$13.50	$15.00	$14.95
Revenue ($M)			93.1	111.0	152.6	280.0	637.0

(Continued)

Table 6 (Continued)

Estimated Worldwide MOS 1Mb Dynamic RAM Shipments
(Thousands of Units)

	1987				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
North America	0.6%	1.1%	1.3%	1.6%	1.3%
Japan	99.4	98.9	98.7	98.3	98.6
Europe	0.0	0.0	0.0	0.0	0.0
Asia Pacific	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S = Sampling

Source: Dataquest
August 1989

DRAM—Data Update

MOS DYNAMIC RAMs—DATA

This section presents unit shipments of the more significant densities of dynamic RAMs (DRAMs) for 1988 and 1989. The 1988 and 1989 estimated shipments are for the 64K to 4Mb densities. Included in the tables are estimated worldwide billing prices for each density and market share data (in units) for North America-based, Japan-based, Europe-based, and Asia/Pacific-based companies. The tables are as follows:

- Table 1—64K DRAM (1988-1989)
- Table 2—256K DRAM (1988-1989)
- Table 3—1Mb DRAM (1988-1989)
- Table 4—4Mb DRAM (1988-1989)

DEFINITIONS

Prices

Average selling price (ASP) is the Dataquest estimate of the average worldwide billing price for that quarter. It incorporates prices for all package types and access times for both commercial and military markets.

Unit Shipments

Shipment data reflect factory revenue shipments as published in earlier sections, with occasional revisions based on the availability of more recent information.

Quarterly Revenue

Revenue is calculated as total units shipped in the quarter, multiplied by the average billing price of that quarter.

Table 1

Estimated Worldwide MOS 64K DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization		1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	NMOS	64Kx1	450	400	350	300	1,500
	NMOS	16Kx4	130	130	100	100	460
Hitachi	NMOS	64Kx1	120	100	60	5	285
	NMOS	16Kx4	30	10	0	0	40
Hyundai	CMOS	64Kx1	800	600	600	500	2,500
Inmos	NMOS	64Kx1	371	201	543	423	1,538
Intel	NMOS	64Kx1	1,050	1,300	1,300	1,050	4,700
Matsushita	NMOS	64Kx1	1400	1300	1,300	1,050	5,050
	NMOS	16Kx4	700	700	700	700	2,800
	NMOS	8Kx8	700	700	700	700	2,800
Micron	NMOS	64Kx1	2,000	2,500	2,500	2,500	9,500
Mitsubishi	NMOS	64Kx1	1,030	800	600	600	3,030
	NMOS	16Kx4	1,100	1,000	1,200	1,200	4,500
Motorola	NMOS	64Kx1	509	340	0	0	849
	NMOS	16Kx4					0
NEC	NMOS	64Kx1	1,500	1,200	1,464	944	5,108
	NMOS	16Kx4	500	350	155	100	1,105
	NMOS	8Kx8	1,650	1,700	1,481	956	5,787
Oki Electric	NMOS	64Kx1	2,000	2,000	2,000	2,000	8,000
Samsung	NMOS	64Kx1	9,000	12,500	12,000	11,500	45,000
SGS-Thomson	NMOS	64Kx1					0
Sharp	NMOS	64Kx1	1,950	2,400	2,400	2,500	9,250
Siemens			0	0	0	0	0
Texas Instruments	NMOS	64Kx1	2,091	2,091	1,742.	1,742	7,666
	NMOS	16Kx4	909	909	758	758	3,334
Toshiba	NMOS	64Kx1	800	800	500	200	2,300
Vitelic	NMOS	64Kx1	0	0	0	0	0
Total			30,790	34,031	32,453	29,828	127,102

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 64K DRAM Shipments (Thousands of Units)

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Year
Percent Change from Previous Quarter	8.1	10.5	(4.6)	(8.1)	
Cumulative Total	2,415,110	2,449,141	2,481,594	2,511,422	
Average Selling Price ($)	1.38	1.44	1.57	1.65	1.50
Revenue ($M)	42.5	49.0	51.0	49.2	190.7

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Total
Market Share					
United States	21.3%	21.0%	19.4%	20.3%	20.5%
Japan	45.7	39.9	40.1	38.1	40.9
Europe	1.2	0.6	1.7	1.4	1.2
Asia/Pacific	31.8	38.5	38.8	40.2	37.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 64K DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	NMOS 64Kx1	300	250	200	175	925
	NMOS 16Kx4	100	80	65	50	295
Hitachi	NMOS 64Kx1	5	5	0	0	10
	NMOS 16Kx4	0	0	0	0	0
Hyundai	CMOS 64Kx1	150	10	0	0	160
Inmos	NMOS 64Kx1					0
Intel	NMOS 64Kx1	623	435	395	226	1,679
Matsushita	NMOS 64Kx1	1,000	700	600	375	2,675
	NMOS 16Kx4	600	500	400	250	1,750
	NMOS 8Kx8	600	500	400	250	1,750
Micron	NMOS 64Kx1	2,283	1,597	1,540	880	6,300
Mitsubishi	NMOS 64Kx1	600	100	0	0	700
	NMOS 16Kx4	500	150	150	150	950
Motorola	NMOS 64Kx1	0	0	0	0	0
	NMOS 16Kx4					0
NEC	NMOS 64Kx1	0	0	0	0	0
	NMOS 16Kx4	0	0	0	0	0
Oki Electric	NMOS 64Kx1	2,100	1,800	500	410	4,810
Samsung	NMOS 64Kx1	11,000	7,500	6,500	5,000	30,000
SGS-Thomson	NMOS 64Kx1					0
Sharp	NMOS 64Kx1	500	100	50	0	650
Siemens		0	0	0	0	0
Texas Instruments	NMOS 64Kx1	2,520	2,520	2,250	2,250	9,540
	NMOS 16Kx4	1,320	1,320	1,100	1,100	4,840
Toshiba	NMOS 64Kx1	0	0	0	0	0
Vitelic	NMOS 64Kx1	0	0	0	0	0
Total		24,201	17,567	14,150	11,116	67,034

(Continued)

Table 1 (Continued)

Estimated Worldwide MOS 64K DRAM Shipments
(Thousands of Units)

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Total
Percent Change from Previous Quarter	(18)	(27)	(19)	(21)	
Cumulative Total	2,535,373	2,552,940	2,567,090	2,578,206	
Average Selling Price ($)	1.69	1.74	1.80	1.64	1.72
Revenue ($M)	40.9	30.6	25.5	18.2	115.2

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Total
Market Share					
United States	27.9%	33.4%	37.4%	40.1%	33.4%
Japan	26.1	23.8	16.7	14.9	21.7
Europe	0	0	0	0	0
Asia/Pacific	46.1	42.7	45.9	45.0	45.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest (June 1990)

Table 2

Estimated Worldwide MOS 256K DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	NMOS 256Kx1	14,500	15,000	14,250	12,825	56,575
	CMOS 256Kx1	4,500	5,000	4,750	4,275	18,525
	NMOS 64Kx4	2,000	2,500	2,375	2,138	9,013
	CMOS 64Kx4	1,300	1,300	1,235	1,112	4,947
	CMOS VRAM x4	1,000	1,350	1,150	954	4,454
Goldstar	CMOS 256Kx1	0	0	100	800	900
Hitachi	NMOS 256Kx1	13,000	12,000	12,000	11,000	48,000
	CMOS 256Kx1	4,000	3,600	3,400	3,000	14,000
	NMOS 64Kx4	4,000	3,600	3,600	3,600	14,800
	CMOS VRAM x4	1,600	2,000	2,000	3,000	8,600
Hyundai	CMOS 256Kx1	200	300	3,500	4,500	8,500
Intel	CMOS 256Kx1	2,100	2,200	1,900	2,100	8,300
Matsushita	NMOS 256Kx1	4,200	5,400	5,600	5,500	20,700
	NMOS 64Kx4	0	0	0	0	0
	NMOS VRAM x4	0	0	0	0	0
Micron	NMOS 256Kx1	15,000	16,500	14,000	15,000	60,500
	NMOS 64Kx4	2,500	2,500	3,000	3,000	11,000
	CMOS VRAM x4	38	270	560	670	1,538
Mitsubishi	NMOS 256Kx1	14,000	14,000	10,000	9,000	47,000
	NMOS 64Kx4	3,300	3,800	2,800	3,300	13,200
	NMOS VRAM x4	2,000	2,000	2,000	2,500	8,500
Motorola	NMOS 256Kx1	7,500	6,100	6,075	4,700	24,375
	NMOS 64Kx4	300	400	525	700	1,925
	NMOS VRAM x4					
NEC	NMOS 256Kx1	17,600	18,450	17,425	17,425	70,900
	NMOS 64Kx4	13,650	14,400	15,675	15,675	59,400
	NMOS VRAM x4	1,850	3,000	3,400	3,550	11,800
NMB	CMOS 256Kx1	8,500	9,600	10,500	11,500	40,100
Oki Electric	NMOS 256Kx1	12,500	13,500	14,000	13,000	53,000
	NMOS 64Kx4	2,000	2,000	2,500	3,000	9,500
Samsung	NMOS 256Kx1	10,000	11,000	11,500	11,000	43,500
	NMOS 64Kx4	2,000	2,000	2,500	3,000	9,500
Sanyo	NMOS 256Kx1	1,000	1,000	900	900	3,800
Sharp	NMOS 256Kx1	9,500	10,000	10,500	10,500	40,500
Siemens	NMOS 256Kx1	3,216	5,542	5,835	6,259	20,852

(Continued)

Table 2 (Continued)

Estimated Worldwide MOS 256K DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Texas Instruments	NMOS 256Kx1	33,511	33,511	32,533	31,111	130,666
	NMOS 64Kx4	4,189	4,189	4,067	3,889	16,334
	NMOS VRAM x4	200	200	400	400	1,200
Toshiba	NMOS 256Kx1	14,000	10,000	9,000	9,000	42,000
	CMOS 256Kx1	0	0	0	0	0
	NMOS 64Kx4	3,000	2,700	2,400	2,000	10,100
Vitelic	CMOS 256Kx1	618	1,350	1,760	2,100	5,828
	CMOS 64Kx4	32	150	440	900	1,522
	CMOS VRAM x4	0	0	0	0	0
Total		234,404	242,412	240,155	238,883	955,854

(Continued)

Table 2 (Continued)

Estimated Worldwide MOS 256K DRAM Shipments (Thousands of Units)

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	1988 Year
Percent Change from Previous Quarter	9	3	(1)	(1)	
Cumulative Total	1,862,155	2,104,567	2,344,722	2,583,605	
Average Selling Price ($)	2.79	2.97	3.19	3.30	3.05
Revenue ($M)	654.0	720.0	766.1	788.3	2,915.4

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	1988 Year
Market Share					
United States	28.2%	27.8%	27.2%	27.0%	27.5%
Japan	65.3	64.4	63.1	62.3	63.8
Europe	1.4	2.3	2.4	2.6	2.2
Asia/Pacific	5.2	5.5	7.3	8.1	6.5
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 2 (Continued)

Estimated Worldwide MOS 256K DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	NMOS 256Kx1	11,000	9,500	8,875	8,300	37,675
	CMOS 256Kx1	4,120	3,940	3,675	3,450	15,185
	NMOS 64Kx4	2,060	1,970	1,820	1,725	7,575
	CMOS 64Kx4	1,070	1,025	1,000	900	3,995
	CMOS VRAM x4	913	822	800	750	3,285
Goldstar	CMOS 256Kx1	1,500	2,400	3,000	3,500	10,400
Hitachi	NMOS 256Kx1	10,600	9,650	8,975	8,000	37,225
	CMOS 256Kx1	2,900	2,600	2,420	2,275	10,195
	NMOS 64Kx4	3,470	3,150	2,930	2,770	12,320
	CMOS VRAM x4	3,000	3,500	4,500	4,500	15,500
Hyundai	CMOS 256Kx1	5,000	5,000	6,000	7,000	23,000
Intel	CMOS 256Kx1	1,940	1,848	1,726	1,637	7,151
Matsushita	NMOS 256Kx1	4,200	4,500	4,000	3,800	16,500
	NMOS 64Kx4	500	500	500	500	2,000
	NMOS VRAM x4	300	300	300	300	1,200
Micron	NMOS 256Kx1	13,900	13,200	12,325	11,700	51,125
	NMOS 64Kx4	2,770	2,640	2,470	2,335	10,215
	CMOS VRAM x4	1,200	1,550	1,200	1,200	5,150
Mitsubishi	NMOS 256Kx1	8,000	7,000	4,400	3,300	22,270
	NMOS 64Kx4	4,400	6,700	5,000	3,750	19,850
	NMOS VRAM x4	2,800	3,700	3,300	2,600	12,400
Motorola	NMOS 256Kx1	4,230	4,230	2,250	3,060	13,770
	NMOS 64Kx4	470	470	250	340	1,530
NEC	NMOS 256Kx1	15,000	15,000	11,000	11,000	52,000
	NMOS 64Kx4	12,000	12,000	10,000	10,000	44,000
	NMOS VRAM x4	3,700	4,600	4,600	4,100	17,000
NMB	CMOS 256Kx1	11,100	10,600	12,700	12,700	47,100
Oki Electric	NMOS 256Kx1	11,500	11,200	11,250	11,800	45,750
	NMOS 64Kx4	4,800	5,200	2,400	2,400	14,800
Samsung	NMOS 256Kx1	11,500	11,100	10,300	10,800	43,700
	NMOS 64Kx4	2,500	2,400	2,200	2,200	9,300
Sanyo	NMOS 256Kx1	1,000	1,000	1,200	1,000	4,200

(Continued)

Table 2 (Continued)

Estimated Worldwide MOS 256K DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Sharp	NMOS 256Kx1	8,080	7,800	7,500	7,000	30,380
Siemens	NMOS 256Kx1	7,059	7,347	5,919	4,048	24,373
Texas Instruments	NMOS 256Kx1	27,298	24,638	22,183	20,613	94,732
	NMOS 64Kx4	3,590	3,425	3,200	3,032	13,247
	NMOS VRAM x4	400	300	600	600	1,900
Toshiba	NMOS 256Kx1	9,000	8,000	7,500	6,500	31,000
	CMOS 256Kx1	500	1,000	1,200	1,500	4,200
	NMOS 64Kx4	3,300	4,200	5,500	4,500	17,500
Vitelic	CMOS 256Kx1	2,400	2,700	2,900	3,100	11,100
	CMOS 64Kx4	1,500	1,800	1,900	2,200	7,400
	CMOS VRAM x4			S	100	100
Total		226,570	224,505	205,768	196,885	853,728

(Continued)

Table 2 (Continued)

Estimated Worldwide MOS 256K DRAM Shipments
(Thousands of Units)

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Year
Percent Change from Previous Quarter	(5)	(1)	(8)	(4)	
Cumulative Total	2,810,175	3,034,680	3,240,448	3,437,333	
Average Selling Price ($)	3.46	3.55	2.61	2.22	2.98
Revenue ($M)	783.9	779.0	537.1	437.1	2,545.0

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Year
Market Share					
United States	26.3%	25.3%	24.8%	25.4%	25.5%
Japan	61.5	62.1	61.9	60.7	61.6
Europe	3.1	3.3	2.9	2.1	2.9
Asia/Pacific	9.0	9.3	10.4	11.9	10.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S=Sampled
Source: Dataquest (June 1990)

Table 3

Estimated Worldwide MOS 1Mb DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	CMOS 1Mx1	2,400	3,400	4,300	5,900	16,000
	CMOS 256Kx4	600	800	1,100	1,500	4,000
	CMOS VRAM x4	180	252	324	444	1,200
Hitachi	CMOS 1Mx1	2,500	3,100	4,500	6,400	16,500
	CMOS 256Kx4	500	1,000	1,600	2,400	5,500
	CMOS VRAM x4	0	0	0	0	0
Hyundai	CMOS 1Mx1	0	0	0	0	0
Intel	CMOS 1Mx1	0	S	150	150	300
Matsushita	CMOS 1Mx1	209	418	836	836	2,300
	CMOS 256Kx4	291	582	1,164	1,164	3,200
	CMOS VRAM x4	0	0	0	0	0
	CMOS VRAM x8	0	0	0	0	0
Micron	CMOS 1Mx1	20	100	300	500	920
Mitsubishi	CMOS 1Mx1	1,900	3,000	4,000	5,000	13,900
	CMOS 256Kx4	1,300	2,000	3,500	4,500	11,300
Motorola	CMOS 1Mx1	600	878	930	1,576	3,984
	CMOS 256Kx4	0	33	303	438	774
NEC	NMOS 1Mx1	180	0	0	0	180
	CMOS 1Mx1	3,000	4,000	5,333	6,733	19,066
	CMOS 256Kx4	1,820	2,000	2,667	3,367	9,854
	CMOS VRAM x4	0	0	0	0	0
NMB	CMOS 1Mx1	5	10	490	440	945
Oki Electric	NMOS 1Mx1	1,500	2,000	3,500	5,000	12,000
	CMOS VRAM x4	0	0	0	0	0
Samsung	CMOS 1Mx1	500	1,800	2,500	4,500	9,300
	CMOS 256Kx4	0	0	0	0	0
Sanyo	CMOS 1Mx1	0	0	0	0	0
Sharp	CMOS 1Mx1	200	300	400	500	1,400
Siemens	CMOS 1Mx1	140	743	1,061	1,822	3,766
	CMOS 256Kx4	31	395	563	966	1,955
Texas Instruments	CMOS 1Mx1	367	1,000	2,000	4,000	7,367
	CMOS 256Kx4	183	500	1,000	2,000	3,683
	CMOS VRAM x4			0	0	0

(Continued)

Table 3 (Continued)

Estimated Worldwide MOS 1Mb DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Toshiba	CMOS 1Mx1	8,500	11,000	13,000	15,000	47,500
	CMOS 256Kx4	2,500	3,300	4,000	6,000	15,800
	CMOS VRAM x4	0	0	0	0	0
	CMOS VRAM x8		0	0	0	0
Vitelic	CMOS 256Kx4	0	0	0	0	0
Total		29,426	42,611	59,521	81,136	212,694

	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	58	45	40	36	
Cumulative Total	76,516	119,127	178,648	259,784	
Average Selling Price ($)	15.20	16.51	17.48	17.28	16.88
Revenue ($M)	447.3	703.5	1,040.4	1,402.0	3,590.3

	1988 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
United States	4.0%	5.9%	7.9%	10.7%	8.0%
Japan	93.7	87.2	85.2	80.3	84.9
Europe	0.6	2.7	2.7	3.4	2.7
Asia/Pacific	1.7	4.2	4.2	5.5	4.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

(Continued)

Table 3 (Continued)

Estimated Worldwide MOS 1Mb DRAM Shipments (Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	CMOS 1Mx1	7,200	9,000	9,600	9,400	35,200
	CMOS 256Kx4	1,800	2,200	2,400	2,400	8,800
	CMOS VRAM x4	630	770	840	840	3,080
Hitachi	CMOS 1Mx1	7,500	8,000	8,500	7,800	31,800
	CMOS 256Kx4	3,000	2,400	4,500	3,200	13,100
	CMOS VRAM x4			100	450	550
Hyundai	CMOS 1Mx1			200	200	400
Intel	CMOS 1Mx1	500	600	1,100	2,000	4,200
Matsushita	CMOS 1Mx1	1,000	2,600	3,300	3,600	10,500
	CMOS 256Kx4	900	1,200	1,500	1,500	5,100
	CMOS VRAM x4	100	200	200	250	750
	CMOS VRAM x8	0	0	0	10	10
Micron	CMOS 1Mx1	600	750	1,000	2,100	4,450
Mitsubishi	CMOS 1Mx1	5,000	6,100	4,700	5,700	21,500
	CMOS 256Kx4	4,000	5,200	2,700	2,200	14,100
Motorola	CMOS 1Mx1	1,560	2,700	3,900	5,700	13,860
	CMOS 256Kx4	1,040	1,800	2,600	3,800	9,240
NEC	CMOS 1Mx1	6,500	7,000	8,000	9,000	30,500
	CMOS 256Kx4	7,000	8,000	8,500	8,500	32,000
	CMOS VRAM x4	15	100	300	500	915
NMB	CMOS 1Mx1	1,200	1,300	2,900	3,300	8,700
Oki Electric	NMOS 1Mx1	6,300	6,900	6,400	6,700	26,300
	CMOS VRAM x4				S	0
Samsung	CMOS 1Mx1	7,100	12,100	15,900	17,000	52,100
	CMOS 256Kx4	400	800	1,500	3,000	5,700
Sanyo	CMOS 1Mx1	10	50	300	1,200	1,560
Sharp	NMOS 1Mx1	660	720	800	800	2,980
Siemens	CMOS 1Mx1	1,573	2,522	3,288	5,970	13,353
	CMOS 256Kx4	1,433	2,257	1,446	2,383	7,519
Texas Instruments	CMOS 1Mx1	3,750	4,460	5,650	6,160	20,020
	CMOS 256Kx4	1,880	2,230	2,800	3,075	9,985
	CMOS VRAM x4			5	20	25

(Continued)

Table 3 (Continued)

Estimated Worldwide MOS 1Mb DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Toshiba	CMOS 1Mx1	16,500	16,000	15,000	14,000	61,500
	CMOS 256Kx4	10,500	13,000	12,500	13,000	49,000
	CMOS VRAM x4	500	1,000	1,000	1,500	4,000
	CMOS VRAM x8		5	20	100	125
Vitelic	CMOS 256Kx4	0	0	S	50	50
Total		100,151	121,964	133,449	147,408	502,972

	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Percent Change from Previous Quarter	23	22	9	10	
Cumulative Total	359,935	481,899	615,348	762,756	
Average Selling Price ($)	17.42	16.36	12.83	9.46	13.61
Revenue ($M)	1,744.6	1,995.3	1,712.2	1,394.5	6,845.1

	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Market Share					
United States	9.3%	10.3%	12.8%	15.5%	12.3%
Japan	80.2	75.2	70.5	65.1	72.0
Europe	3.0	3.9	3.5	5.7	4.1
Asia/Pacific	7.5	10.6	13.2	13.7	11.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S=Sampled
Source: Dataquest (June 1990)

Table 4

Estimated Worldwide MOS 4Mb DRAM Shipments
(Thousands of Units)

		1988				
Company	MOS Process/ Organization	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	CMOS 4Mx1	0	0	0	1	1
	CMOS 1Mx4	0	0	0	0	0
Hitachi	CMOS 4Mx1	0	0	0	0	0
	CMOS 1Mx4	0	0	1	3	4
Matsushita	CMOS 1Mx4	0	0	0	0	0
Mitsubishi	CMOS 1Mx4	0	0	0	0	0
Motorola	CMOS 1Mx4				0	0
NEC	CMOS 4Mx1	0	0	1	2	3
Oki Electric	CMOS 4Mx1	0	0	0	0	0
	CMOS 1Mx4	0	0	0	1	1
Siemens	CMOS 1Mx4	0	0	0	0	0
Texas Instruments	CMOS 1Mx4	0	0	0	0	0
Toshiba	CMOS 4Mx1	0	0	0	0	0
	CMOS 1Mx4	0	0	2	8	7
Total		0	0	4	12	16

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 4Mb DRAM Shipments (Thousands of Units)

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Year
Percent Change from Previous Quarter				200	
Cumulative Total			4	16	
Average Selling Price ($)			540.00	428.21	456.16
Revenue ($M)	0	0	2.2	5.1	7.3

	1988 1st Qtr.	1988 2nd Qtr.	1988 3rd Qtr.	1988 4th Qtr.	Year
Market Share					
United States	NA	NA	0	0	0
Japan	NA	NA	100.0%	100.0%	100.0%
Europe	NA	NA	0	0	0
Asia/Pacific	NA	NA	0	0	0
Total	NA	NA	100.0%	100.0%	100.0%

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 4Mb DRAM Shipments
(Thousands of Units)

Company	MOS Process/ Organization	1989 1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Year
Fujitsu	CMOS 4Mx1	3	5	15	95	118
	CMOS 1Mx4	0	0	1	5	6
Hitachi	CMOS 4Mx1	0	0	40	100	140
	CMOS 1Mx4	20	40	133	267	460
Matsushita	CMOS 1Mx4		S	2	15	17
Mitsubishi	CMOS 1Mx4	S	1	2	6	9
Motorola	CMOS 1Mx4				15	15
NEC	CMOS 4Mx1	20	53	100	200	373
Oki Electric	CMOS 4Mx1	0	1	3	12	16
	CMOS 1Mx4	2	2	10	28	42
Siemens	CMOS 1Mx4		S	2	4	6
Texas Instruments	CMOS 1Mx4				15	15
Toshiba	CMOS 4Mx1	13	33	133	200	379
	CMOS 1Mx4	14	40	100	133	287
Total		72	175	541	1,095	1,883

(Continued)

Table 4 (Continued)

Estimated Worldwide MOS 4Mb DRAM Shipments
(Thousands of Units)

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Year
Percent Change from Previous Quarter	350	143	209	102	
Cumulative Total	88	263	804	1,899	
Average Selling Price ($)	322.70	220.02	136.00	87.78	122.91
Revenue ($M)	23.2	38.5	73.6	96.1	231.4

	1989 1st Qtr.	1989 2nd Qtr.	1989 3rd Qtr.	1989 4th Qtr.	Year
Market Share					
United States	0	0	0	2.7%	1.6%
Japan	100.0%	100.0%	99.6%	96.9	98.1
Europe	0	0	0.4	0.4	0.3
Asia/Pacific	0	0	0	0	0
Total	100.0%	100.0%	100.0%	100.0%	100.0%

S=Sampled
NA=Not available
Source: Dataquest (June 1990)